International Maritime Lecturers Association

National University "Odessa Maritime Academy"

Proceedings

of the 13th International Conference on Engine Room Simulators

ICERS

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National University «Odessa Maritime Academy»

Proceedings of the 13th International Conference on Engine Room Simulators

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Також роботи охоплюють такі теми, як освіта та підготовка з тренажерами машинного відділення; нові методи (методики) та технології; підготовка кадрів в області ефективності використання енергетичних ресурсів із застосуванням тренажерів машинного відділення; особисті якості та навички міжособистісного спілкування в роботі з тренажерами машинного відділення; аналіз і оцінка в роботі з тренажерами машинного відділення; ПДНВ 2010 та тренажери машинного відділення; аналіз, пошук і усунення несправностей; додаткові теми та питання по тренажерів.

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FOREWORD TO THE PROCEEDINGS

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DEAR COLLEAGUES!

It is a great honor for the National University "Odessa Maritime Academy" to host the 13 th International Conference on Engine Room Simulators (ICERS13).

The University has a long-term tradition of use of engine room simulators of different producers (Søren T. Lyngsø, Norcontrol, Haven Automation Ltd., TRANSAS, Kongsberg Maritime AS) for marine engineers training and improving their professional skills.

Holding of ICERS13 provides a unique opportunity to exchange experience among professionals involved in production and operation of marine engines, mechanisms and systems, creation and use of engine room simulators in marine engineers training.

Continuous improvement of engine room simulators enhances the level of safe and efficient vessels operation.

This book consists of papers clustered in sub-themes: Education and Training with ERS, New Methods and Technologies, Energy Efficiency Training with ERS, Soft Skills in ERS, Assessment and Evaluation in ERS, STCW 2010 and ERS, Troubleshooting Analysis, Special Topics in Simulators.

We hope that the 13th International Conference on Engine Room Simulators in Odessa will become an important milestone in the development of the new approaches to the Marine Engineers MET system as well as the implementation of the joint (educational establishments and ERS producers) contemporary achievements in the work of the shipping companies of the world.

Prof. Dr. Mykhaylo Miyusov
Rector of National University "Odessa Maritime Academy"
Chair of Local Organizing Committee

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HOW KONGSBERG MEETS NEW ENVIRONMENTAL REQUIREMENTS FOR ENGINE ROOM SIMULATION

Arild Hermansen, Product Advisor

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There has been ongoing development of environmental protection equipment due to new rules and regulations that have recently come into force. KONGSBERG has experienced an increased demand for simulators where various emissions reduction equipment and other environmental protection systems are included.

At the time the NOx Tier II limits came into force, engine tuning was sufficient to reduce NOx emissions (at the cost of higher fuel consumption). This was not enough to meet the Tier III limits. To comply with the NOx Tier III limits, KONGSBERG added a Selective Catalytic Reduction system to the low speed mechanical camshaft engine simulator model to facilitate training in this matter. Fuel-water emulsion was also included, in order to study the effect of mixing water into the fuel.

To comply with NOx Tier III for medium speed diesel engines, KONGSBERG has developed new dual fuel engine models (HFO/MDO/LNG). In connection to the use of LNG as fuel, IMO added to the Standards of Training, Certification and Watchkeeping (STCW) Convention aspects of the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code), including LNG fuel-handling and bunkering.

To meet the bunkering part of the IGF code, KONGSBERG has developed a new Cruise Ferry engine room model. This fulfils engine plant demands for energy efficiency and low environmental impact. It contains training for the bunkering and operation of a cruise ferry that employs a multiple installation of the Wärtsilä medium speed, four-stroke, LNG and diesel oil 8L50DF engine to generate power for a high-voltage switchboard.

Our newly designed low speed model, the MAN 6S70ME-C Suezmax Crude Oil Carrier, includes an open loop wet scrubber to comply with the SOx limits in both ECA and global areas without using high cost low sulphur fuel. The engine model includes a replica of the engine manufacturer's engine control system, which allows fine tuning of max pressure and by that, the NOx emission.

Since new regulation regarding ballast water treatment enters into force September 2017, KONGSBERG has included a Ballast Water Treatment system based on Alfa Laval's design. The ballast water system/ballast water treatment system facilitates ballast water management training.

Introduction

For most of our simulator models, emission reduction systems were requested by our customers, especially those located close to environment controlled areas. It started with our low speed LCC which has a MAN B&W MC90 engine installed. Even though the LCC is not the most common vessel type when it comes to NOx reduction installations it was the most sophisticated engine model KONGSBERG had back then. It was suitable for studying the effect of injection timing adjustment, use of Fuel-Water Emulsion and Selective Catalytic Reactor, regarding NOx.

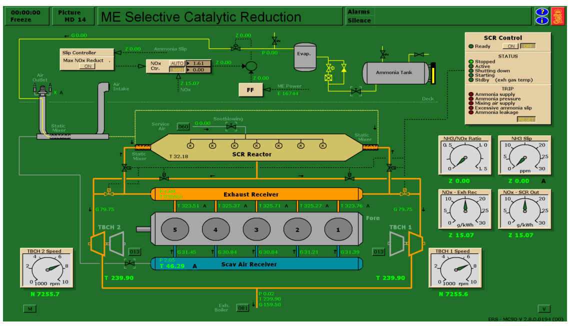

Figure 1. Selective Catalytic Reactor

Selective Catalytic Reduction

To comply with the NOx Tier III limits, KONGSBERG added a Selective Catalytic Reduction (SCR) system to the low speed mechanical camshaft engine simulator model to facilitate training in this matter.

The SCR unit is used to treat the exhaust before it enters the turbocharger. Ammonia is added to the gas stream, and the mixture then passes through a special catalyst at a temperature between 300 and 400°C. Within the SCR Reactor the hot exhaust gases that contain NOx gases are mixed with the ammonia stream. This reduces the NOx to N_2 and H_2O.

Fuel Injection

The low speed model with mechanical camshaft, required manual adjustment of the injection timing, either by use of the common VIT or individually on each high pressure pump.

Our new low speed model, the 6S70ME-C, SuezMax, includes a replica of MAN's engine control system which includes Emission Running Mode.

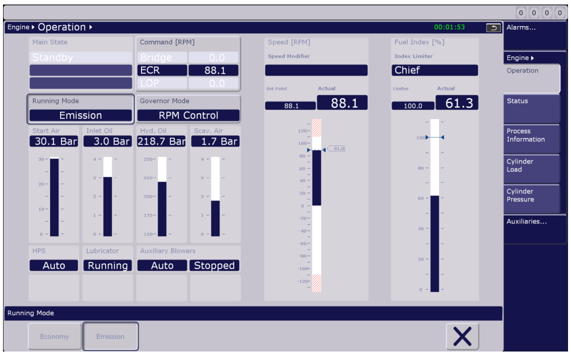

Figure 2. The 6S70ME-C in Emission mode

When running in this mode, the FIVA valve injection settings are changed, such that max pressure is lowered (which cause lower combustion temperature) and by that, reduced NOx.

Main Engine Scrubber

To comply with the SOx limits in both ECA and global areas without using high cost low sulphur fuel, an open loop wet scrubber is included in the SuezMax model. The reference ship doesn't have a scrubber installed, but we decided to install it to meet customer's training requirements. There are several variants of scrubber systems so KONGSBERG decided to model the wet scrubber type which would be typical for this type of vessel. The open loop wet scrubber is a sea water in/sea water out variant. In case of restrictions regarding discharge to sea, the discharge water can be routed to a dedicated ballast water tank.

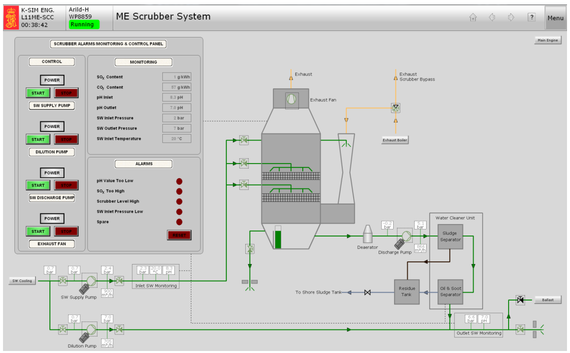

Figure 3. Main Engine Scrubber

The water mixture generated during the scrubbing process falls to a wet sump at the bottom of the scrubber. This water, called washwater, is removed from the scrubber sump by gravity or by a pump, after passing through a deaerator in some systems, to a hydrocyclone or separator to remove the residuals from the washwater. The removed residuals are discharged to a dedicated residue tank on board. MARPOL Annex VI Regulation 16, Paragraph 2.6 prohibits incineration of sludge generated from a scrubber; it must be disposed of at suitable reception facilities ashore.

Ballast Water Treatment System.

Since new regulation regarding ballast water treatment enters into force September 2017, KONGSBERG has included a Ballast Water Treatment system based on Alfa Laval's design. The ballast water system/ballast water treatment system facilitates ballast water management training.

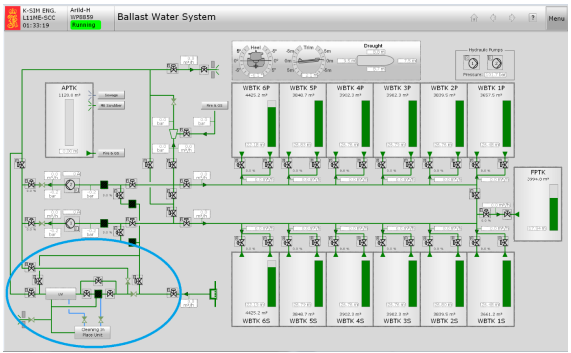

Figure 4. Ballast Water Treatment

The simulated BWT system is a fully automated treatment system for the biological disinfection of ballast water. It combines initial filtration with UV treatment to remove organisms. The system includes a cleaning unit, UV reactor unit and a filter. The cleaning unit circulates a reusable, non-toxic and biodegradable cleaning solution to ensure maximum performance of the UV reactor. The filter is used during ballasting (by-passed during deballasting) to block intake of larger organisms. The filter is cleaned via automatic backflushing using a small portion of the system flow.

Dual Fuel Engines

KONGSBERG's latest development regarding environment friendly engine models is the K-Sim Engine LNG Cruise Ferry, inspired by Wärtsilä LNG control system and Wärtsilä 8L50DF engines.

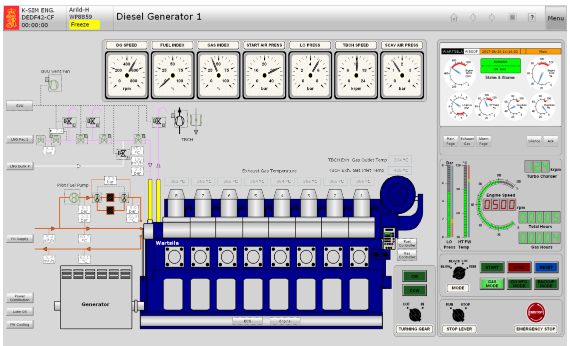

Figure 5. Wärtsilä 8L50DF

Recently, IMO added aspects of the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code), including LNG fuel handling and bunkering, to Standards of Training, Certification and Watch keeping (STCW). The handling of LNG and other low-flashpoint fuels for ships will be a part of maritime training standards in 2017.

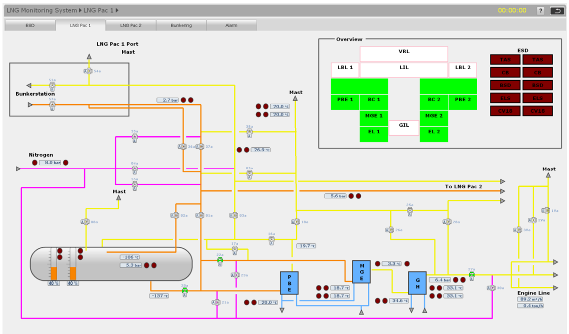

Figure 6. LNG Monitoring System

The new K-Sim engine model is based on a 'State-of-the-art' cruise ferry and fulfils all demands of an engine plant for energy efficiency combined with low environmental impact. The model will contain process systems to allow training scenarios for bunkering and operation of a cruise ferry that holds a multiple installation of the Wärtsilä 8L50DF medium speed (four stroke) Dual fuel (LNG) gas and diesel oil that generates power to a High Voltage switch board.

Conclusion:

Based on the environmental focus we see in the shipping industry, new IMO regulations, more Emission Controlled Areas and feedback from our customers, KONGSBERG sees an increased demand for simulators which facilitate training in this matter.

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ASPECTS OF MARITIME RESOURCE MANAGEMENT TRAINING FOR EMERGENCY STEERING SCENARIOS ON AZIMUTH THUSTERS

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Abstract: This study addresses the emergency steering problem on a vessel equipped with azimuth thrusters. A pair of omnidirectional thrusters, which are often equipped with variable pitch propellers and operate in a combined mode, imply a potential for a variety of different emergency scenarios.

Azimuth thrusters' fault scenarios were classified with predefined risk levels depending on the area, time limitation, mode of operation and fault itself. Mutual responsibilities and action algorithms for bridge and engine teams in a step-by-step manner have been developed for each scenario.

Personnel behavioural differences in both expected and unexpected emergencies have also been studied.

Keywords: maritime resource management, emergency steering, azimuthal propulsion.

INTRODUCTION. Azimuth thrusters are widely used in the maritime industry, specifically on tugs, offshore and passenger vessels. They are renowned for providing vessels with exceptional maneuverability.

Azimuth propulsion performs best in automated low and zero-speed tracking applications such as auto-tracking and dynamic positioning, as system can apply necessary steering forces at any speed in any directions.

However, it also has some drawbacks. Higher complexity leads to two apparent problems:

- Vessel with azimuth thrusters is much more complicated in manual handling.
- Higher propulsion system complexity leads to a larger possibility for technical problems.

Many technical problems related to seals and bearings cannot be solved in a day and, apparently, do not appear in a day. They require correct assessment of visible symptoms, possible defects location and timely corrective maintenance.

When it comes to steering system fault, it is more situational and often requires immediate actions from both bridge and engine room teams.

Therefore, simulator training can help to build up a habit for specific actions and a communication flow between teams in case of such emergencies.

1. STEERING MODES HIERARCHY. A typical azimuth thrusters system has a specific procedural flow given in fig. 1.

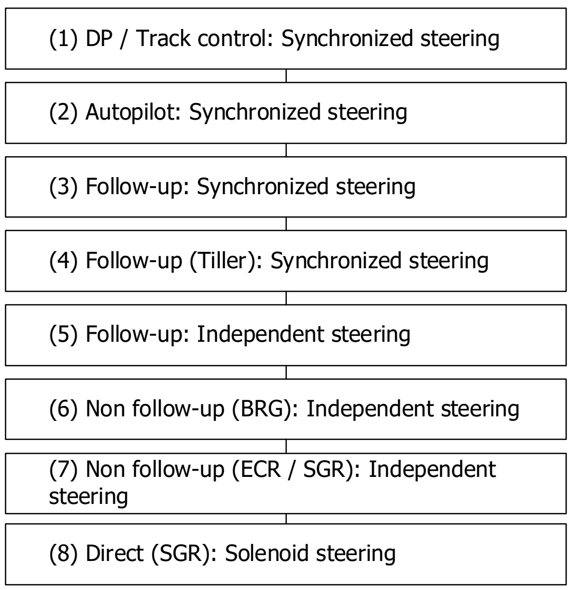

Figure 1. Steering modes hierarchy

Modes (1) and (2) usually require routine monitoring and minimum intervention from an operator, except parameters adjustment, based on ship behavior.

However, simple things like steering angle limitation along with reduced speed may lead to temporary loss of steering in poor weather conditions. Also in synchronous (both thrusters engaged in steering) auto tracking mode vessel speed might be unstable. This problem can be treated with setting the system into asynchronous mode, where one of the thrusters is pushing only straight ahead. From the other hand, on the minimum speed of 1.5-2.5 knots, increase of rudder limit above conventional 35° can dramatically improve the ship's stability on track.

Modes (3) and (4) are commonly used at high and moderate speeds to change heading manually. In this case, rudder limits have to be checked prior to maneuver to avoid abrupt turning, as all produced thrust will be directed to a given angle.

Mode (5) is a maneuvering mode, which requires specific skills from an operator. Manual maneuvering technics and precautions on thrusters' allocation is discussed in several publications including [1, 3, 4]. *This stipulates the first stage of MRM training, dedicated to gaining a manual handling skill for the bridge staff.*

Non-follow up (6) is the closest to emergency mode, when a thruster does not respond to manipulator. Generally, there are might be three options available for the operator:

- NFU Steering angle;
- NFU RPM;
- NFU Pitch angle.

Simply wrong sequence of actions during a transfer from one control system to another (i.e. from DP to a conventional autopilot) may lead to a situation when one of the thrusters is stuck on a certain azimuth angle.

This situation has to be assessed immediately and resolved with use of NFU control buttons.

Modes (6)-(8) are emergency modes, which require constant communication with an engine team. Non-follow up and direct solenoid steering can only save a vessel from imminent danger, after that a better solution has to be found in order to regain control of the vessel.

2. RISK BASED APPROACH. There is no danger in the loss of steering alone. However, depending on the situation, loss of steering may lead to a navigational incident such as grounding, collision or various heavy weather damage (i.e. loss of cargo due to heavy rolling resulted from vessels inability to keep a safe heading).

In relation to groundings and collisions, intuitional approach can be used.

As the RISK is a product of a LIKELIHOOD (LH) and a SEVERITY (SV), we should define these two components first.

Apparently, being closer to a hazard with no steering means bigger likelihood of running across that hazard. There are several factors influencing the LIKELIHOOD.

Let's name the first factor HAZARDS DENCITY (HD). Even if the initial CPA (second factor) is non-zero there is still a risk to hit an object in dense traffic or narrow waters. Although, if it is a ship, it will most likely try to deviate from our way to give us sea room as necessary, which somewhat reduces the RISK.

However, the most critical is the time factor or TCPA to the closest hazard, which almost straightforwardly specifies how much time we have to solve the problem to avoid grounding or collision.

In the most general cases, the SEVERITY of collision or grounding can be related strait to a ship's velocity. The higher the velocity the more damage may be caused.

In order to obtain correct LH value HD, CPA and TCPA shall be inversely proportional:

$$LH = \frac{1}{HD} \cdot \frac{1}{CPA} \cdot \frac{1}{TCPA} \cdot ST, \qquad (1)$$

where ST – hazard movability index.
Basing on the kinematic energy equation

$$E = 0,5 \cdot mU^2,$$

where m – ship's mass; U – ship's speed, although mass can be assumed as constant and thus will not affect the RISK for the particular vessel, severity can be given as

$$SV = U^2, \qquad (2)$$

In table 1 RISK level is given in each line for a possible collision with a stationary object.

Table 1. Risk assessment factors

Likelihood				Severity	Risk
HD, nm	CPA, nm	TCPA, hours	Statio-nary	Speed	
10	1	2	0.5 - NO	1	0.05
5	0.5	1		5	2
2	0.25	0.5	1.0 - YES	10	40
0.5	0.1	0.25		20	1600

These factors form multi-dimensional RISK. However, to get better visual representation lets define HD = 1, CPA = 1 for a stationary target and calculate the RISK matrix.

Table 2. Risk matrix: loss of steering

Risk		TCPA, hours			
		1	0.75	0.5	0.25
Speed, knots	1	1	1.33	2	4
	5	25	33	50	100
	10	100	133	200	400
	20	400	533	800	1600

RISK levels can be described as follows:

BLACK (risk > 400) – immediate actions required to avoid an accident or to minimize its consequences. Speed has to be reduced in any possible way. Assessment of possible catastrophic consequences to be done.

BLUE (risk > 200) – immediate actions required to avoid an accident or to minimize its consequences. Speed has to be reduced in any possible way.

RED (risk > 100) – Speed has to be reduced to a level where additional means of steering (retractable or side thrusters) can be utilized. As soon as safe heading is achieved, assess options for emergency anchorage. Try to regain the steering with main means of propulsion.

YELLOW (risk < 100) – additional means of steering can be utilized. Assess options for emergency anchorage. Try to regain the steering with main means of propulsion.

3. POWER MANAGEMENT AND BLACKOUT PREVENTION. There is a variety of possible faults that may happen to the steerable thrusters [6, 7], which goes all the way from power generation to a directed thrust delivery.

This stipulates the second stage of MRM training, dedicated to gaining a power management skill for the engine staff. This also includes changeover and synchronization procedures between generators and system restart after blackout.

Generally speaking, a blackout can be avoided by utilizing two different approaches [8]. The first one is used on conventional DP II/III class vessels, which usually have from four to six generators. During DP operations, a vessel usually has an open bus bar tie breaker, which splits power delivery in two equal groups, feeding two separate groups of thrusters.

Such approach advantages are elimination of total blackout in case of any single electrical or mechanical fault, greater reliability and less diesel-generator (DG) restarting time in case of partial blackout. Disadvantages are high fuel consumption at low loads, low power plant flexibility, in addition blackout on one side leads to inability to operate a certain group of

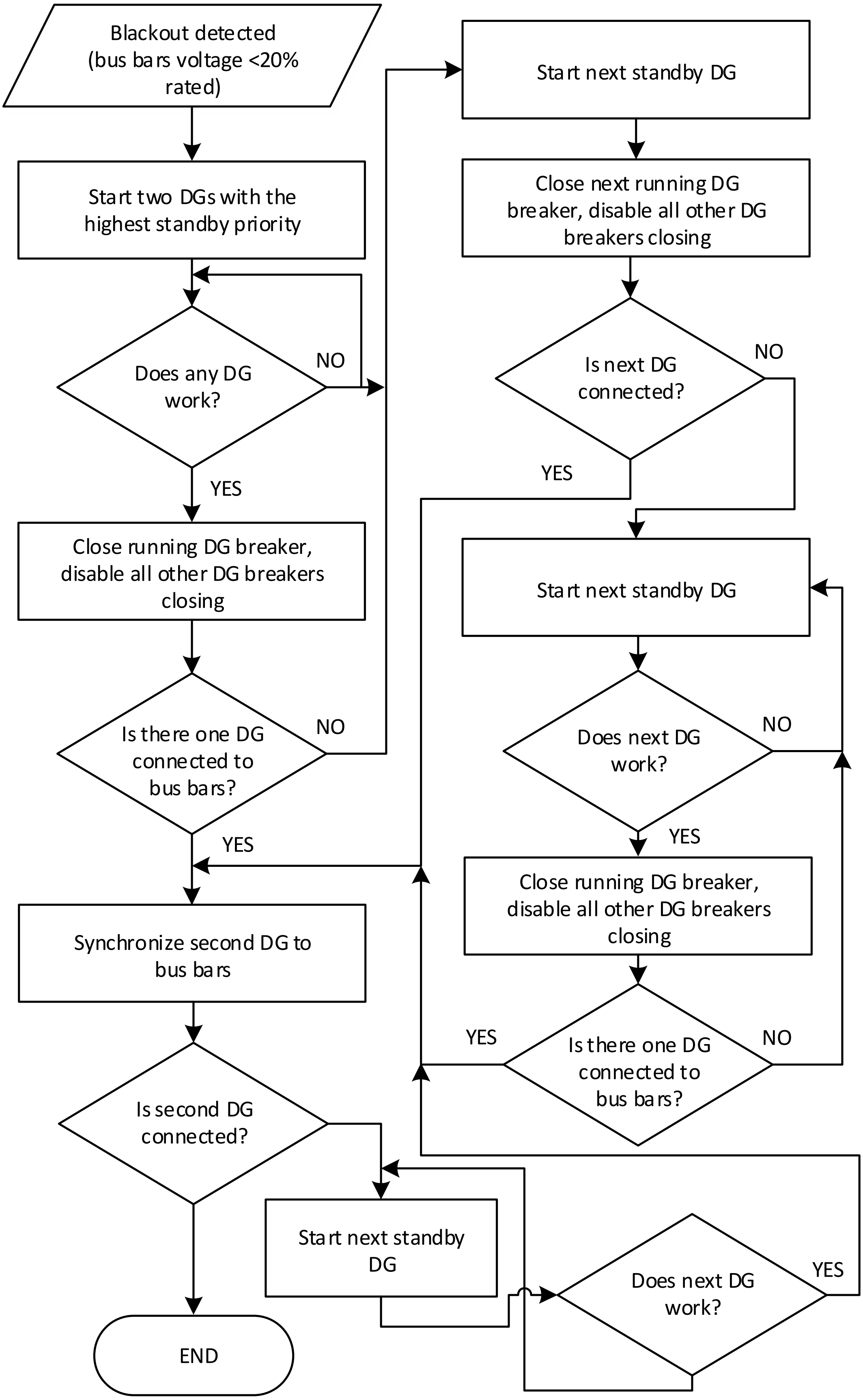

Figure 2. Flowchart on power restore after full blackout

thrusters and apparently reduces the steering ability.

The second way of providing electrical power continuity without splitting bus bars is the application of power plant advanced protection system.

The primary function of protection schemes is to isolate faulty circuits and limit damage to equipment. The greatest threat to any system is the short circuit fault, which can alter system operation in a sudden and possibly violent manner. Electromagnetic forces generated by large fault currents can cause mechanical damage to transformer and machine windings and the intense heat associated with arcing has caused fire at fault locations. In DP and other operations, even greater emphasis must be placed on the need to maintain supplies for propulsion. The arguments for and against operating with bus sections connected have been discussed earlier and are still the subject of much debate. Operation of the power system with bus sections connected offers many operational advantages with only slight risk of complete blackout. The risk cannot be considered negligible, however, and operators choosing to take advantage of this mode of operation may wish to consider installing one of the higher specification bus-bar protection methods. There are four types of protection that perform this task:

- zone protection;
- directional protection;
- protection by time discrimination;
- optical arc detection.

Such approach allows the power plant to be more flexible in most of known ships' operation modes but requires more sophisticated and expensive power management and protection equipment comparing the split bus bars operation.

Engine team actions in case of full or partial blackout are given on figure 2.

4. EMERGENCY STEERING. In a wider scope of the problem it is not only solenoid steering from the thrusters' gear compartment, but also all possible emergency actions taken by deck and engine departments, and communication between them. *Which is the third stage of MRM training*. This includes:

- control transfer from autopilot to feedback and non-follow up modes on the bridge;
- full or partial control transfer from Bridge to ECR (one group of thrusters is controlled on the Bridge, another – in ECR);
- troubleshooting and equipment restart on the ECR side;
- ensuring steerage and maneuverability or emergency anchoring on the Bridge side;
- transferring the control back to Engine room.

Introducing realistic scenarios and time limits related to existing navigational hazards helps to improve deck and engine officers' trouble shooting and crisis management skills.

On the working vessel, these scenarios usually are only limited to a table talk. Which is understandable, as the vessel schedule, mode or area of operation might not allow to carry out a proper training.

However, hands-on experience is extremely important when it comes to emergencies. Crew shall not only know what to do, but be able to act in a quick and efficient manner. This can only be achieved with dedicated simulator training.

For the purpose of simulator training vessel specific action algorithms can be really useful as a step-by-step to-do list and communication protocol, which has to be discussed and agreed within Bridge and Engine teams.

There are several events related to steering that may substantially affect vessel's controllability, which also have previously occurred in the industry:

- thruster starts to rotate freely;
- thruster goes to full power load unintentionally;
- thruster freeze on certain azimuth;
- thruster stops due to failure.

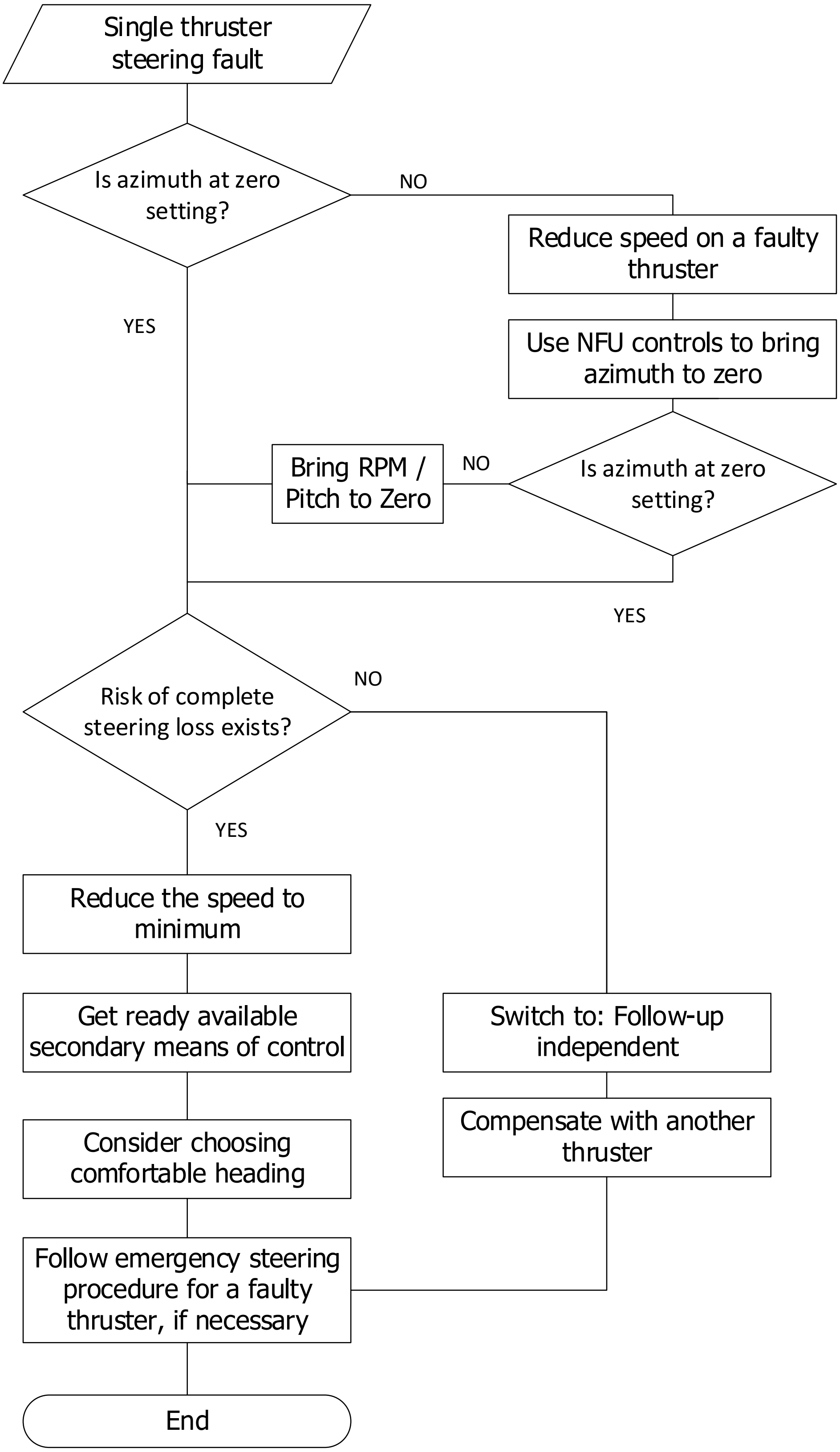

Figure 3. Actions flowchart for a single thruster failure

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Apparently, if a thruster's pitch or RPM is at zero or even below some critical value any steering with such thruster will be ineffective.

The latter has two different perspectives. When the steering mechanism works normally and thrust is lost, heading control will be also lost.

However, when thruster's azimuth cannot be controlled, the very first action required is to set thrust to zero.

Actions flowchart for a single thruster fault is shown on figure 3.

Required actions shall also be chosen with regard to existing risk level. For instance, if a vessel is steaming at 20 knots the very first action in case of any serious steering fault is to slow down appropriately in order to reduce possible harm and to give an engine team more time for troubleshooting.

Another consideration is that the vessel cannot effectively use additional means of control such as side thrusters, retractable thrusters or anchors at high speed. If the steering ability is seriously degraded, the deck officer has to ensure that the vessel is going slow enough in order to deploy an additional thruster or to use anchors as necessary.

5. BEHAVIORAL ASPECTS. Team reaction on faults and communication in the process of training changes dramatically.

There are several factors, which were observed during practical exercise.

Bridge and engine control room familiarization obviously has the greatest effect on response time. This also includes knowledge of warning and alarm sounds and indicators, and same important knowledge of how to silence the alarm buzzers. This recalls another important subject of alarms standardization an ergonomics, but usually a team has to deal with whatever is already installed.

Secondly, communication in between bridge and engine team has to be clear and precise in order to provide the best response time.

Not only language barrier may be a problem, but is also awareness on both ends of the phone line.

It is good practice to have a toolbox meeting (briefing) between deck and engine teams prior to critical operations and practice emergency scenarios as a team, including VHF and phone communication.

Also, it is recommended to send for MRM training same teams that will actually work together. It does help the crew to feel more comfortable in the future, if difficulties occur.

Finally, practicing all the stages of emergency gives both teams clear understanding of what may happen and how to deal with it. This builds up the operator's ability to recognize how a critical situation develops and what are the best ways to keep it from escalating or at least to minimize the harm.

CONCLUSIONS.

Vessel equipped with azimuth thrusters have complicated steering system architecture, which stipulates many possible faults, but also many troubleshooting alternatives. Knowledge of these alternatives can help to avoid incidents related to loss of steering.

As offered in the article, the best way to get hands-on experience on dealing with a steering system faults is the Maritime Resource Management training, which includes both bridge and engine teams.

Suggested MRM training should consist of three stages:

- azimuth thrusters manual handling training for deck officers;
- power management and troubleshooting for engineers;
- emergency steering training for both teams involved in same scenario.

Generic steering system failure risk assessment method and emergency actions flowcharts are provided in this article.

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SIMULATOR TRAINING IN SHIPS ENERGY MANAGEMENT

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Abstract: The downturn in the shipping market has driven the constant review of commercial vessel running costs. The reduction of "Green House Gasses" (GHG) and the other pollutants caused by shipping operations has become a priority for both international and nation regulatory bodies. Modern ships are required to operate a Ships Energy Efficiency Management Plan (SEEMP). The object of this paper is to demonstrate where simulation can help in the training of Marine Technical Officers as to where energy savings can be made, monitor energy consumption and how to make continuous improvements.

There are numerous computer based monitoring systems on board modern vessels. The collection of data from and the integration of these systems will become essential if ships officers and shore based ship managers are to improve the efficiency of their ships going forward.

Modern navigation and engine room simulators use advance hydrodynamic and thermodynamic modelling techniques that replicate the hull performance of the ship and its machinery. To date energy efficiency training has focused on the correct adjustment of the main engine and its auxiliary systems. There are numerous other factors that affect the ships energy efficiency.

- Weather routing
- Speed optimisation
- Optimum trim
- Optimum ballast
- Optimum use of rudder and heading control
- Propulsion system maintenance
- Waste Heat Recovery
- Electrical Energy Management
- Potential use of emerging alternative fuels

As energy efficiency, has become more important many ships now have advance software based energy efficiency instrumentation installed. In addition to fuel flow rates and total fuel used the software also uses sea trail data to predict optimum energy efficiency. By the adjustment of the ships speed, draft and trim optimum performance can be achieved. To allow training in the use of these instruments engine room simulators should include an example of energy efficiency software. The instrument could be "simulated" or a real system interconnected to the simulator "stimulated".

Weather routing is normally a subject for navigational officers training. However, it is important for engineers to understand the effects that environmental conditions have on the ships machinery. Bridge engine room simulator interconnection allows the adjustment of environmental conditions. The resultant effects on hull resistance is passed to the engine room simulator effecting energy usage. Using the simulators built in trending feature the student can observe how weather effects energy consumption in real time.

Figure 1. Transas Simulated Energy Efficiency Monitor

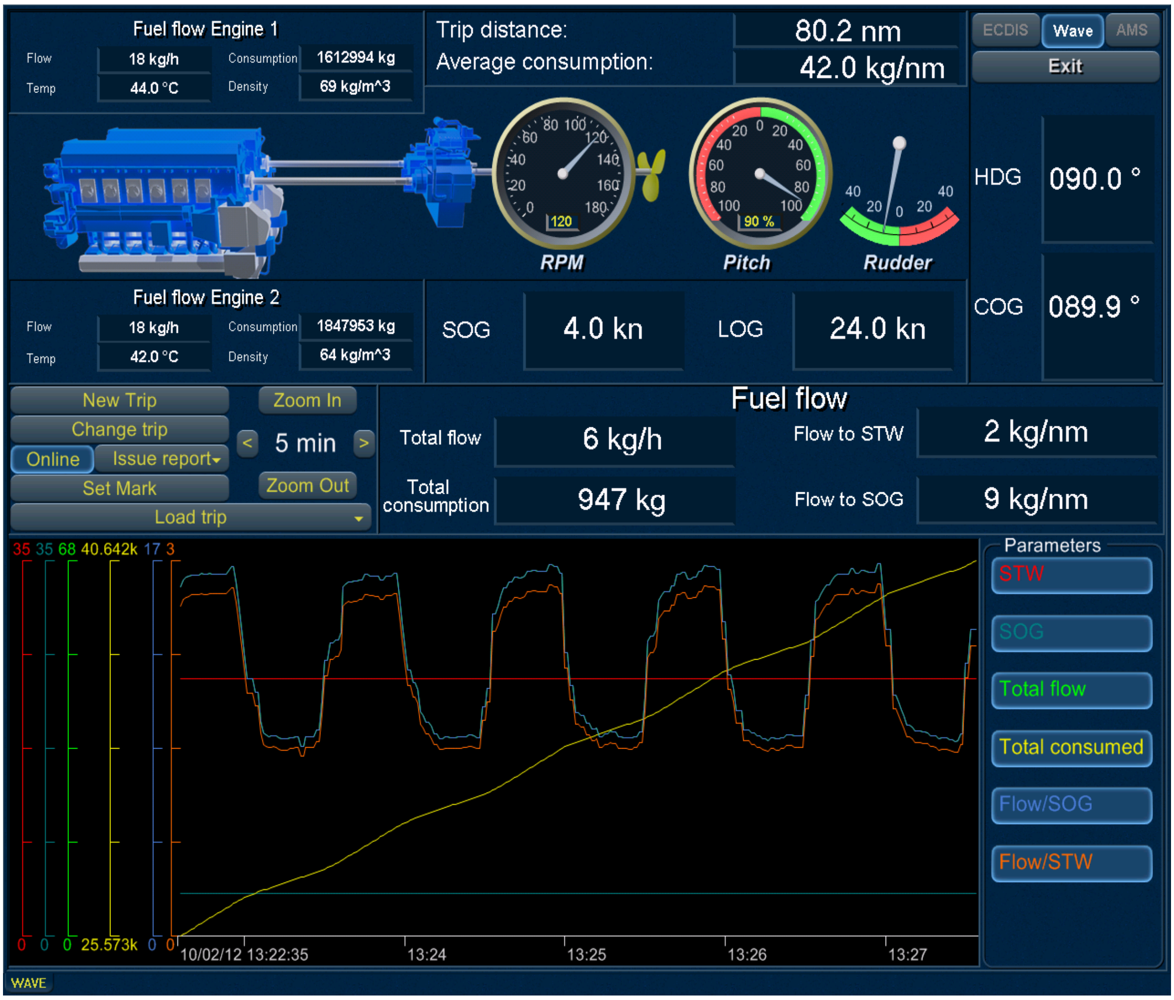

Figure 2. Transas Interconnected Wave Fuel Efficiency Monitor

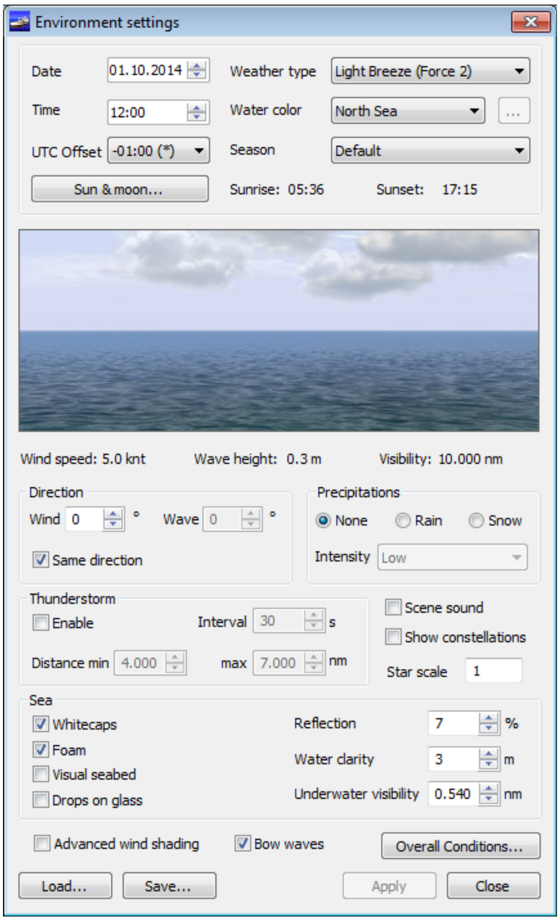

Figure 3. Bridge Simulator Environmental Conditions Adjustment

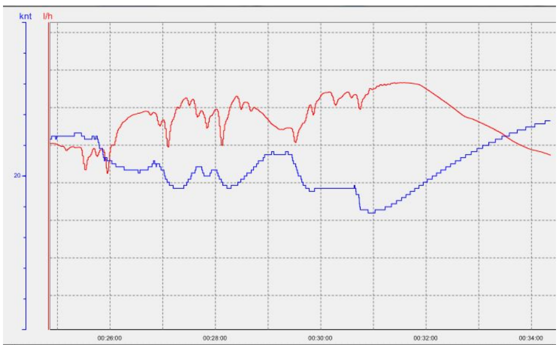

Figure 4. Fuel flow (red) and speed (blue) at varying sea states

Ships have an economical speed range. Slow speed steaming has become a popular method of reducing fuel costs. There are commercial factors involved in determining the passage speed of a ship. Dependant on the market price of the ship's cargo it may be necessary to speed up or slow down a ship. Simulation can demonstrate the relationship between ships speed and energy usage.

Experiments have shown that adjustments of the ships trim and draft has a considerable effect on hull resistance. Energy efficiency software uses sea trail and test tank data to predict the optimal trim and draft at various speeds through that water. These effects are modelled in advanced navigation simulators hydrodynamic models. By connecting the engine room simulator to the navigation simulator models energy usage at various speeds and trims can be demonstrated.

Figure 5. Speed and Fuel consumption after predicted trim applied

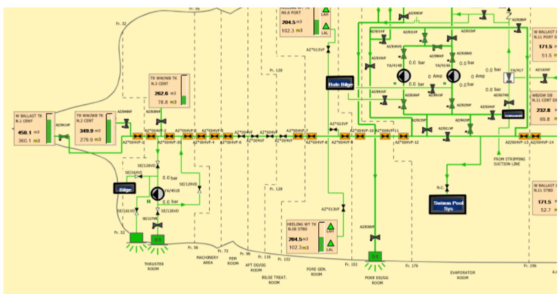

Figure 6. Corrected Ballast

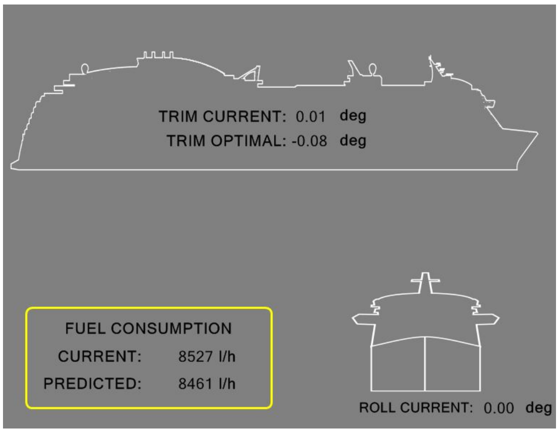

Figure 7. Recommended Trim and Predicted Fuel Consumption

Excessive use of the rudder increases hull resistance. Using small rudder angles and slower turn rates can save a considerable amount of energy in a large ship. Incorrect adjustment of the autopilot gain causing the rudder to “hunt” also wastes energy. Again, using the simulators instruments and modelling the energy usage at varying rudder angle can be demonstrated.

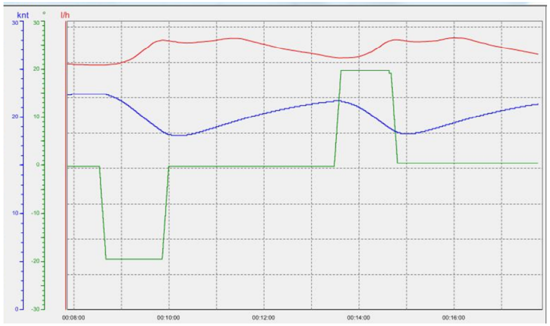

Figure 8. Fuel flow (red), speed (blue) rate and rudder angle (green)

The adjustments to the main engine fuel injection system, troubleshooting combustion faults and main engine systems are an established part of engine room simulator functionality. These features are only one piece of the energy efficiency jigsaw. Their use in conjunction with productive energy efficiency software will enhance training outcomes.

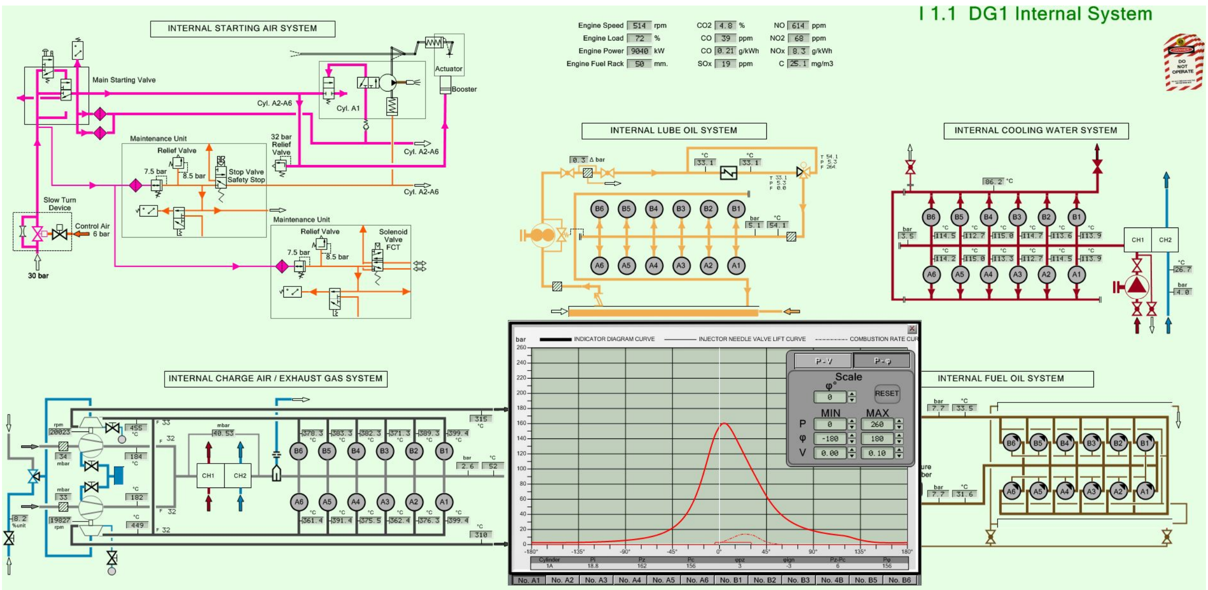

Figure 9. Simulator Engine Analytics

Exhaust gas boilers have provided a method of waste heat recovery for many years. Shipbuilders are now looking at other areas of the ships plant to recover heat. For example: modern cruise ships have systems that recover heat from the incinerators and main engine cooling systems to provide heat for the evaporators and air-conditioning plants.

One of the most innovative measures to improve energy efficiency in recent years is the introduction of frequency controlled motors. Ships cooling systems are engineered to operate in sea temperatures ranging from 40 to 1 degrees Celsius. Single speed pumps designed to provide enough cooling flow in areas of high sea water temperature waste energy when the ship is operating in lower temperature water. Regulating the pumps speed to suite the cooling demand saves a considerable amount of energy. Manufacturers are now introducing frequency controlled variable speed pumps into their simulators. Further saving can be achieved during the passage planning process by routing the ship through lower temperature tidal streams.

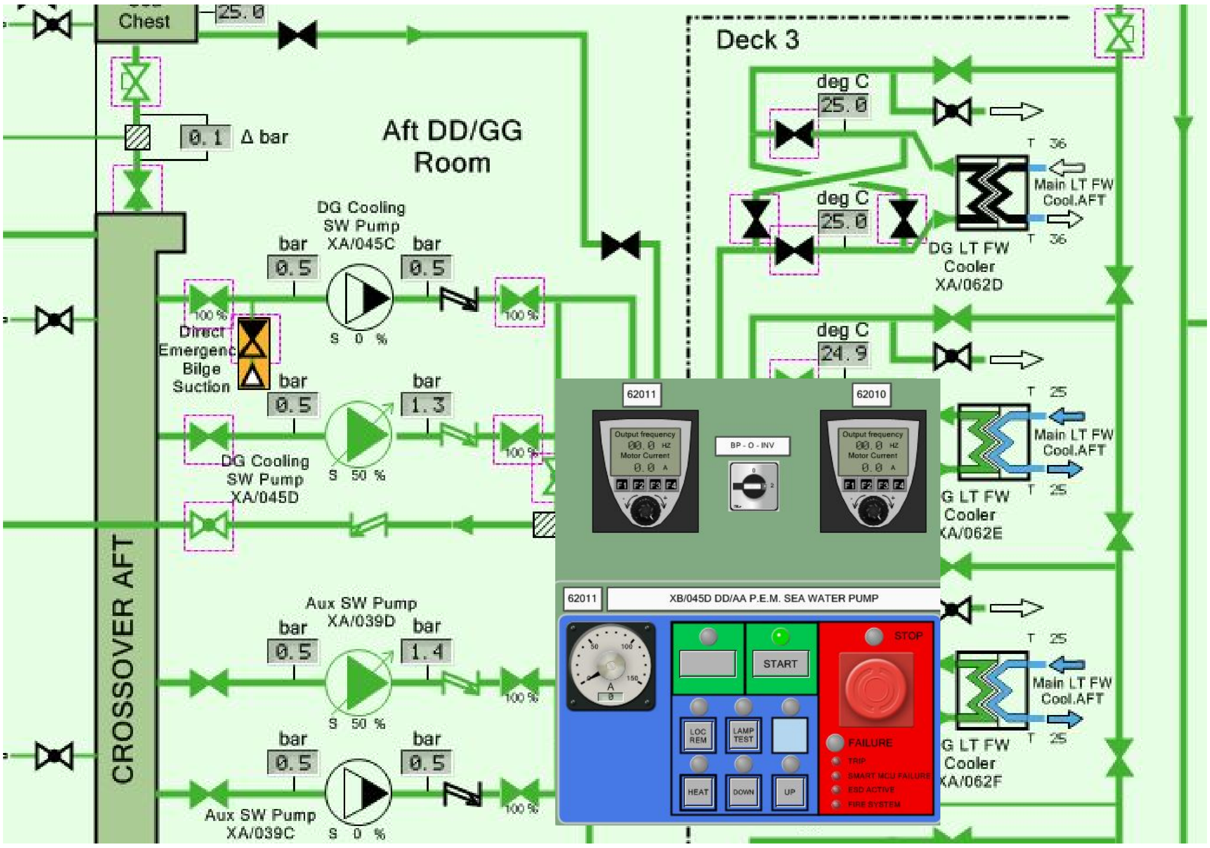

Figure 10. Variable Speed Cooling Pumps

Considering the above factors passage planning is becoming a very complex operation. The source data required such as advanced weather prediction, tidal stream prediction, bunker prices, cargo market prices and security intelligence may not be available to the planners on board the ship. Many shipping companies are setting up offices to provide decision making support to allow safe and economical passage plans to be produced. Simulation can play its part here too. Once a proposed passage plan is produced, fast time simulation can check the proposed passage plan is safe and will achieve optimum energy savings. The simulator models can be continuously adjusted using feedback data from completed passages ensuring the fidelity of the simulated quality checks. To assist in the task Transas is amalgamating it products in its THESIS vision (Transas Harmonised Eco System of Integrated Solutions)

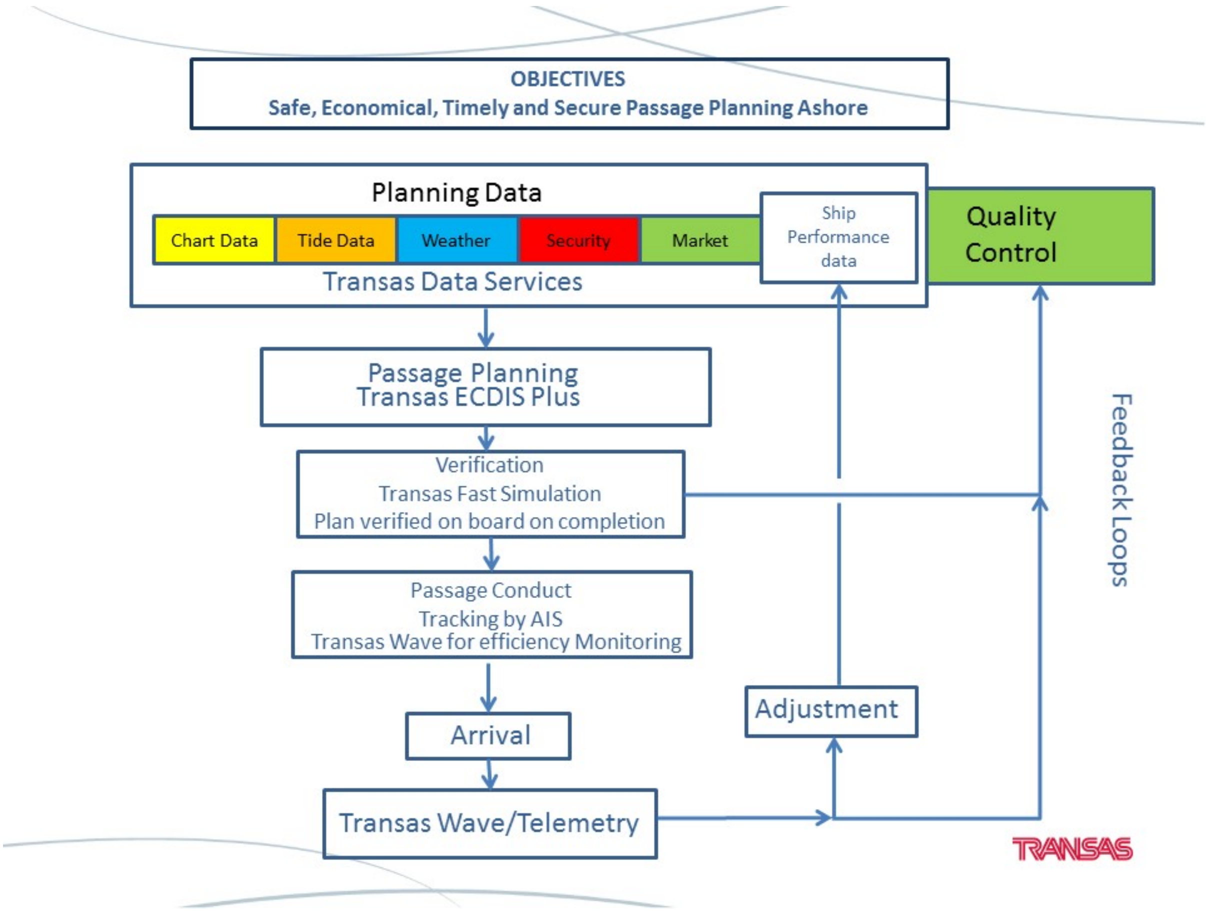

Figure 11. Passage Planning Quality Checks using Simulation

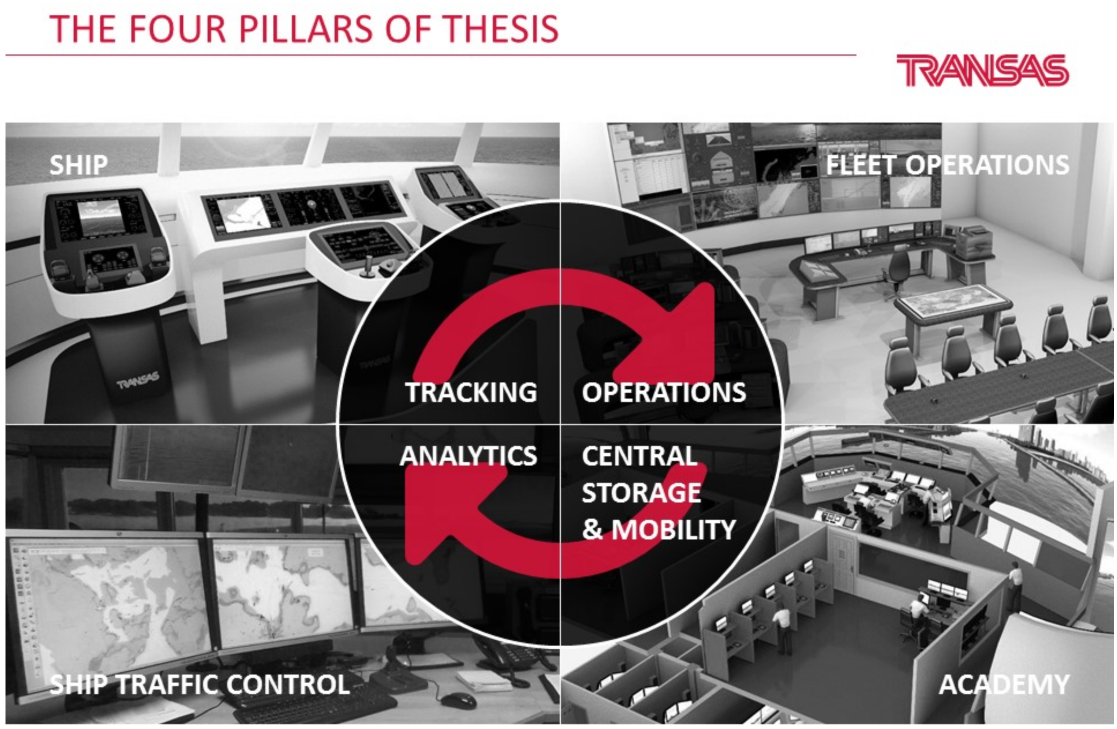

Figure 12. The Four Pillars of Transas Thesis

In conclusion, there is about to be a revolution in the way that ships are operated. Passage planning will no longer be the simple task of drawing a line on a chart from A to B and then sailing the course. Passage planning will become a task carried out by a shore base support team. This is due to the numerous factors involved and the volume of data required. Advanced simulation techniques will not only provide training in energy efficiency techniques but become a tool to verify the plans produced ashore in shipping offices.

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THE ENVIRONMENTAL AWARENESS IN THE ENGINE ROOM SIMULATOR TRAINING

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Abstract: The environmental awareness in the engine room simulator training is the main subject of this paper. The latest legal requirements for the reduced emission of SO_2*,* NO_x *and* CO_2 *imply not only the new onboard ship technology but also the improved environmental awareness of the ship crew. The problem requires the close co-operation between the navigational and the engineering officers but the engine room simulator is the right place where the available solutions can be compared and evaluated. One the other hand the engineering officers should be aware that technical state of the engine and its tuning has the significant influence of the environment pollution. The paper shows the examples how this problem is implemented in the existing engine room simulators.*

Keywords: engine room simulator, environmental awareness.

The advanced mathematical modelling available today, makes possible to extend a scope of the training offered by the engine room simulators by addressing the environmental awareness problems. Virtual Engine Room 6 (VER6) is the first engine room simulator where special ECO Data module has been added. This module uses the exhaust data from the sophisticated combustion process model which are normally available as the exhaust analyser readings (Fig. 1).

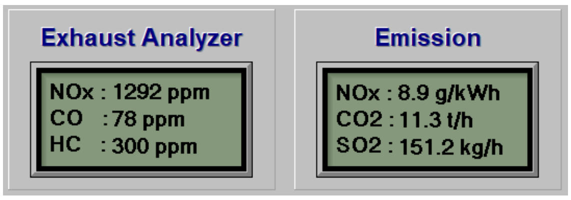

Figure 1.The exhaust analyzer display in VER6 simulator

The ECO Data should be used in order to see the influence of the selected ME operational parameters and the ambient conditions on the fuels consumption and the environment pollution. In general, this data should awake the economic and ecological awareness of the trainees.

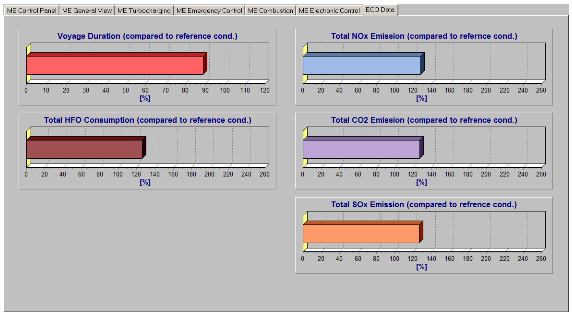

Figure 2. The ECO Data bars in VER6 simulator

The ME ECO Data System window includes several data bars showing the data which is necessary for the economic and ecologic voyage planning. The presented data includes:

<u>Estimated voyage duration</u> (without the time in the harbour and during the manoeuvring, canal passage etc.). This estimation is based on the theoretical assumption that the current (observed) ship speed will be maintained as a mean speed during the whole voyage. So, let's assume that one would like to shorten the voyage time by 10% (Fig. 3).

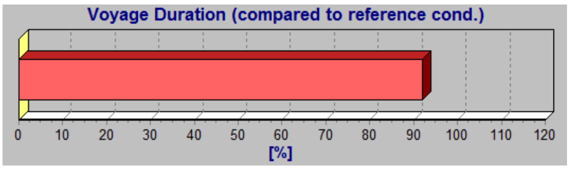

Figure 3. The example of voyage time shorter by 10%

Total estimated HFO consumption by ME only (i.e. without the fuel consumption by the main boiler or MDO by the diesel generators, incinerator etc.). In our example the HFO fuel cost will increase by ca. 35% (Fig. 4).

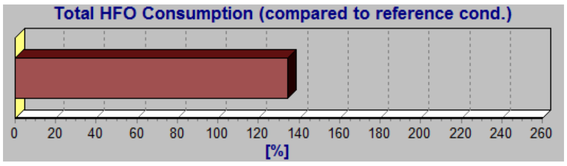

Figure 4. The example of the HFO cost consumption increase by 35%

Total NOx emission by ME only (i.e. without the fuel consumption by the main boiler or MDO by the diesel generators, incinerator etc.). In our example there will be almost no NOx emission increase (Fig. 5) due to the fact that the engine has an electronic control the injection advance will be delayed at higher loads.

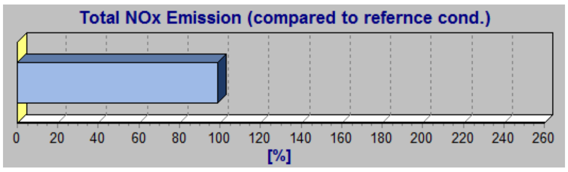

Figure 5. The example of the total NOx emission estimation

Total CO_2 emission by ME only (i.e. without the fuel consumption by the main boiler or MDO by the diesel generators, incinerator etc.). For the above given example, the total CO_2 will increase by ca. 35% (Fig.5).

The another example (Fig. 6 and Fig. 7) shows that switching the injection timing of the electronically controlled engine from Economy Mode to Emission Mode will cause small increase of the fuel consumption but significant decrease of the NOx emission.

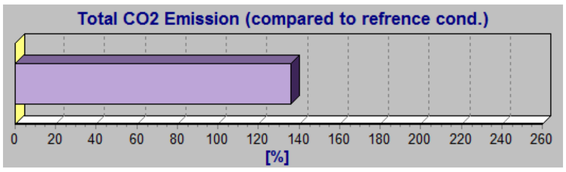

Figure 5. The example of the CO2 emission increase by 35%

Total SOx emission by ME only (i.e. without the fuel consumption by the main boiler). This factor depends strongly by sulphur content in the fuel so the very significant change can be observed when switching from HFO to LSF.

All above mentioned data is presented as the relative values (%) in comparison to the reference conditions which are: 70 rpm, 25% of the ship load, calm sea and 3.5% sulphur in the fuel.

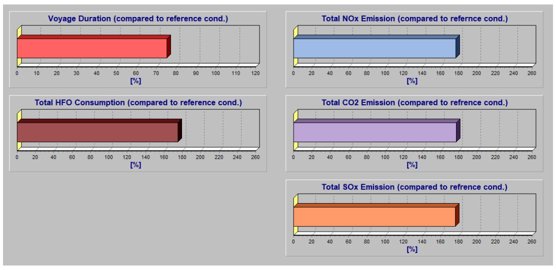

Figure 6. ECO Data in Economy Mode

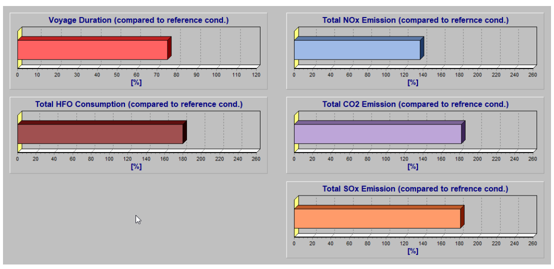

Figure 7. ECO Data in Emission Mode

The environmental awareness is also a part of the maritime training at management level when using Turbo Diesel 5 (TD5) simulator.

Turbo Diesel 5 offers the possibility to observe the influence of mixed engine faults on numerous operational parameters. As an example, the influence of the single and multiple (mixed) engine faults on NOx emission will be discussed. Fig. 8 shows, how does NOx emission and concentration in the exhaust gases depend on the injection advance angle. It is easy to conclude that the recommended by an engine producer injection timing (18 deg before TDC) offers the lowest NOx emission.

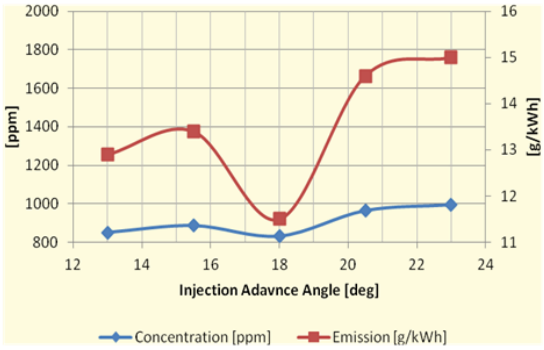

Figure 8. NOx emission and concentration as a function of an injection advance angle

On the other hand, the air filter cross section decrease which simulates the dirty air filer and a decreased air flow through the engine, lower air/fuel ratio and the significant increase of NOx emission (Fig. 9) what it is well known from the literature [1, 2, 3].

The emission is much higher and far above even the MARPOL - Tier I [4] limits when the third fault i.e. dirty air filer simulation is mixed in (Fig. 11).

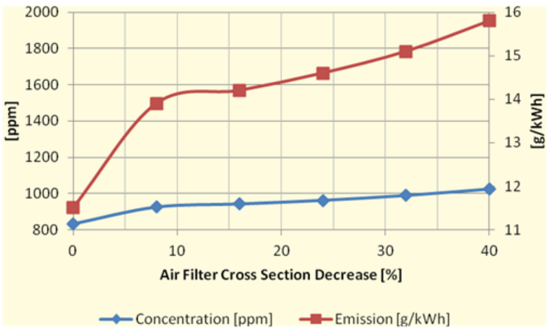

Figure 9. NOx emission and concentration as a function of an air filter cross section decrease

When the dirty exhaust duct is simulated and the injection advance angle is changed (Fig. 10) the lack of an air dominates the influence of the optimal injection timing and the total NOx emission is higher than when both single faults are simulated.

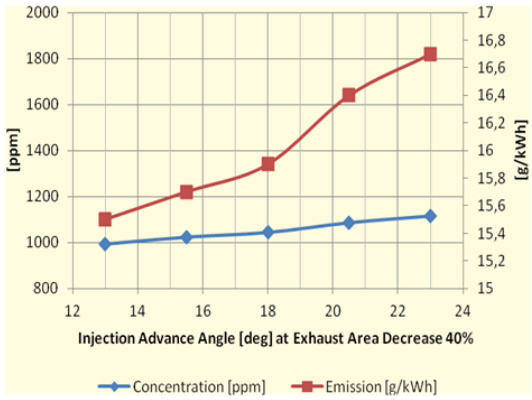

Figure 10. NOx emission and concentration as a function an injection advance angle and dirty exhaust

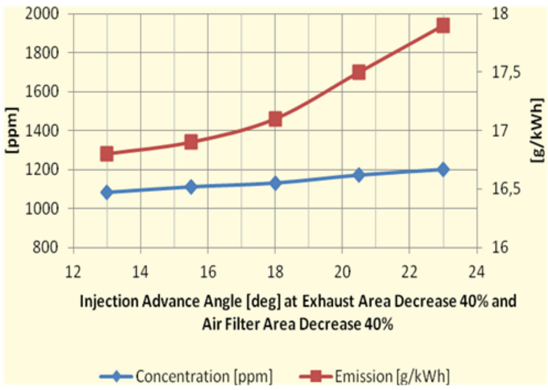

Figure 11. NOx emission and concentration as a function of an injection advance angle, dirty exhaust and dirty air filter

The above described observations imply the need to care of the turbocharging system cleanliness as an important measure to prevent the environment pollution by NOx emission. On the other hand, when the proper flow of the turbocharging air is provided, it is necessary take care about the injection adjustment as an effective measure of the environment protection.

CONCLUSION

The presented examples show that it is possible to extend the functionality of the engine room simulators by including the environmental awareness as well. This may look as a step outside of the today engine room functionality but it is probably the anticipation of the functionality from tomorrow.

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MARITIME CRM TRAINING ERROR MANAGEMENT IN ER SIMULATION TASKS

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Abstract: As in similar safety-critical industries, the analysis of maritime accidents over the years has revealed shortcomings in the ability of operators to manage both resources and human errors. CRM training has been seen increasingly as a fundamental part of the human error management philosophy. The International Maritime Organization recognizes the need for non-technical or resource management skills, but both the standards of competence and their assessment criteria are immature in comparison for example with civil aviation. Although CRM training has become well established in the maritime curricula, as with civil aviation, there remains a question mark about how effective such training actually might be in improving safety performance. Analysis of recent casualties also suggest that CRM training, although important, may not be a panacea for operator error and that organizational factors must also be taken into account.

In setting an agenda for future maritime research in this area, one of many issues need to be addressed:

If the direct training of resource and error management skills is pursued, to what extent will such skills, learned in a simulated environment, transfer to the real world? What are the optimum training environments to ensure effective transfer?

This paper is an attempt to share obtained experience of ERS usage in CRM training provided in our company since 2010. Manila Amendments 2010 of STCW Convention specify the minimum standard of competence in crisis management and human behavior skills for senior officers on mandatory basis commenced on 01.Jan. 2017.

Making mistakes is normal human behavior. Through management of these mistakes, we learn and thereby improve our performance. The highly recognized Danish engineer, Dr. Jens Rasmussen, classified human performance into three levels of activity: Skill-based Performance, Rule-based Performance, Knowledge-based Performance. Human behavior in these levels of activity often determines risk of making mistakes as well as their categories (errors of commission, errors of omission, errors of substitution, recognition failures, mistaken assumptions, etc.). Usage properly prepared as close as possible to reality scenarios for ERS exercises, be ready to change an exercise development ("node" point), know how to assess trainees behavior and mistakes management (Communication, Leadership/Teamwork, Situation Awareness, Decision making) during the exercise progress can be key prerequisite for improving CRM training in maritime industry.

Some examples of usage of TRANSAS full mission engine room simulator ERS5000 together with TRANSAS full mission bridge simulator NTPRO5000 for CRM course development in our Company are available in this paper.

Creating scenarios in ERS5000 for CRM course should be based on an obvious fact that human errors do not occur as isolated glitches in people's mind but are shaped by local circumstances. Our working environment, and by that I mean not only physical environment but also corporate culture in which we are operating, can have a determining influence on how we perform a task. This environment can actually pre-program the error we commit.

Simulator exercises are satiated with events thus that during student responses on these events their behavior qualities such as communication skills, leadership and teamwork, situation awareness abilities, decision making skills, synergy, assertiveness, error management can be clearly enough observed.

On completion of an exercise quality debriefing is being carried out. This is one of the most important step on the way to successful result of CRM training, to assess above mentioned student behavior qualities. The debriefing allows to consider success and failure, identify lessons (good and bad), maximize learning, agree areas for improvement.

Desirable success of a simulator exercise can be determined (but not limited) by:

- Creation of technically logical scenario of the exercise and adhering it during the exercise development
- Instructor readiness to react timely and properly to possible deviation from exercise scenario (node point)
- Qualitative inter communication establishment: ERS – ERS instructor – Bridge Simulator
- Qualitative audio and video supervision of students behavior
- Possibility to play back the recording audio and video information during the de-briefing process.

Training Department of our Company designed CRM course for senior officers (5 navigators and 5 engineers – common participation of the CRM course) in two parts: theoretical and practical. The theoretical part includes topics: communication, leadership and team work, situational awareness, decision making. The practical part includes at least 5 exercises with various scenarios. Audio and video recording of students behavior during the exercises allows organize qualitative after exercise debriefing with emphasis on the student behavior aspects. Every student plays different appointed role in every exercise – chief engineer, 2-nd engineer, 3-rd engineer, 4-th engineer, observer. As per exercise scenario the student is expected to behave in accordance with this role. Patterns of interactions between engine room team leaders and other engine room team members are being compared to try and determine if there are any particular patterns that lead to the successful management of all simulated emergency events. The simulator operator participates in the roles of Extra Second Engineer, Electrical Engineer, Mechanic but only by radio or phone. In these roles the simulator operator can act as a facilitator for the not wholly scripted research exercise scenario. The Mechanic is available to work under the supervision of the Extra Second Engineer. The first scenario is created for the simulator familiarization. Once simulator familiarization has been achieved, team roles have been assigned, and the scenario briefing has been given, the course exercises are undertaken day by day.

Observations are made with the instructor and a student being an acknowledged observer. It is understood that there is the potential for reactivity effects using this method of observation. However, interesting evidence over many years from professional marine engineering officers using the full mission Engine Room Simulator at V. Ships (Ukraine) Training Centre has indicated that the closed circuit video and audio monitoring systems, used for observation, are unobtrusive, and do not cause any reactivity effects.

Behavioral markers that could be used to assess student actions in view of:

- communication skills (understanding, close loop, follow-up, communicating in a way that shares ones mental model),
- indication of teamwork and the building of a shared mental model,
- leadership and team work (synergy, assertiveness)
- level of anticipation of other team members needs and anticipation of future actions and task requirements (indication of the level of situational awareness),
- delegation of work tasks,
- patterns of movement.

The events simulated for various ERS exercises during CRM courses allow to observe the most of above listed behavior markers.

ERS familiarization exercise (to prepare plant from COLD IRON condition to readiness for maneuvering) is developed on the first day of CRM course shows as technical as soft skill potential of engineer participants.

All exercises in the course are created for similar plant of Tanker LCC:

Ship type	*Large crude oil carrier*	*Main Engine*
Draft Displacement LOA Beam	*f5.7m a9.3m* *77,100t* *282.00m* *32.00m*	*MAN B&W 6S60MC +FPP (12,240 kW, 105 RPM)*

Thus we have posssibility to abstract from technical issues and concentrate on human soft skill.

Individual and combined exercises created for CRM course based commonly on real incidents:

- Full Sea_Unidentified Leakage in ER_Total Loss of Cooling;
- Full Sea_Handover of the watch_various situations and faults are introduced;
- Maneuvering Mode_Europort out_ several faults with Fuel oil systems and Steerng gear (latent and alarmed), various distructions are introduced;
- Full Sea_Maneuvering Mode_ Gibraltar Straights _Eastbound_ Alarmed and Latent faults of Lubricating oil systems, Oil Mist Detector activation are introduced.

On an exercise completion the students are required to debrief the exercie development without assisstance of the instructor trying to put aside technical issues and relying mostly on human behaviour factors: communication, leadership and teamwork, situation awareness, decision making, etc. It's suggested the students will be able to assess their own actions and behaviour, determine success and what to be improved. Thereafter the instructor carries out debriefing with usage of his own and the observer's oversights as well as video and audio records of the exersice process. To estimate the students action and behavior above mentioned behavior markers are being widely used by the instructor. It was noted such practice increases substantially the CRM course effectiveness. Day by day of the course development shows improvement of the non-technical or resource management skills of the students. They become in increasing extent able to understand and use conceptions of behavior factors, to see possibility of error chain formation leading to incidents and search ways to interrupt such formation due to improvement of communication, leadership qualities, team work, situational awareness and decision making skills, i.e. effective management of crew resources. This allows to be on the way of human error management: avoid errors, trap errors, mitigate consequences of errors.

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DEVELOPMENT AND IMPLEMENTATION OF SEMI-SUBMERSIBLE HEAVY LIFT VESSEL SIMULATOR

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Abstract: The vessel Taiankou made in China is a semi-submersible heavy lift vessel; the operations of it are complicated and difficult. In order to train students and fresh crews safely and economically, the semi-submersible heavy lift vessel simulator was developed. The simulator is composed of engine control room, bridge room, ship power station, visual simulation station, instructor station, and so on. The paper introduces the development and implementation procedure of Taiankou simulator. The key questions and technical essentials involved in real-time simulation system are explained briefly. The whole design of systemic scheme, selection of simulation platform, work principle of visual simulation and networking process are also involved.

Keywords: semi-submersible vessel, simulator, visual simulation, Taiankou.

1. INTRODUCTION

Taiankou is a semi-submersible heavy lift vessel, its maximum dive draft is 19m, and its navigation zone is unlimited navigation areas. There is no large-scale two-stroke main diesel engine and rudder controlling course in traditional mechanical propulsion vessel. Instead, it is equipped with DP(Dynamic Positioning) system, SIMOS IMAC(Integrated Monitoring and Alarm Control)55 developed by Siemens, two sets of electric propulsion systems with 360 degree full rotation pod SSP. The semi-submersible heavy lift vessel is shown in Figure 1.

Figure 1. Semi-submersible Heavy Lift Vessel *Taiankou*

2. SIMULATOR LAYOUT

There are four separated rooms in *Taiankou* simulation system, as shown in Figure 2. Instructor station, bridge control console and DP console are located in bridge control room, engine control console is arranged in engine control room, medium and low voltage panels, right and left local control boxes are located in ship power station, HTC VIVE (Very Immersive Virtual Experience) products are arranged in VR room.

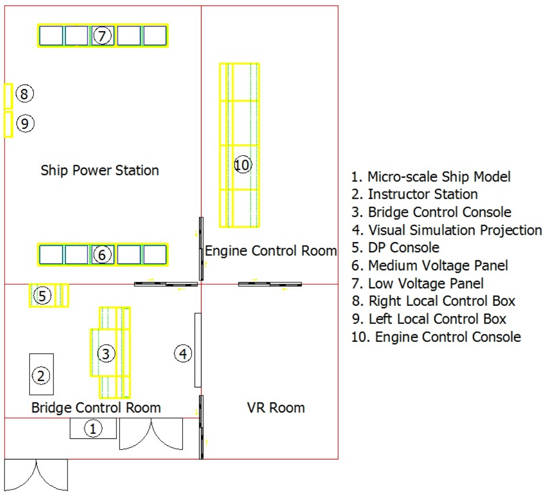

Figure 2. Layout of Simulator

3. NETWORK

There are 8 nodes in the wireless network, as shown in Table 1.

Table 1. Table of Network Nodes

No.	Node Name	IP Address	Description
1	IC1	192.168.100.31	Interface Computer 1
2	IC2	192.168.100.32	Interface Computer 2
3	IC3	192.168.100.33	Interface Computer 3
4	IC4	192.168.100.34	Interface Computer 4
5	BMC	192.168.100.35	Bridge Monitor
6	DPW	192.168.100.36	DP Monitor
7	VSW	192.168.100.37	Visual Simulator
8	MMW	192.168.100.30	Main Workstation

2.4G and 5G are both available. IC1~IC4 are industrial computers. Interface system is in the charge of them. Meanwhile, every interface computer plays the role of monitoring computer. BMC (Bridge Monitoring Computer) is equipped in bridge control console. DPW (Dynamic Positioning Workstation) is equipped in DP console. VSW (Visual Simulation Workstation) is equipped in VR room. MMW (Main Model Workstation) is used for mathematic model calculation, at the same time, it is the instructor computer and responsible for the mathematical model of operation, setting the malfunction, etc. Network of Simulator is shown in Figure 3.

Figure 3. Network of Simulator

4. SYSTEM COMPOSITION

Bridge Control Console (BCC) is shown in Figure 4. Speed governing and steering wheel to SSP of each side can be accomplished by two respectively pod telegraphs on the BCC. In addition, the operation to bow thruster is achieved by a telegraph in the middle of BCC. The setting of external disturbance, such as wind, wave, current, can be accomplished by the PC on the BCC. Both strength and orientation of them can be setting one by one to verify the performance of dynamic positioning (DP).

A large scale display unit jointed with four LED monitors is installed in front of BCC. The temporal navigational posture and external environment of the semi-submersible heavy lift vessel can be showed dynamically in real time. The viewpoint can be switched to undersea to observe the SSP operative condition of both sides. Meanwhile, the virtual engine room roam can be realized by the visual simulation system. Both manual mode and automatic mode are available in virtual roam.

Figure 4. Overview of Bridge Control Console

The Engine Control Console (ECC) is equipped in the engine control room, as shown in Figure 5. There are four consoles and two computers in it. The management of internal interface system in the ECC is in the charge of the left computer; the management of low voltage power station interface system is in the charge of the right computer. At the same time, both computers play the role of monitoring computer to monitor and control the pipeline system, thermal engineering system, power and electric system, and so on.

Figure 5. Overview of Engine Control Console

One of the diesel engine monitoring interfaces is shown in Figure 6.

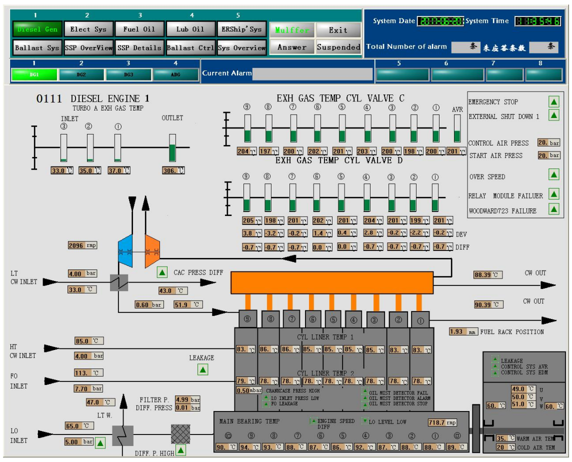

Figure 6. Diesel Engine Monitoring Interface

The vessel middle voltage power station is also located in the ECC. The power station consists of the middle voltage switch board and low voltage switch board. The middle voltage switch board consists of three generator control panels, synchronous panel 6.6kV switchboard and diagram of power panel, as shown in Figure 7.

Before DP operation, at least one generator should be connected on each side of the bus tie breaker. If the bus tiebreaker is closed during DP class 2 operations, the power management system function for load dependent stop is disabled.

Figure 7. Middle Voltage Power Station

The low voltage switch board consists of auxiliary generator panel, two rotating converter panels, synchronous panel 450V auxiliary switchboard, and emergency generator panel, as shown in Figure 8.

Figure 8. Low Voltage Power Station

The 230V main switchboard is to be supplied from the starboard side 450V auxiliary switchboard during DP AUTR (Class 2) operations. The reason is that the emergency switchboard is supplied from the port 450V auxiliary switchboard.

The power plant diagram of vessel is shown in Figure 9.

As the generators are rated at 3900kW and for Class 2 DP operations, two will be connected to the switchboard at any one time. There is the danger that the generators will be run at very low loads. The diesel engines have a facility whereby after a set running period at low loads one engine will increase the load to "burn off" excess carbon build up. Care must be taken if using this function on DP and it may be better practice to ensure that the engines have been maintained prior to DP operation.

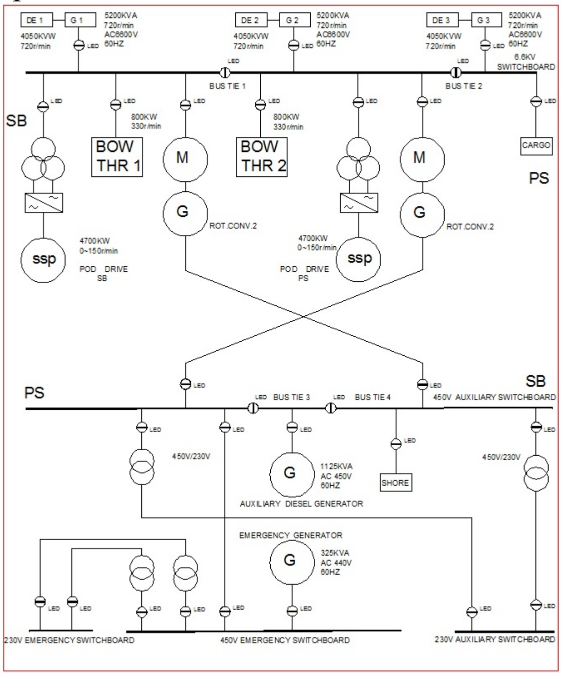

Figure 9. Diagram of Power Plant

Furthermore, two SSP local control box of port and starboard sides are equipped in the engine room to simulate local operation under emergency working condition, as shown in Figure 10. The small scale physical models of SSPs can be driven and rotated along with the operation of mathematic models in some version.

Figure 10. Local Control Box

5. CONCLUSION

Taiankou simulator is a large teaching and training equipment. Plenty of technologies, such as mathematic and physical modeling, computer application and simulation, visual simulation have been employed synthetically to improve the efficiency and real-time quality.

ACKNOWLEDGMENT

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DETERMINING OF THE "GREIFSWALD" M/V-ENGINES' OPERATING-CONDITION PARAMETERS FOR THEIR FURTHER USAGE IN THE SIMULATOR DEVELOPMENT PROBLEMS

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Abstract: The marine medium-speed diesel engine operating-condition parameters can be used for developing or correcting the special-purpose ship's main power plant simulator characteristics. Monitoring of the performance of four main engines installed on the m/v "Greifswald" was carried out during the voyage that took place in January 2015 on the "Odessa-Istanbul-Odessa" navigation line. The existing weather conditions permitted, while maintaining an equal load on the engines, to carry out a parametrical diagnosis of all the main-engine cylinders, including the diagnosis of the high pressure fuel injection equipment (FIE), valves timing gears (VTG) and cylinder piston groups (CPG). The D4.OH (DEPAS) computer-based diagnosis system was used for determining of the operating-condition parameters. Due to the fact that the D4.OH system uses the methods of data algorithmic synchronization, vibration and acoustic determination of the fuel injection and gas distribution parameters, it is a convenient means for diagnosing medium-speed diesel engines, which are not fitted with any power actuator to be used for taking indicator diagrams. Diagnostics data obtained enable to improve the accuracy of the marine power plant simulator characteristics, as well as to monitor the status of CPGs, and repair deficiencies in FIE and VTG. D4.OH-assisted determination and further uniform distribution of the power among the engine cylinders gives a possibility to equalize heat and mechanical loads. All the carried out procedure package has promoted lowering of the general level of vibration and heat-release rate in the CPG parts, a reduction of the specific fuel consumption, a service-life rise, a decrease of the risk of an emergency occurrence in the course of the ship's operation. Interrelationships among the parameters are taken into account when developing marine power plant simulators.

Key words: marine power plant simulators, marine medium-speed diesel engines, parametrical diagnostics, high-pressure fuel injection equipment, valve timing gears, spectrum analysis.

Introduction

The "Greifswald" automobile and railroad / passenger ferry is a modern cargo-and-passenger ship equipped with four main 6VDS48/42AL-2U medium-speed diesel engines manufactured by "SKL MOTOREN UND SYSTEMTECHNIK GmbH".

In the course of the diesel engine running process, there occurs natural maladjustment in the FIE and VTG assemblies, as well as wear of the main CPG units. These changes, being non-critical during the time between overhauls, decrease, however, the quality of the cylinder working process and, consequently, increase the specific fuel consumption and general vibration level in the engines. Moreover, with all that a non-uniformity of the thermal and mechanical load distribution among the cylinders increases, which raises the risk of emergency occurrence.

Serious problems would arise while operating the ship's electric power stations. With the generating sets running in parallel, periodic processes of active energy exchange would arise between the diesel generators. The main cause of this phenomenon is the dynamic instability of the engine rotational speed. To a considerable extent this instability is the condition of the instability of the working process and torque in some engine cylinders. This, being combined with the self-excited vibrations in the rotational speed governing system, leads to setting up of considerable exchange of the active power fluctuations while running the generating sets in parallel. In this connection, equalization of the loads and power output unbalance leveling among engine cylinders promotes a reduction of the fluctuation processes of energy exchange between the diesel-generator sets and their service-life rise.

Periodic indication enables to reveal and remove the causes of the cylinder power output unbalance and to eliminate the above stated problems.

In this case the diesel engine (condition) displaying was carried out by means of D4.0H parametrical diagnosis system [3].

Determination of the working process essential parameters

The D4.0H system determines the following working process essential parameters (Fig. 1):

- p_i , N_i - mean indicated pressure and indicated cylinder power output;
- p'_c - pressure and crankshaft rotation angle (CRA) at the beginning of the fuel ignition in the power cylinder;
- p_c (p_{comp}) - pressure at the end of the compression stroke;
- p_Z (p_{max}) - maximum fuel combustion pressure and appropriate angle, CRA;
- p_{EXP} - pressure on the expansion line (36º CRA after top dead centre, TDC);

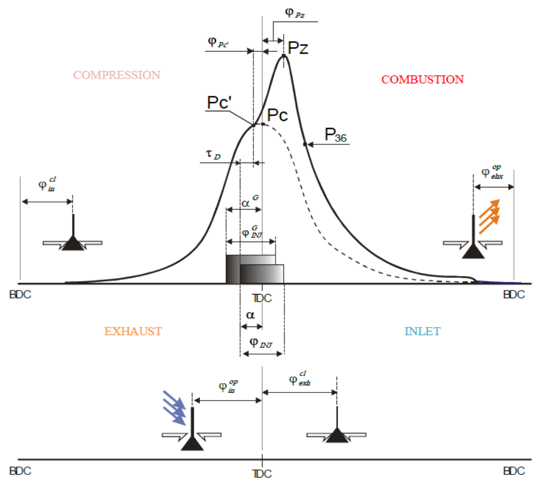

Figure 1. Developed indicator diagram of a four-stroke diesel engine with marked essential parameters of the working process

- gas distribution phases (referred to the angles of closing of the inlet and exhaust valves making part of the valve timing gears, VTG;
- geometrical (referred to HPFP) and actual (referred to the movement of the fuel injection valve needle) fuel injection phases;
- τ_D - fuel self-ignition angle and delay time (obtained by means of calculation).

Determining of the fuel injection and gas distribution phases, as well as diagnosis of the high pressure fuel injection equipment and valve timing gears, are carried out by means of analyzing of the vibration and acoustic signals given by the appropriate assemblies. For this purpose the system is equipped with VS-20m high-frequency vibration sensitive transducer mounted on a magnetic platform providing a reliable contact of the transducer with a metal setting shelf to diagnose the assembly on a running engine. The usage of the vibration and acoustic method is fully in line with the up to date concept of the “non-destructive diagnosis control”. VS-20m is used to obtain information about the commencement of fuel supply / cut-off (geometrical fuel supply phases) and the lift / fit of the fuel injection valve needle (actual fuel supply phases).

The traditional diagnostics of a high pressure fuel injection system, FIE implies taking a fuel oil pressure diagram (Fig. 2). Undoubtedly, diagram analysis gives the most accurate data on the technical condition of the high pressure fuel pump (HPFP) and of the fuel injection valve. The maximum values of the fuel injection pressure *(Pf.max, fig. 3)* on the modern FIE are quite great: up to 300 MPa on the modern high-speed and medium-speed diesel engines (HSD and MSD) and going up to 200 MPa on slow-speed diesel engines (SSD). With all that, the injection phase amounts to 10-20º CTA, which, with big crankshaft rotating speeds characterizes an abrupt dynamic process having big amplitudes and pressure build-up velocity. Several worldwide companies manufacture specific pressure transducers able to operate in such severe conditions *(kistler.com, imes.de, optrand.com).*

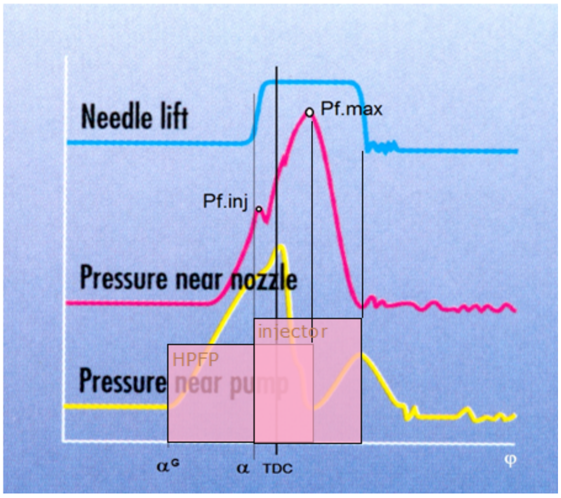

Figure 2. Diagrams of the pressure available in a fuel system at the time of injection (from top to bottom: linear displacement of the needle, fuel pressure at the atomizer nozzles, pressure after HPFP)

Of course, with so high pressures, fitting of non-standard transducers to the FIE and monitoring of the fuel injection process can be carried out only under laboratory conditions. In practice, on board a transport ship, any fitting of non-standard equipment to the high pressure fuel system is prohibited, since with depressurization, explosion or fire probability would be too big. Under such circumstances, fuel injection equipment assembly vibration and acoustic signal analysis is almost the only alternative. This method is used in the D4.0H system to analyse the fuel supply phases and diagnose the HPFP and fuel injection valves.

In order to determine the fuel supply geometrical phases (α^G, $\varphi_{inj}{}^G$ -see Fig. 1) the VS-20m transducer is fitted onto the blank flange opposite the HPFP plunger pair cut-off port (Fig. 3, b). In this position the transducer indicates vibration signals setting in at the start of fuel supply fuel cut off by the HPFP.

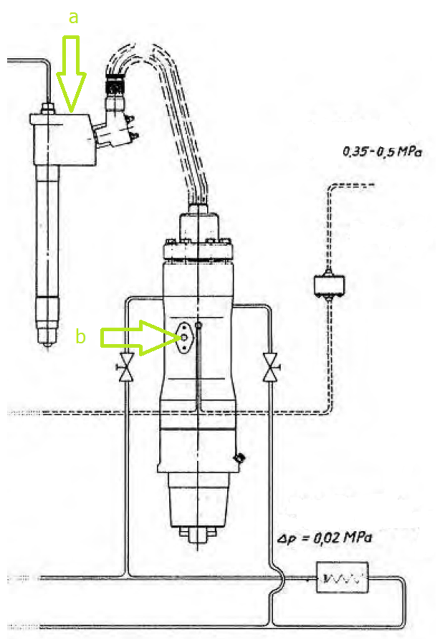

Figure 3. Places where the VS-20m transducer is to be fitted while indicating the diesel engine condition

For the determining of the actual fuel supply phases (α, φ_{inj} see Fig.1) and diagnosing the general condition of the high pressure FIE, the VS-20m transducer is fitted on the end face of the fuel injection valve, perpendicularly to the needle lift (Fig. 3, a). In this case the transducer records vibration signals setting in when the fuel injection valve needle is lifted or fitted.

When the vibration transducer is fitted onto the injection valve, it additionally records impacts caused by the fitting (closing) gas distribution valves (see the phases $\varphi_{in}{}^{cl}$, $\varphi_{exh}{}^{cl}$ - Fig. 1). If the amplitude of the valve closing signals is insufficiently big, while fitting the transducer on the end face of the injection valve, a place is chosen on the cylinder cover, in the immediate vicinity to the valves.

Determining of the fuel self-ignition delay

The time between the beginning of the fuel injection into the cylinder and the beginning of its ignition is regarded as the fuel self-ignition delay. In Fig. 4 it corresponds to the phases α and $\varphi Pc'$

$$\varphi\tau_D = \left|\alpha - \varphi P_C'\right|, [^\circ \text{ CTA}]$$

The relation between the CTA and self-ignition delay:

$$\tau_D = \frac{\varphi\tau_D}{6 \times RPM}, [\text{мс}]$$

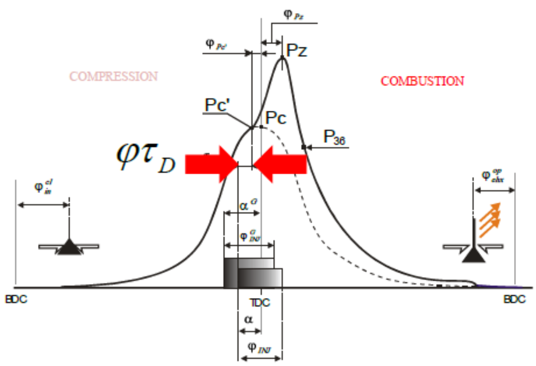

Figure 4. Fuel self-ignition delay

The self-ignition delay is caused by the following each other and intersecting physical and chemical processes:

- fuel atomization and vaporization, mixing it with air in the compression chamber;
- chemical delay due to the development of pre-flame processes.

General form of the formula used to assess the self-ignition delay [5]:

$$\tau_D = \frac{C}{p^n}\exp\left(\frac{E}{RT}\right),$$

where: p, T = pressure and temperature of the gasses in the cylinder at the moment o fuel injection; E= energy of the fuel activation; R = gas constant; C, n = empirical coefficients.

In order to upgrade the fuel combustion, to raise the operating cycle economical efficiency and to reduce the dynamic loads on the crank mechanism and bearings, it is necessary to decrease the self-ignition delay. The essential procedures aiming a decrease of the self-ignition delay are the following:

- fuel injection pressure elevation and improvement of the mixing quality;
- preadmission into the cylinder of a smaller portion of fuel to make a place of self-ignition before injecting the main portion of fuel (see wartsila.com).

Determination of the pressure, at which the combustion in the cylinder begins, is conducted by analyzing of the second-order cylinder gas pressure curve derivative, Fig. 5.

$$\varphi_{Pc'} = \frac{d^2p}{d\varphi^2} \Rightarrow \max$$

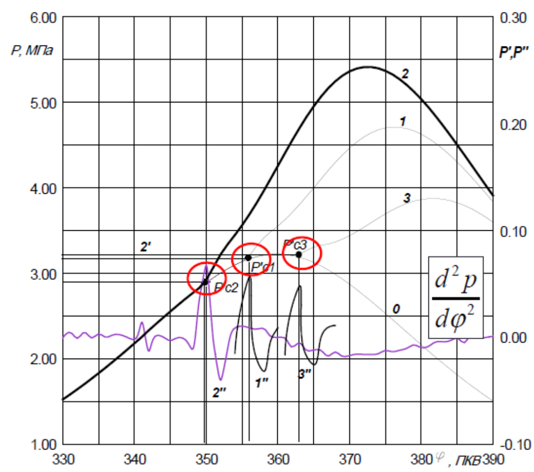

Figure 5. Determination at different injection advance angles of the point at which the combustion in the cylinder begins

Noise in the numerical data (A to D converter errors and electronic noise of the sensing element signal amplifier to A to D converter) causes considerable errors in the calculation of the first-, and especially, second-order cylinder gas pressure curve derivatives. Searching for the maximum of the second-order derivative can be performed only after pressure diagram processing by means of a correctly constructed digital-data filter (Low Pass Filter) [6].

The parameters used to describe mechanical loads affecting the bearings and crank mechanism components are: the maximum degree of pressure increase and pressure build-up velocity while burning the fuel oil, Fig. 6.

The pressure increase degree is defined as:

$$\lambda = \frac{p_Z}{p_C},$$

or, with early fuel injection advance angles, from the approximated dependence

$$\tilde{\lambda} = \frac{p_Z}{p'_C}.$$

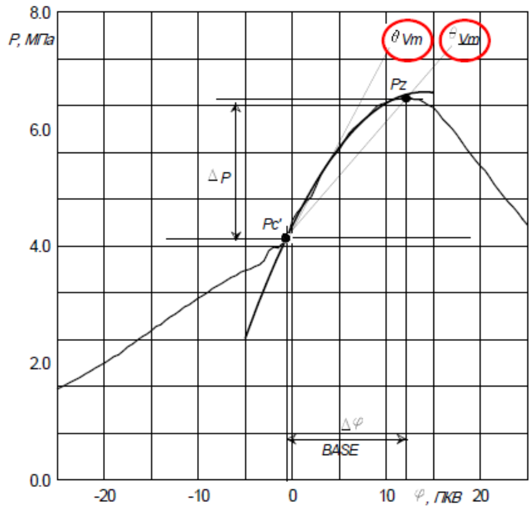

Figure 6. Determining of the maximum and medium pressure build-up velocity during the combustion

The maximum pressure build-up velocity in the course of combustion is defined as the maximum value of the pressure curve first-order derivative, and in most cases, it occurs in the period immediately following the fuel ignition

$$v_m = \max \frac{dp}{d\varphi}, \varphi \in \text{BASE}.$$

In practice, the frequently used parameter is the pressure build-up medium velocity of the fuel combustion starting at the moment of the fuel ignition and going to the moment of reaching the maximum combustion pressure:

$$v_m = \max \frac{dp}{d\varphi}, \varphi \in \text{BASE}.$$

$$\Delta p = p_Z - p'_C, \text{a } \Delta\varphi = \varphi p_Z - \varphi p'_C.$$

The pressure on the expansion line (36° CTA after TDC) is one of the working process parameters (see Fig. 1), characterizing the fuel after-combustion and heat stress level in the CPG parts. The value $p_{EXP}(p_{36})$ correlates with the exhaust gas temperature.

The thermodynamic meaning of the 36° CTA after TDC phase gets understandable after an analysis of the curve of the cycle total work (or the cycle specific work – the current mean indicated pressure of the cycle, (Fig. 8) has been carried out

$$p_i = MIP = \frac{1}{V_S}\int pdV,$$

where: *pi, MIP* = mean indicated pressure; *Vs* = cylinder displacement volume; *p* = gas pressure in the cylinder.

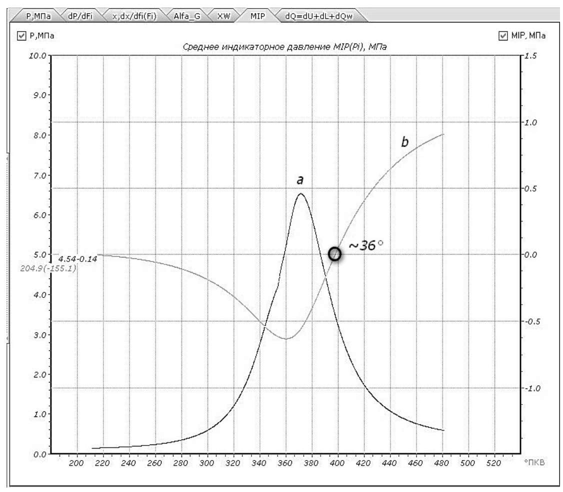

Figure 7. Indicator diagram of the cycle total specific work *pi, MIP*

At the compression stroke the engine consumes energy, and at the combustion or expansion stroke (during the downward motion of the piston) after having passed

TDC – the engine puts energy out. If you consider the energy balance of a separately taken working cycle, then it is natural that at the beginning of the expansion stroke the engine compensates the expenses of the compression stroke. Then, by a certain moment, those expenses will have been fully compensated, and further on the engine will be putting power out, that is to say the profitable part of the working cycle will be occurring.

The curve of the cycle total work (*pi, MIP)* is shown in the Fig. 7, b. It is evident, that the maximum total negative work at the compression stroke falls on the TDC, further the compensation of the expenses follows. At ~36º CRA after TDC all the expenses have been compensated, and after 36º the cycle total work is positive. This conclusion proved to be true (accurate to within ±5) for all the medium-speed and slow-speed diesel engines investigated by the authors of this paper. The point 36º CRA after TDC at the combustion – expansion stroke can be named "zero energy balance" of the working cycle.

When we compare the two working cycles and in the event of the pressure at 36º CRA after TDC appearing greater we understand that higher temperature of the gases in the cylinder on the expansion line and, consequently, higher temperature of the exhaust gases are available. In practice, in those cases when there is no control, or it is temporarily impossible to control the exhaust gas temperature after the cylinders, we can consider $p_{EXP}(p_{36})$ for their relative estimation.

Results of the m/v "Greifswald" main engine diagnosing

Before carrying out the display procedure, initial data (table 1) required for the calculation of the mean indicated pressure and indicated cylinder power output were set up.

Table 1. Initial data of the 6VDS48/42AL-2U ME to be used for calculating *MIP, Ni*

$n_{cyl} = 6;$	number of cylinders
$n(rpm) = 500rpm$	rotational speed under design condition
$D = 0.42м$	cylinder bore
$S = 0.48м$	piston stroke
$\varepsilon = 12.5$	compression ratio (rated)
$\lambda_{Ш} = \frac{R_{KP}}{L_{Ш}} = \frac{S}{2*L_{Ш}} = \frac{21.71}{2*53.0} = 0.2048$	ratio of the crank radius Rkp to the length of the connecting rod, where: Lш = 53.0 cm measured between the centres of the bearigs

In the Fig. 8 the indicator diagrams of the Main Engines (ME) of the m/v "Greifswald", which were taken under the operating conditions, are brought together. The conclusions made on the basis of the ME diagnosis results are the following:

- ME1, cyl.2 – reduced power output and low level of all the working cycle parameters were observed. The
- compression and condition of the FIE and VGT to be verified;
- combustion knocking resulting from an inadequate fuel atomization in the ME2 cyl.3,5,6; ME3 cyl.3; ME4. cyl.4. was observed. FIE of these cylinders to be verified;
- ME2 cyl.2 and ME3 cyl.2 – "tough operation" due to an early fuel injection was observed;
- ME1 cyl.3 was relatively overloaded; fractional fuel injection is probable;

- the greatest inter-cylinder power output unbalance was observed in the ME1 and ME2. After an overhaul of the ME1 cyl.2, cycle fuel supply adjustment will be required;
- balancing of the cylinder power output on the ME3 and ME4 proved to be satisfactory.

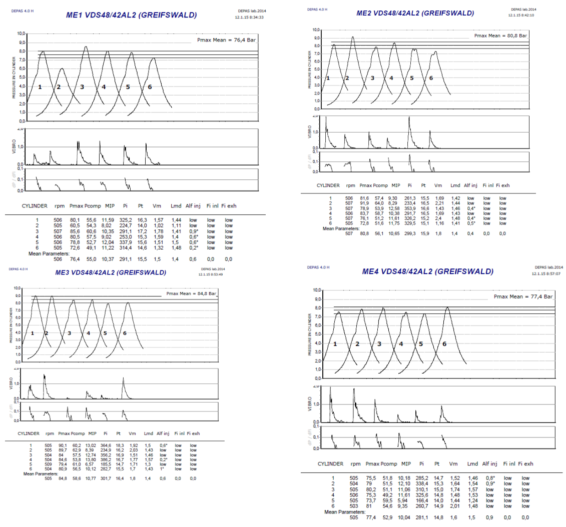

Figure 8. The brought-together indicator diagrams of the 6VDS48/42AL-2U ME of the m/v “Greifswald”

Conclusion

The results obtained by indicating the main engine working process in the form of parameter interrelations can be used for developing or correcting the characteristics of the special-purpose ships’ machinery space simulators.

From the point of view of the main diesels engineering condition diagnostics, the following operations were carried out. Equalization of the power output among the cylinders, that resulted in a uniform distribution of the heat duty and mechanical loads among the cylinders and, as a consequence, an increase of the power reserve, a decrease of the general vibration level, a decrease of the specific fuel consumption and an increase of the engine service-life, provided that CPG, FIE and VTG deficiencies had been previously removed, [7].

As applied to electric power systems, the power equalization among the cylinders promoted the removal of the self-sustained power exchange processes between the generating sets.

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CONCEPTS OF ETM (ENGINE-ROOM TEAM MANAGEMENT) FOR SAFETY OPERATION OF SHIP ENGINE POWER PLANT -SUGGESTION OF SCENARIO SUITABLE FOR COMPETENCY EVALUATION-

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Abstract: The STCW 2010 Manila amendments made, among other things, Engine room Resource Management Training mandatory and thus caused the use of Engine Room Simulator unavoidable. When we deal with trainings of marine engineers, whether it is intended for each person or for a team as a whole, it is necessary to clarify what sort of contents are necessary for the education and training in achieving team activity, and what should be assessed in such education and training. Most of shipping companies have created the contents of education and training on their own and carried them out to improve ship operation safety level. These trainings are the so-called trainings on ERM or ETM (BRM or BTM). However, the difference between ERM and ETM (Engine-room Team Management) has not been clarified sufficiently so far and contents of both functions are still quite vague. The objective of this paper is to show necessary points on effective education and training for improving safety level of plants operation through team activities, which was made by an engine room team to deal with difficult operating situations where team activity is required. And then the difference between ETM and ERM is clarified through the behavioral analysis on marine engineers of engine-room teams. And a scenario suitable for competency evaluation is prepared. IMO revised the STCW at Manila convention in 2010 and included the necessity of training on the management of engine room team activities in the standards. It suggests that IMO recognized the effectiveness of team activities and the necessity of such training. However, IMO has not specifically mentioned the contents of the necessary functions of team activities from the viewpoints of team management. Moreover, the training items of the revised STCW are only focusing on ERM and the standards does not include the necessity of Engine-room Team Management. Meanwhile, in deck department of our university, the effective educational training course has already been established as the results of a study by Prof. Hiroaki KOBAYASHI, and the educational course on BTM/BRM that he developed has been certified as the model course for training on BTM/BRM by the Class NK (Internationally authorized maritime classification society). In fact, this BTM/BRM training course intends higher quality than the standard IMO recommends. This paper shows the concepts of effective management for team activities in engine room. It is based on Prof. Kobayashi's theory that covers wider management area than that of the revised STCW to improve the safe operation. In addition, a proposal is made on what should be considered in creating training scenarios suitable for competency evaluation.

Keywords: team management, engine-room, ETM/ERM, training scenario.

1. INTRODUCTION

ERM became mandatory educated and necessary acquired competency for seafarers at STCW Manila amendment. Education with an effective and reasonable education system leads to a reduction in accident occurrence. Our research group is continuously working on this theme. In this study, we describe the characteristics of the activities in the engine department that affect team management training, and further describe the development of the training system that is in line with the purpose.

2. BTM/BRM

Our research group is studying the ETM/ ERM training based on the training based on the preceding BTM/BRM theory.

2.1 Reason Why BTM/BRM is Considered Necessary

In our research group, BTM/BRM training theory by Professor Kobayashi has already been established and is certified as a training method by the Classification Society as will be described later. Basically, we presume that Team Management /Resource Management training system in the engine department can be executed in the same way as the above BTM/BRM training system. However, there are parts that need to be taken into consideration for constructing the training system due to the difference in characteristics between the deck department and the engine department described later. This section gives an outlines of the above training theory by Professor Kobayashi which is the basis of the ETM/ERM training system.

The status of the ship operation is determined by various factors. The theory think mariners are one of these factors. Other factors are environmental factors, which determine the degree of difficulty of the navigation environment and determine the degree of skill required of mariner's competency. The degree of competency that mariner can demonstrate depends on the rank of mariner's license, the length of onboard experience, the degree of fatigue and tension at that time. When comparing the difficulty of the navigation environment and the degree of mariner's competency, the safe ship operation is established in the situation where the degree of mariner's competency exceeds.

Fig. 1 shows the relation between the competency required by environment to accomplish the safe operation in the condition and the mariner's competency that can be carried out by the mariner [1]. It is possible to discuss whether safe operation is established by these two correlations.

For example, the situation of single watch in a situation where the difficulty of the environment such as sailing on the ocean is low compare with mariner's competency is shown at point "A" in Fig. 1.

When entering the narrow water area where vessels concentrate at point "B", the level demanded by the environment on the horizontal axis rises. At this time, it is difficult to establish safe operation, so the captain orders to organize bridge team by multiple mariners. If the skill level that this team can perform is indicated by point "C" on the vertical axis, safe operation can be established again. However, according to the analysis of accidents that occurred during bridge team organized, it was pointed out that bridge team is not functioning effectively. So it can be said that the purpose of organizing BTM/BRM is to maintain the state of point "C" by maintaining the skill of the team at the expected level.

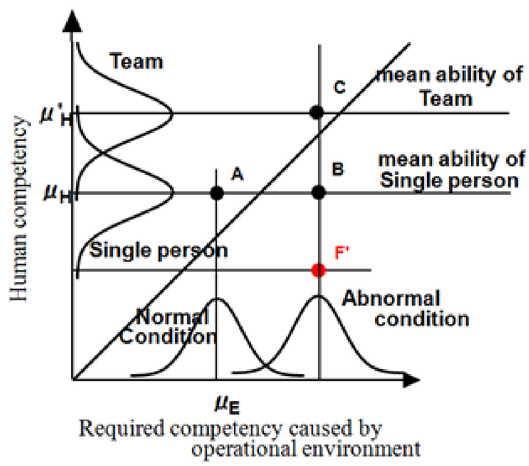

Figure 1 Engine room team activity and Single person competency

2.2 Functions Required for Team Activities

The qualitative difference between the single watch and team activities is whether the mariner executes the necessary work or multiple mariners share it. Techniques that need to be executed in team activities are clarified by clarifying this difference.

Individual work performed by multiple mariners in team activities need to be analyzed and evaluated to reflect the results in operation. The process of consolidation takes the form of reporting the result of execution of work. The report is information transmission and communication. Then it is necessary to carry out appropriate communication to realize appropriate team activities. In the case of a single watch, communication is not necessary. In the team activities, team members can integrate their work by making the communication properly, as a result the team has the same objective consciousness and can work to cut off the chain of human errors. Furthermore, it is necessary to grasp the situation of the other members, not to divide the work individually by the multiple mariners. We defined this behavior as a corporation. By appropriately executing the corporation, we realize cooperative action among team members, perform supportive actions to other team members, and confirm the actions of other members, thereby making the occurrence of human error can be detected.

The above two items are functions to be executed by all team members including the leader. In order for these functions to be sufficiently executed, it is necessary to have a function of activating team activities by team leaders. It is the function to oversee the entire team, to analyze and evaluate the results of the work carried out by the team members, and to make action decisions for safe operation. To accomplish these details, the leader clearly announces the content of the achievement of the team's purpose, concretely shows the necessary actions, evaluates the skills of the members, instructs the contents of the work, and monitors the behavior of the members. Then activate it to maintain the best activity state, execute information exchange and cooperative function. Individual mariners need to have basic marine and mechanical knowledge and physical and mental health to realize the functions described above [1].

Training system based on this theory is adopted as a standard for certification of training on BTM of Class NK, a classification society.

2.3 Reason Why Training is Necessary

Training has been carried out for individual skills navigation technique with the clarification of the contents and the necessity is pointed out, but since the skills necessary for the team activities pointed out in 2.2 are necessary skills in addition to the basic skills, so specialized training is necessary for team activity.

We take the position that the basic requirements of contents of the above 2.1-2.3 are the same in engine department.

3. CHARACTERISTICS OF TEAM MANAGEMENT IN ENGINE ROOM (DIFFERENCE BETWEEN BRIDGE ACTIVITY AND ENGINE ROOM ACTIVITY)

Based on the BTM/BRM training system that Prof. Kobayashi mentioned above, we have been studying to construct an ETM/ERM training system using ERS [2,3]. Following these studies, the chief engineers who experienced the actual work are conducting verification experiments to have the training scenario under consideration implemented. In this process, the difference between the activity in the bridge and in the engine room has come to be seen. These have not been clarified until before, but these are shown here.

3.1 Scene that Needs Team Activities in Engine Room

Firstly, in the deck department, the occurrence interval and the contents of the occurring events for various events occurring in the actual watch are suitable for creating the training scenario. Events occurring in the deck department are caused by vessels actually encountered during ship navigation, due to conditions in the navigation area, due to ocean conditions or area, etc. These can be set as scenarios for simulator training as events requiring with doing some works. In comparison, in the engine room, the start and stop of the main engine, switching of operating equipment and troubleshooting etc. can consider the events which are required to do some work, but in particular trouble correspondences do not occur continuously in the normal state.

3.2 Difference of Simulator Device

Secondly, the simulator device which is the exercise site of the BTM/BRM in the deck department has some sort of fixed form as a navigational simulator, and similarly, even in actual machines, there is a fixed form. In this case, it is possible to expect normal operation during exercise by learning the characteristics of the ship assumed as a simulator device and practicing for proficiency in operation. But in the case of an engine simulator there is no fixed form. There are simulators of various styles by each manufacturer, and there are simulator devices corresponding to each real ship. Since ERS has various types of simulator devices, it takes a long time to master operation.

3.3 Current Status of Team Activities

Finally, in the engine room, it is executed that the chief engineer is almighty and the subordinates move with the instructions by chief engineer, and there is a tendency to have little point of view to effectively demonstrate the power of the team.

Because there is a difference between the deck department and the engine department like these, it is possible to create a good training system by knowing the characteristics of human beings in the engine department well.

4. DEVELOPMENT OF ERM

Therefore, we are considering a method of developing ERM on the premise of the features shown in the previous section. What is important as a prerequisite is that the necessary requirements for team activities are almost the same as those shown in the deck section shown in section 1. It is also necessary to train this in the ERM/ETM training of the engineering department to set the training goal. Furthermore, although there are differences in conditions of the simulator device as shown in section 2, it is necessary to establish an ETM/ERM training method using a simulator device that reproduces the onboard engine room. In ETM/ERM training, mariners must make up teams, to implement appropriate scenarios that set operation training using simulators and be evaluated using appropriate evaluation methods. By doing so, mariners can be evaluated the degree of satisfaction of the current situation to the requirements of individual team activities, and furthermore by implementing appropriate debriefing, it is possible to train competencies of team activities.

5. CONSTRUCTION OF ERM TRAINING SYSTEM

In order to establish the training as described in Section 3, we are preparing the following facilities/items based on the characteristics of the engine room activity shown in above 3.

5.1 Simulator Device [3]

In our university, in order to implement effective simulator training, the simulator equipment was equipped with equipment with the following functions. ‘Close similarity in operation’ indicates that how you operate and observe machinery is quite similar as onboard a real ship. ‘Close similarity in accessibility’ suggests that the methods to check the circumstances of events in an engine room are similar as onboard a real ship. Both of these characteristics suggest that actions taken by trainees in such an environment should be easily monitored. ‘Adequate monitoring system’ is requiring the condition in which judgments and actions of trainees are easily monitored and recorded with these monitoring and recording themselves minimally affecting them.

5.2 Educational Materials

As pointed out in 3.2, when performing operation training using a simulator, it is conceivable that the degree of familiarity with the simulator device influences the behavior. In order to complement the time required for this familiarization, we prepare educational materials to help understanding of the engine system that the simulator device reproduces. There is no large difference between the plant of the existing ship and the plant in the simulator as the basic understanding method of the plant. However, as seen in actual ships, there are cases where the design of the cooling system and etc. are different for each ship. In order to assist this understanding, the following documents were prepared in the engine control room.

-Hard copy of piping diagram of the whole engine area

-Hard copy of the mimic panel that can be checked on the control room console monitor

-Hard copy of the list of important values during normal operation, alarm ringing setting value, slow down setting value, shut down setting value

-Main engine description table

-Operating status list of important equipment at the start of scenario

Regarding the hard copy of the numerical value list of the normal operation, the alarm ringing setting, the slowdown setting, and the shutdown setting, there are cases where the engineer considers these setting values as the judgment standard of the countermeasure action implementation during the verification experiment, so we prepared for the purpose of assisting this. In addition, the main engine description table and the operating status list of important equipment at the start of scenario are intended to help understand the situation of the plant. By using these, it was possible to check at the time of the scenario training in the normal state or compare it when confirming the numerical value at the time of sounding the alarm.

5.3 Scenario

The scenario for training at the simulator device using the data shown in 5.2 was prepared as follows. Events to be set into the scenario are grouped as "Starting and stopping of the main engine", "Switching equipment", "Corresponding to malfunction", "Other". In one scenario, several events are set up and the assessor evaluates whether or not the team member, including the chief engineer and other team members, is executing necessary requirements as team activities. The group "starting and stopping of the main institution" and "switching equipment" is completed upon completion of the request, but in some cases it takes time to search the correspondence method for the group "corresponding to malfunction". In such a case, for example, when a stop of the main engine occurs, the simulator training may be ended without being able to evaluate the event set later, but this is not reasonable. In order to avoid such a situation, repairing time was set as a standard time for dealing with malfunctions. If the response is not completed within this repairing time, the system will cancel the malfunction in the scenario to eliminate the problem to continue the subsequent events. It should be noted that the evaluation does not get worse due to failure resolving in “corresponding to malfunction” events. For example, it is important for a team leader to take the following actions when an event corresponding to a problem occurs. The chief engineer who is the team leader notifies the contents of malfunction to the team in order to share information to the team when the trouble is detected by sounding an alarm and instructs the members to gather necessary information. Based on the reports from each member, the chief engineer announces his own consideration and instructs each member to give further information and instructs corresponding actions so that the team aims to deal with the malfunction. By checking the situation again, as a result of considering the information that could be confirmed, share the information if the problem has been resolved, if not, advance further consideration and instruct further information offer. In this way, the chief engineer always needs to check the current situation of the team and the plant, share it and activate the team to solve the problem. Again, failing to solve the malfunction will not adversely affect the evaluation of team activities. In this way, scenarios are created by combining events.

5.4 Recording, evaluation and debriefing of simulator training

The scenario training carried out in this way is recorded by video and sound. During the training of the simulator, the assessor will evaluate the behavior of the team under training in the other room while checking the state of the plant simulating the video monitor and sound, evaluating the action based on the appropriately prepared assessment sheet, and the results are reported to team members during debriefing. This scenario training and debriefing will always be carried out continuously and this combination will be carried out multiple times. If there are problems with team activities, they will be improved by pointing out and practicing. Also, by implementing it several times, we will try to emerge latent team behavior characteristics.

6. INTRODUCTION OF SCENARIO EXAMPLE

In this section, we introduce an example of creating the scenario shown in section 4 (3) and carrying out the training. The execution situation of the two events from the training that we did for the team consisting of the chief engineer and two young Engineers explain next. Regarding the personnel allocation during execution of the scenario, the chief engineer is located in the control room, and two young engineers are placed in each of the control room and the engine room.

Case1 The problem that we set is a decrease in the cooling water flow rate of the high-temperature cooling water heat exchanger (central cooler). In this event, the alarm that initially sounds is that of the LO line. After informing the alarm contents, the chief engineer announced the contents of the alarm, and instructed the members to gather information. Although there was a misunderstanding of the cooling system and there was a case where the instruction was wrong, the engineer in the engine room noticed, he inform to reconfirm the instructions to the chief engineer, and the chief engineer made acknowledgment and re-instructed etc. were observed. Based on the information gathered, the chief engineer reviewed with the piping diagram which is the educational material and examined it and instructed the members to collect further information and to continuously monitor and report the state quantity. The chief engineer seemed to be conducting a situation judgment such as instructing the engineer to report the degree of change of the state quantity. In addition, two engineers responded to it, afterwards it was confirmed that they properly responded, including answering the instructions of the chief engineer with an explanation of the degree of temperature change. During the discussion the chief engineer consulted with the control room engineer and investigated the relevant slow down requirements from the list. Ultimately the repairing time was over while judging as a wait - and - soak, and the simulator training advanced to the next event. However, at the time of debriefing, the chief engineer said that assuming that instructions would be given if the situation got worse, in this case the necessity to properly set the repairing time became clear. The chief engineer and engineer's team behavior and the team's actions could be evaluated appropriately.

Case2 This event is a trouble set in the scenario after receiving scenario training in Case 1 and after receiving debriefing. This malfunction is a malfunction of the LO pump with generator motor. An alarm for the lowering of the generator inlet LO pressure sounded. The chief engineer reported the contents of the alarm to the engine room and asked for a report on the state quantity at the site. The chief engineer told the engineer in the control room that it would confirm the piping drawing, and after investigating, put the idea on the control room and the engine room as follows. "Since it first doubts the contamination of the LO filter, if there is a plurality of filters, the replacement should be executed." In response to this, the engineer in the engine room executed the filter exchange, confirmed the pressure, then reported to the chief engineer ”Switches the filter, but there seems to be no pressure change”. After that, the chief engineer checked the status of the generator and the amount of electricity used, the chief engineer integrated the information, informed the engine room and the engine control room that the pump malfunction was suspected, and confirmed the presence or absence of a spare machine of the LO pump. It was reported that there was no spare machine for the LO pump, and the chief engineer instructed the exchange of the used generator. Since the control position was in the remote mode, the chief engineer instructed the engine room to confirm the operation state of the diesel engine for the driving generator, then started the standby generator, switched the power supply, then reported the situation after confirming the situation. The engineer reported the fact that there was no problem properly, along with the numerical value, and the trouble was resolved. This is an example in which communication and corporation and leader activities were successfully implemented by the chief engineer and the engineer.

Case 3 The set malfunction is the temperature rise of the main bearing. When the temperature rise alarm sounded, the chief engineer confirmed the contents to the engine control room engineer and asked for confirmation at the engine room. The chief engineer also confirmed that the temperature was high on the console monitor at the engine control room and confirmed that the temperature was rising only for the specific bearings on the monitor, so chief engineer asked for confirmation whether this was the case also on the engine room. In addition, the condition of the exhaust gas temperature and the slowdown requirement were confirmed by the chief engineer and the engineer at the engine control room, the chief engineer and the engineer confirmed at the engine control room to stop the engine if the slowdown was effective. The chief engineer confirmed that the temperature rise of the bearings is confirmed well to the both engineers. Since the engine chief thinks that the ship should not be stopped as much as possible, there is awareness that it seems to want to confirm by checking a little more, and there was awareness to consult this on the bridge. The engineer of the engine control room confirmed "There is a possibility of stopping the engine" to the bridge, and as a result the bridge’s answer was "Although it is difficult to stop the engine, it is possible to slow down to half." The chief engineer and engineer in the engine control room consulted and decided to slow down to half and contacted the bridge. At the stage of trying the operation after this, since the operation authority of the main engine was on the bridge, they asked the bridge to slow down the main engine to the half. When deceleration began after this, there was a report from the engine room saying "Deceleration of the main engine started." In response to this, the chief engineer told the both engineers "to slow down and see the state of the main engine, which means that if the temperature settles down, something that had been stuck in the bearings could be taken, monitor the temperature continuously "instructions. Even if the deceleration of the main engine was completed, this event ended without the situation where the bearing was higher than the other bearings. In the activities of the team in this event, there should be a report from the engine control room to the engine room at the timing of deceleration from the bridge. Other team activities were good.

6. CONCLUSION

Development of a training method that utilized the theory of BTM/BRM training system which has already been proven in the deck department to ETM/ERM indicated the following.

(1) We developed an ETM/ERM training system inheriting the BTM training system developed based on the theory of BTM/BRM by Prof. Kobayashi and certified by classification society, Class NK.

(2) It was shown that the team activities in the engine department had characteristics different from the team activities in the deck department. In the simulator training, we showed a method to enable team activity to be evaluated continuously even during scenario execution due to introduction of repairing time and intervention on malfunction.

(3) Based on the characteristics of the engine department, we developed an effective training system using ERS.

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ABOUT PRACTICAL PREPARATION ON THE FULL MISSION SIMULATOR COMPLEX OF THE SHIP'S AUTOMATED ELECTRIC POWER PLANT

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Abstract: This article discusses practical preparation of marine engineers on the full mission simulator complex of the Ship's Automated Electrical Power Plant.

A fullmission simulator complex of the ship's automated power management system meets International Convention STCW 78(with Manila amendments 2010) requirements in the part of adequate reproduction of its operational modes corresponding to the actual configuration and layout of the ship's automated power management system with real consumers and typical loads. The simulator is fully consistent with the goals and objectives of the practical training, as well as the goals and objectives of proficiency testing engine department officers on issues technical maintenance the real ship's equipment(High Voltage installations included) and means of automation.Odessa Maritime Training Centre provides new training courses, which training courses topics are: Marine high voltage installations - electrical safety, maintenance, adjusting; Ship electrical energy generating and distribution; Ship power management system; Programmable Logic Controller (Basic, and advanced); Advanced Instrumentation and Process Control;Automated electric drive technology;Control communication and information network; Diesel engine monitoring and control; Ship's Energy efficiency systems.

The Simulators Complex is designed to training and proficiency testing of cadets and students of maritime educational institutions, as well as training and proficiency testing of marine specialists (mechanics and electricians) by watchkeeping and maintenance of modern integrated automated control systems of ship's electric power plant and the individual ship electromechanical systems, including high-voltage systems. A simulators complex provides adequate reproduction of the operating situations on the technical use of the real ship and automation equipment, provide training on monitoring, control and management diesel-generator sets in the hand, semi-automatic and automatic modes of power station, control and management of the electromechanical systems, as well as the decision of tasks of parameterization, visualization, etc. Besides mode combinations of monitoring, control and management, the simulator complex provides an opportunity to various fault simulation. It allows the student to focus on the work of the automatic control system in the emergency situations and work out the operations ofthe watchkeeper in conditions of searching, localization and troubleshooting equipment.

Keywords:A full mission simulator complex of ship's automated power management system, microcontroller control technology, practical training and proficiency testing,training courses topics.

The Navigation Safety along with other factors is largely determined by the reliability of the operation of ship systems "man-machine" and therefore lies at the basis of modern engineering preparation and training methods of the ship engine department specialists [1]. Electrical equipment and automation facilities of a modern vessel are characterized by high energy saturation and a high level of automation based on modern computer control technologies.Virtually all ship electric powermanagement systems, cargo and navigation systems are integrated into a single general ship automation system, have a flexible system for programming operating modes, appropriate techniques and methods for technical operation, fault diagnosis, adjusting and setup.All this diversity and complexity of tasks stipulate the need for a high level of training and erudition of the ship's engineer to ensure the required maintenancelevel of the electrical equipment and electronic automation equipment.Today, shipboard electro-technical officers and marine engineers must have a wide range of professional knowledge and skills: from working with hand tools and measuring instruments to using moderncomputer control, monitoring and communication technologies, providing both watchkeeping and non-watch maintenance of ship complexes and systems.

The International Convention STCW 78 with the Manila Amendments 2010 [2, 4] made significant changes and additions to the standards of competence for ship electro-technical officers (Section A-III / 6) and marine engineers (sections A-III / 1, A-III / 2), which required the processing of educational standards, the development and mastery of the new programs both theoretical and practical preparation and training.According to the new Convention, practical training is extended to 12 months, of which at least 6 months must be on board.In this regard, the urgency of practical training is growing, which should be carried out in approved laboratory and training complexes of the maritime university that meet the requirements (section A-I / 12) of the Convention.The actuality of simulator practical training is also determined by the fact that many of practical tasks and operational situations for managing ship systems and complexes, due to objective reasons related to the mode of operation of the vessel and ensuring its survivability and safety, cannot be realized on the ship in sufficient for the future specialistvolume.Therefore, the development and creation of specialized, virtually functioning (not virtual) and maximally close to the ship configuration of simulator complexes based on real equipment and modern microcontroller control technologies, will solve very important tasks of preparation and training for future ship engineers [3, 5, 6].

The main idea and approach, which we relied on when developing and creating a simulator complex, is that the adequacy of reproduction of operational situations for maintenance and use of ship electrical and automation equipment, which the Convention emphasizes, is possible and expedient in our opinion only on real ship equipment.Therefore, in the practical training of shipboard electro-technical officers and marine engineers, only the ship's equipment and means of automation, which are actually functioning and as close as possible to the current configuration, should be used, and approved by the main Marine Classification Societies, and, therefore, used on ships.Moreover, it is precisely the specific ship's technical means and systems, and not their virtual counterparts, that are the objects of professional activity application of the shipboard electro-technical officers and marine engineers, to which their attention is mainly directed and whose trouble-free functioning is necessary to ensure.

Realizing the above idea and approach, in full compliance with all the requirements of the Convention (section A-I / 12), simulators of this type have been developed and created at the Department of Ship Electro mechanics and Electrical Engineering of the National University "Odessa Maritime Academy", consisting of a simulator of the ship's automated electric power plant and simulator of PLC based control and modelling of electromechanical systems.

The presentation of a full mission simulator complex of automated shipboard electrical power system (PMS) was held at the National University “Odessa Maritime Academy” on September 18, 2014 in accordance with the requirements of International Convention STCW 78 with the 2010 Manila Amendments in terms of adequate reproduction of its operating modes corresponding to the actual configuration and layout of the ship's automated power plant with real customers and the common load. The simulator is fully consistent with the goals and objectives of practical training, as well as the goals and objectives of competence assurance of engine crew (ship engineers and electrical officers) concerning the technical operation of the real ship's equipment and automation means.

The Simulators Complex are designed to training and proficiency testing of cadets and students of maritime educational institutions, as well as training and proficiency testing of marine specialists (electro-technical officers and marine engineers) by watchkeeping and maintenance of modern integrated automated control systems of ship's electric power plant and the individual ship electromechanical systems (individual electric drives), including high-voltage installations. A simulators complex provides adequate reproduction of the operating situations on the technical use of the real ship automation equipment, provide training on monitoring, control and managementdiesel-generator sets in the hand, semi-automatic and automatic modes of PMS, control and management of the electromechanical systems (electric drives), as well as the decision of tasks of parameterization, adjusting, visualization, etc. Besides mode combinations of monitoring, control and management, the simulator complex provides an opportunity to various fault simulation. It allows the student (cadet) to focus on the work of the automatic control system in the emergency situations and work out the operations ofthe watchkeeper in conditions ofsearching, localization and troubleshooting equipment [7-9].

Thus, the full mission simulator complex (PMS) designed to training and proficiency testing of marine specialists (electro-technical officers and marine engineers) entirely is consistent with the functions of the "Electrical, electronic and control systems" and "Maintenance and repair" of standard A-III / 1, A-III / 2, A-III / 6 of the International Convention STCW-78 with the Manila amendments, as well as relevant competence required for the ship electro-technical officers and marine engineers as a result of training.

All equipment of the complex, including individual elements, as well as automation equipment are combined into asingle control network with the support of the basic communication protocols used on ships, such as Modbus, Fieldbus, CANopen, Ethernet, CC-Link as well as with the possibility of remote control, monitoring and data transmission.

Dispatch (operator) control and mode data collection of simulator equipment as well as the organization and carrying out of direct educational process of practical training and competency assessment of trainees is carried out by means of specialist software – SCADA Expert VijeoCitect V7.40.

The full mission simulator consists of a main switch board (MSB), three main and one emergency generator sets, typical loads (electric drives of various ship mechanisms), 13 workplaces of operators (trainees) and 2 workstations of the instructors.

(MSB) comprises 14 sections (4 sections of high voltage equipment): two sections of synchronous generators (№1, №2); synchronization and control section; asynchronous generator section and reactive power control panel (power factor cosφ correction); section of consumer groups and sections №1 of the emergency (harbor) generator. Sections 8-10 of the consumer groups №2, as well as the sections 11-14 of highvoltage consumers are in another room of simulator complex.Sections 1-7 and 11-14 are shown in Fig. 1.

Figure 1. Sections (panels) 1-7 and 11-14 of MSB

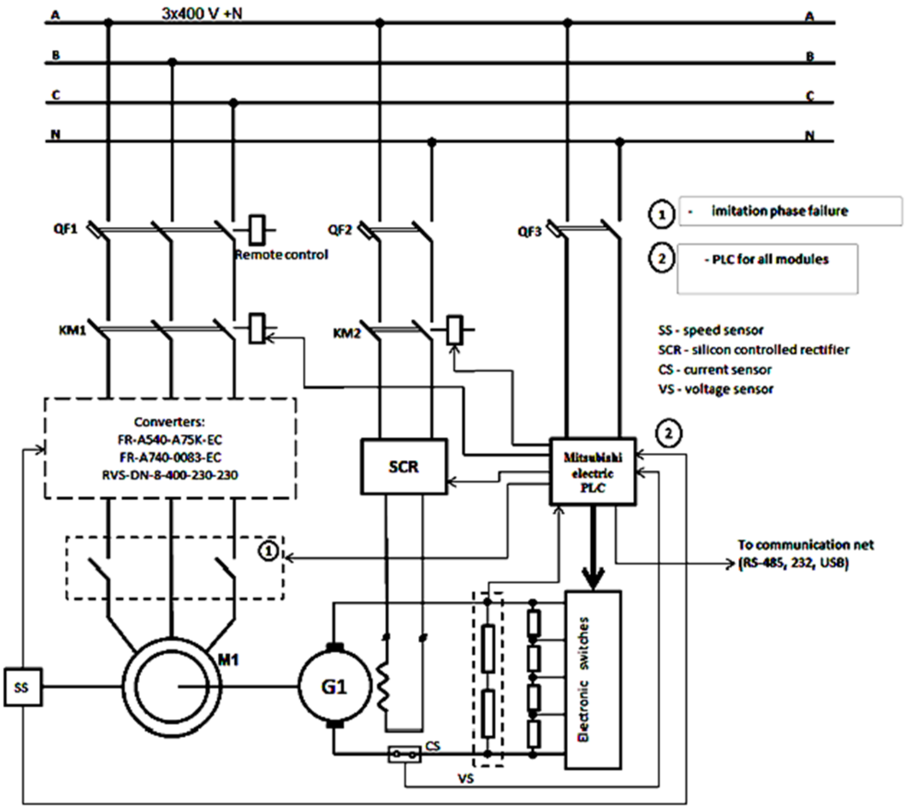

Figure 2. Electromechanical module (electric drive) with PLC controlled load

Functional diagram of an electromechanical module (electric drive) with PLC controlled load is shown in Fig. 2.

Various converters such as AC-DC, AC-AC, frequency converters of such as FR - A740, FR - A540, Altivar 71 produced by Mitsubishi Electric and Schneider Electric are used as power converters.The direct current generator serves as an operating mechanism (load) each of the motors.This generator relates to its shaft, and in turn, its load is simulated by connection with appropriate controller pull-up resistors on specific algorithm corresponding to the specific load of the real ship's machinery.

Power Management System (PMS) is based on the microcontrollers - C6200 and M2500 produced by SELCO company, microcontrollers PPM of DEIF company, embedded in each generator section and section of shore supply (see fig. 3).

Figure 3. Controllers of PMS

The main power plant consists of two diesel-generator sets, model GMS10PX of Powerlink Machine Co company, synchronous brushless generator rated of 8 kW, rated voltage of 380/220 V. Drive motors of generators № 1 and № 2 – Diesel Engine of PX380G type. Diesel operation is carried out by diesel microcontrollers M2500 by SELCO, which are embedded in each section of the synchronous generator. Asynchronous shaft generator (3.0 kW) (ASG) is the third main generator based on serial asynchronous machine of AIR 100S4 type with capacitor excitation. Prime mover of ASG (the main engine of the vessel on a real ship) - asynchronous motor with a capacity of 4.0 kW. Frequency converter Altivar 71 by Schneider Electric is used to power supply and control the drive motor of shaft generator (simulated behaviour of the drive shaft on a real ship, depending on the main engineoperation, weather conditions for sailing etc.).

The asynchronous shaft generator section also includes a dynamic reactive power compensation system (power factor correction of the entire electrical installation).A dynamic power factor correction (PFC) system consist with power factor controller BR7000 series – T15/S485, V7.0, thyristor modules TSM – LC-I type, multi-purpose measuring interface MMI7000-S, (produced by EPCOS).

The programmable logic controller Modicon M340 from Schneider Electric with expansion modules and the corresponding programming environment Unity Pro S v.7.0 (see fig.4) is chosen as a platform for visualization and remote control of the operating modes of the entire training complex or its individual devices.

General management and control of the simulator complex equipment as a whole or parts thereof, monitoring and collection of the operating data of the simulator equipment, as well as the organization and conduct of the online educational process of practical training and evaluation of the trainees' competence are carried out by means of specialized software - SCADA Expert VijeoCitect V7.40.

The electromechanical systems laboratory is the part of simulator complex and consists of actually functioning devices that are as close as possible to the modern configuration of marine control equipment and means of automation. So, the laboratory fully meets the standard requirements to the use of simulators (Section A-I/12, Part 1 - performance requirements), STCW 78 with Manila Amendments.

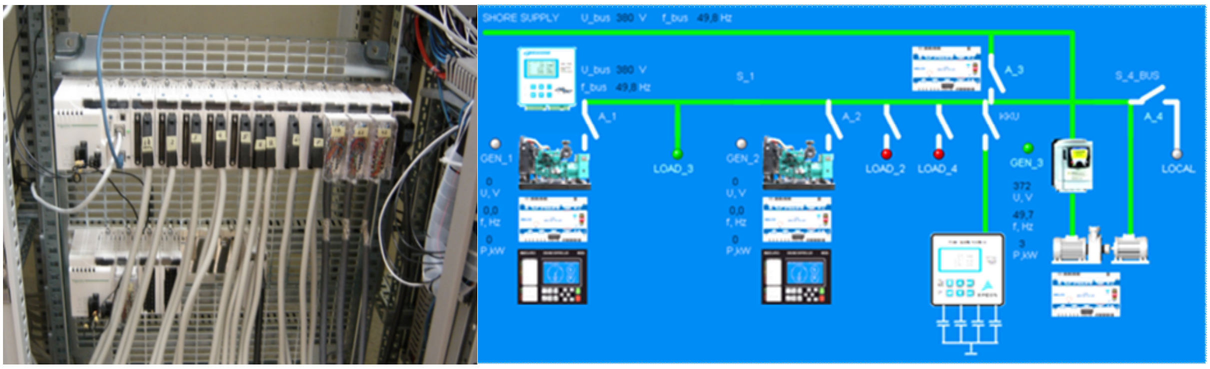

Figure 4. Example of visualization SCADA control and monitoring of the training complex

The licensed software MELSOFT iQ Works and FR-Configurator from Mitsubishi Electric is used in the laboratory that consists of 12 modern Laboratory Stands, based on nowadays Mitsubishi Electric equipment. One of the above mentioned Stands with PLC FL3U, ALPHA2, graphic operation panel GT14 and also frequency converted drive FR-E720 can be seen on the Fig.5.

Figure 5. Laboratory stand of PLC laboratory

All installation, including separate units and control systems is incorporated in common communication control and information network, supported by main ships communication protocol, such as Modbus, Fieldbus, Ethernet, CC-link as well as possibility of remote control and data transmitting.

The laboratory-based training programs fully cover the minimum qualifications, knowledge, understanding and proficiency for marine electro-technical officers and for marine engineers.

Training and competence testing programs for ship electro-technical officers and marine engineers are carried out on the basis of the simulator complex equipment:

- Marine high voltage installations: electrical safety, maintenance, adjusting;
- Ship electrical energy generating and distribution;
- Ship power management system;
- Programmable Logic Controller (Basic, and advanced);
- Advanced Instrumentation and Process Control;
- Automated electric drive technology;
- Energy efficient operation of ship;
- Control communication and information network on shipboard.

A short list of tasks which can be solved on the simulator complex equipment:

1. Skill development of analysis of ship electricalpower management system, modern layoutof PMS, electric power distribution, including high-voltage. Research and practical testing of the operator's actions in different control modes of power plant. Alert messages and operator’s work with alarm and event log. Research of specific features of the protection settings and controller's parameters, generator cut-out switch. Skill development of connectivity issues and microcontroller installation for the purposes of typical power plant automation. Research, protection settings and controller's parameters of high- voltage systems. Economic and safe exploitation of

diesel-generators, devices and equipment distribution systems. Analysis of the situation and practical testing of the operator's actions in different control modes of power plant, including emergency situations. Skill development of algorithms of typical power plant automation and microcontroller installation. Protection settings and controller's parameters with the use of appropriate software and troubleshooting.

2. Operating skills acquisition with the modern programmable logic controller (PLC) based on the controllers of such firms as Mitsubishi Electric, DEIF, SELCO, EPCOS, Schneider Electric series Alpha2, Q, FX3U, TeSys U, Modicon M340, C6200, M2500, PPM, BR7000, etc. in terms of management of various marine systems and complexes. Familiarity with the program for the configuration of microcontrollers.Microcontroller's configuration and monitoring with the use of service software. Loading of configuration files to the microcontroller. Connection to microcontrollers and the use of additional devices (digital operator, remote display, PC). Sample program development of different types for PLC that address the solving of specific marine tasks.

3. Skills acquisition of technical use and maintenance of modern instrumentation and control systems. Research and parameter setting of communication protocol between microcontrollers, local controlled objects with the remote-control arrangement and monitoring system, using real equipment and automation means.

4. The use of modern energy-saving technologies used on ships, in terms of frequency-controlled drives of various marine machinery and systems, dynamic reactive power compensation system, increase of power factor of ship's power plant.

The full mission simulator complex of ship electrical power management system is designed to provide scientific and technical training of masters, postgraduate and Ph.D. candidates, to conduct basic and applied researches in the field of exploitation and automation of the marine transport means. Certainly, it will contribute to quality improvement of education and training of scientific personnel.

Conclusions. A full mission simulator (PMS) designed to enable practical training and competence assurance of engine crew's officers on the functions "Electrical, electronic and control systems" and "Main and repair" entirely meets the requirements of section A-I / 12 of the STCW Code 78 with the Manila amendments carried on real equipment and means of automation, corresponds to the real configuration and layout of marine automatic power plant with real customers and common load.

The simulator is fully consistent with the goals and objectives of practical training, as well as the goals and objectives of competence assurance of engine crew.

The simulator reproduces the actual operating conditions (PMS) for teaching skills of maintenance and repair, consistent with the purposes of training, besides it enables to demonstrate these skills in order to assess competencies.

The simulator provides controlled operational conditions including emergency situations corresponding to the goals and objectives of training, as well as enables to simulate different operational situations.

The simulator allows the learner to control both the power plant and the individual electromechanical objects in anautomated or automation modes of operation from any computer workstation or directly using the real operation controls, to observe the operating parameters of control objects. More than that, the learner has access to the learning and teaching and reference materials on the simulator.

The simulator allows the teacher (instructor) follow and record the learner's actions for the further errors analysis.

Indicated simulators are carried out with the possibility of remote control, monitoring, and remote access to the learning and teaching and reference materials.

Future marine engineer, having studied actual functioning, complex equipment, receives sufficient knowledge, enabling him to implement effectively the required control functions, diagnosis and parameterization tasks, which is very important for the modern marine specialist. Undoubtedly, it will increase the security of vessel exploitation and equipment, as well as will enable to solve specific engineering challenges.

Simulator training program fully covers the minimum competence, knowledge, understanding and professionalism specified in section A-III / 6 of the International Convention STCW 78 for marine electricians, as well as in section A-III / 1 and A-III / 2 for marine engineers. Therefore, the training on these, really functioning and as close as possible to the ship's configuration training complexes having the certificate of Association of Classification Societies can be set off in the total 12-month enumeration census of practical training future electricians and mechanics. This is important if one bear in mind that it is not always possible to o simulate all kinds of emergencies and regimes in marine conditions.

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MODELLING OF FUEL CONSUMPTION AND EMISSIONS IN TRANSIENT OPERATION DURING SHIP MANOEUVERING

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Abstract: This article discusses a method of developing a model for four-stroke medium-speed engines which is able to predict the fuel consumption (efficiency) and emissions during ship manoeuvring. Meaning the operation point changes during manoeuvring there is a transient operating behaviour which has to be considered in the model. Connecting the engine model together with a powertrain model this combination is integrated into a simulator to reproduce the whole shipping operation. The goal of this simulator is to predict the influence of different manoeuvring strategies on fuel efficiency and emissions.

Therefore the following method/workflow is applied: Specification of typical reference manoeuvres, measurements at the test bed to reproduce those manoeuvres, development of the powertrain and engine models including sub models (e.g. combustion model), validation of the models (using measurement data), integration into the ship engine simulator.

Keywords: manoeuvring, ship simulator, modelling, combustion engines, emissions.

Harder emission regulation on the one hand and higher ecological sensibility in public discussion on the other hand necessitate to focus not only on fuel consumption but also on reducing emissions (even) in the maritime sector. Improved or new propulsion and combustion concepts or alternative fuels are just as promising to fulfil these increasing requirements as an improved utilisation of both refitted and existing systems.

Referred to the vessel's main propulsion the operation strategy can be divided into two general modes. On the high seas at constant speed or anchored at the port the transient behaviour or rather its change of fuel consumption and emissions is low and the main vessels are running in steady mode. However, while manoeuvring, e.g. in coastal area or especially at entering the harbour, the operation is highly unsteady. Varying orders in terms of using the machinery or helm when accelerate, decelerate or during the ships turning manoeuvre result in fluctuating operation requirements. An increased fuel consumption and higher emissions are the consequences.

Especially during that described transient operation mode, the set-up of the machinery system and the varying user behaviour become a significant impact. Hence, evaluating, comparing and predicting various manoeuvring strategies is promising in terms of reducing fuel consumption and emissions.

The publicity-funded project for modelling of emissions and fuel consumption during ship manoeuvring, short name "MEmBran", is taking up this issue and contains a detailed consideration of transient operation. A model is developed to simulate the ship's operation considering the transient behaviour of manoeuvring. One of the elemental models is the in-cylinder process (containing the combustion process) which has the most important impact to predict fuel consumption and emissions in relation to the operating point.

The aspiration of the entire model of the ship simulator is to predict fuel consumption and emissions during the ship's manoeuvring and to enable proactive and more efficiently maritime navigation. Therefore, thermodynamic and partially empiric approaches are used to calculate the in-cylinder process. Elemental reactions kinetics are used to predict emissions.

The method is the following: As a first step the definition and specification of typical reference manoeuvres has to be clarified. Like in all model development methods measurement data, which should represent the reference manoeuvres, are needed for parameter setting and validation of the models. During measurement data acquisition the transient operating behaviour has to be taken into account which is also part of discussion in this article.

The development of the engine model contains, as the main part, the combustion model which is significant to predict real efficiency and (pollutant) emissions. For that purpose, some thermodynamic approaches and elemental reactions kinetics are used. Setting of model parameters is done based on measurement data.

Subsequently, the validation of models is done using a method which increases its accuracy step by step. Firstly, the model should predict steady measurement data followed by multiple steady data validations for different operating points. The final step is based on transient operating validation as well as setting control parameters for the change of operating points.

Finally, the integration of the models into the ship engine simulator for ship operation is done. Therefore, the complexity of the model is reduced to reach real-time capability. For future usage in prediction of optimized manoeuvring multiple real-time capability is necessary. In the long-term the conceivable purpose is that the simulator tool is able to give advice to the vessels bridge regarding to the optimum manoeuver, i.e. increasing efficiency and lower emissions.

Experimental data

An engine operation (point) can be described by engine torque and engine speed rate. Additional, boundary conditions like intake air pressure should also be known. Manoeuvring is characterized by a certain change of operation, thus change of load and other conditions. Based on this reference data of manoeuvring more detailed data could be generated at a medium-speed engine test bed while reproducing also this transient behaviour.

The internal combustion engines operation is a result of its combustion process and its conditions in the combustion chamber. One of those main information is delivered by the in-cylinder pressure. Evaluating this type of measurement data is usually called in-cylinder pressure analysis. A thermodynamic analysis of the pressure curve leads to the heat release rate which delivers the information to calculate fuel consumption and efficiency and details about the procedure of the combustion process at all.

Averaged in-cylinder pressure analysis

In general and steady engine operation the averaged in-cylinder pressure analysis is used to evaluate the measurement data generated at the test bed. For steady operation there is no special treatment of single cycle data but averaging over a large number of cycles results in one mean resp. representative cycle.

The analysis contains two general paths depending on the resolution of the measurements data, meaning, whether they are indicated or non-indicated signals. To consider factors like cyclic variations an averaging of the measurement data is recommend. This should be applied for both pathways but regarding also its resolution. Altogether, the following procedure is applicable (see figure 1):

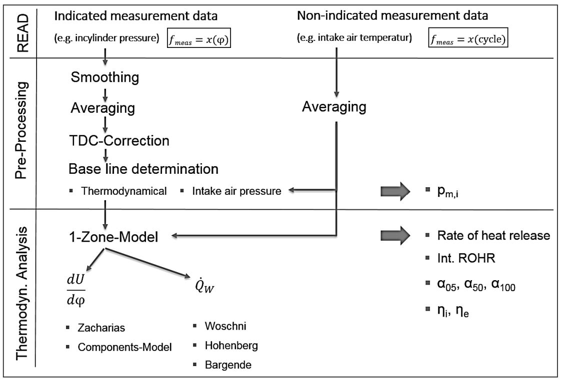

Figure 1. Approach of the averaged in-cylinder pressure analysis to evaluate the measurement data applied on steady engine operation

An indicated, thus crank angle dependent signal, is for example the in-cylinder pressure. Besides averaging (over the whole number of cycles) further pre-processing is needed: smoothing (of measurement noise), top-dead-centre-correction (to get the real assignment of cylinder volume) and base line determination (since pressure signal is usually only available as relative and not absolute pressures signal).
The non-indicated signals (without crank angle resolution) need to be averaged only over the whole number of cycles or time.

After this, pre-processing characteristic parameters like indicated mean pressure (1), can be calculated which are engine capacity specific benchmarks:

$$p_{IMEP} = \frac{1}{V_h} \oint p_i dV \,, \qquad (1)$$

Based on engine torque, the break mean effective pressure is

$$p_{EMEP} = \frac{M \cdot 2\pi}{V_h \cdot i} \qquad (2)$$

with $i=0.5$ for 4-stroke and $i=1$ for 2-stroke engines.

To obtain information about the combustion process a thermodynamic analysis is necessary which delivers combustion process specific parameters like the heat release rate, the integrated heat release rate and the efficiency. Therefore the mass balance and the balance of energy is required to get information about the internal energy of the system. While analysing the combustion process in the combustion chamber usually the high-pressure phase is of interests, meaning the intake and exhaust valves are closed and mass and energy balance (see equation 3) can be simplified:

$$\frac{dU}{dt} = -p\frac{dV}{dt} + \dot{Q}_B + \dot{Q}_W + \dot{H}_{Fuel} \qquad (3)$$

The reaction enthalpy which results in or is equal to the heat release rate Q_B, which is

$$\dot{Q}_B = \dot{m}_{fuel} \cdot LHV_{fuel} \qquad (4)$$

denotes the fuel mass flow and the fuels lower heating value. In this way the fuel consumption can be calculated by analysing the pressure curve.

Furthermore, the thermal equation of states for an ideal gas or a real gas approach can be used for the behaviour of the gas mixture. In addition, data for the thermodynamic properties of all fluid media (gas, fuel, gas mixture, exhaust gas) need to be provided including caloric data. For specific mixture with carbon-hydrogen-ratios (CH-ratio) similar to Diesel fuel the Justi [1] or Zacharias [2] data can be used. Otherwise a component approach is recommended also to calculate exhaust gas composition and its caloric data for flexible CH-ratio, e.g. the NASA polynomials [3].

The heat flow Q_W between combustion chamber walls and gas mixture inside the system is adapted from an approach by Newton as

$$\dot{Q}_W = \alpha \cdot A \cdot (T_{Wall} - T_{Gas}) \,. \qquad (5)$$

Approaches for the heat transfer coefficient α of the wall heat transfer model which contains both, the conduction part of the chamber walls and the volume averaged convection inside the chamber, were established by Woschni [4], Hohenberg [5], Bargende [6] etc.

Transient in-cylinder pressure analysis

However, for some application the averaged in-cylinder pressure analysis (which is developed to evaluate steady engine operation) cannot be used because there is transient operation. Meaning, the pressure rates measured with crank angle resolution differ cycle by cycle. Even the operation parameter (e.g. engine torque and speed, intake air and exhaust air condition) are by definition instationary. Some cases are cold start, engine run-up [7], or transient operation mode of the engine during e.g. ship manoeuvring. For this transient approach some differences exist.

Already during measurement data acquisition the transient operating behaviour has to be taken into account, i.e. the following has to be considered (see figure 2).

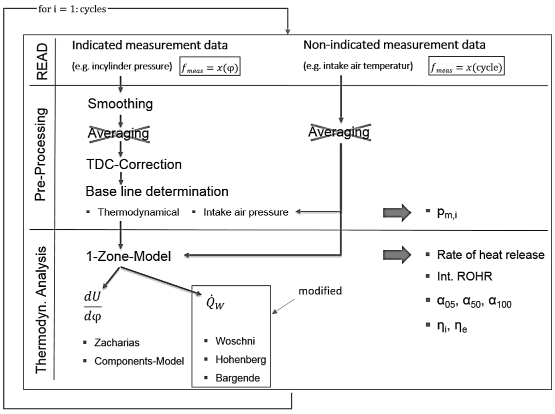

Figure 2. Approach of the transient in-cylinder pressure analysis to evaluate the measurement data of transient engine operation

The engine speed and engine torque have to be measured cycle by cycle while in-cylinder pressure, intake air and exhaust gas (back) pressure, fuel (rail) pressure and current (energizing) of injector has to be resolved in crank angle accuracy. Also analysis of transient measurement data differs to steady data since averaging methods are not possible. Instead every single cycle has to be evaluated.

In contrast to the mean in-cylinder pressure analysis not the averaged pressure rate of every measured cycle but every single cycle should be solved separately and in sequence (one by one) in the thermodynamic analysis.

Furthermore, a modified wall heat transfer model should be used as Leisek did for engine run-ups [8]. The main difference in his approach is the engine speed dependency of the heat transfer coefficient with the different impact on convection influenced by the combustion induced turbulence in comparison to the flow conditions in the combustion chamber caused by the pistons movement.

Engine Model

The engine model is subpart of the entire model of the simulator and is still in the phase of development. Some advancement will follow. Hence, the present state will be described followed by the conception for the next steps of further development.

Besides the cylinder model the engine model consists of the path of the intake air and the exhaust which is going be extended with a model of the exhaust gas turbocharger.

Path of intake air and exhaust gas

The engine's pipes are modelled as zero dimensional without capturing pipe dynamics. Nevertheless, the dynamic behaviour can be achieved by setting of appropriate boundary conditions (like pressure boundary condition in crank angle accuracy) if known from measurement data.

Pressure loses are considered in two different ways. For pipes, there is a pressure loss model depending on the wall friction. Also components which act as a throttle, like intake and exhaust valves, are taken into account. Therefore, the effective cross sectional area in relation to the valve's stroke should either be known or is calculated via discharge coefficient.

Combustion model

A main part of the engine model is the combustion model approach which should be on the one hand side at a good accuracy and on the other hand side as simple as possible to minimize computational time. For this reason the implemented model for the prediction of the heat release rate in a high-performance diesel engine is either a zero-dimensional one or will contain phenomenological approaches.

Well-known approaches which promises very low computational effort are surrogate heat release models like the one formulated and named for Vibe [9] (see equation 5).

$$\frac{Q_B(\varphi)}{Q_{B,\max}} = 1 - \exp\left[-a\left(\frac{\varphi - \varphi_{BB}}{\Delta\varphi_{BD}}\right)^{m+1}\right] \quad (6)$$

Therein, the parameter a describes the completeness of the fuels reaction during combustion and the parameter m is responsible for the form of the heat release rate. The two crank angle parameters φ_{BB} and φ_{BD} denote begin of burning and the burning duration.

The advantageous simplicity of these mathematically models on the one hand is also their disadvantage on the other hand because they are only low based on physical relations. Only the (geometrical) form of the heat release rate is approximated by form parameters.

To approximate the heat release rate of a compressed ignition diesel fuel typically combustion process, its characteristics should be described at first, which can be divided into three phases [10] (see figure 3). The premixed phase starts after the ignition delay which occurs after start of injection of the fuel (SOI). Once all premixed fuel is burned, the mixing controlled phase begins, meaning the rate of burning is primarily controlled by the fuel-air-mixing process. This lasts until the spray cone of fuel fades out and fuel-air mixing becomes of minor importance. Instead, chemical reactions become rate-determining due to decreasing temperature (extension of the cylinder volume) and decreasing oxygen concentration in the late combustion phase.

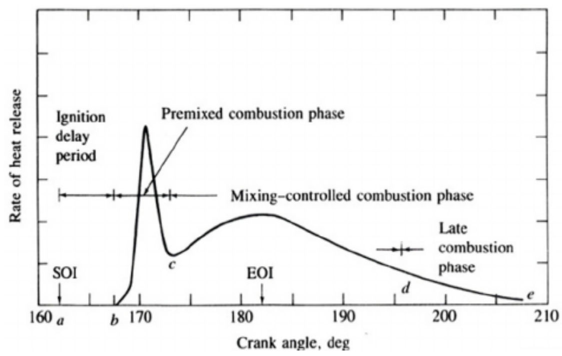

Figure 3. Phases of combustion in a compressed ignition combustion process: Start of Injection (SOI) and ignition delay, premixed phase, mixing-controlled phase, end of injection (EOI) and late combustion phase [10]

To fulfil a typically heat release rate of a compressed ignition combustion process a single Vibe-function is insufficient. An additional Vibe-function can be used to describe the premixed phase. However, the exponential form of the Vibe-function cannot describe the late combustion phase accurately. Instead, the polygon-hyperbola-function of Schreiner [11] should be used.

Using the mentioned in-cylinder pressure analysis of measurement data to fit these simple heat release models is a quite possible method and works for the reproduction of a known heat release rate.

More challenging is the ability to predict an unknown heat release rate, i.e. there is no measurement data to fit. For this case, these mathematical functions are incapable because they are only mathematically based and have neither an empirically nor a physically part of modelling.

For the development of a simple combustion model the following method will be used to combine the simplicity of a mathematically approximated model with empirical and physical approaches:

- In the first phase the required model (form) parameters can be approximated by using the measurement data, i.e. the modeled heat release can be directly fitted to measurement data.
- Later, in the second phase the prediction of heat release rate proceed empirically, i.e. empirical function calculate the form parameters in relation to specific

input parameters like intake air condition, air-fuel ratio, EGR ratio.

- Finally, the part of empirical functions should be reduced and replaced with physical based models. The direct impact of injection rate should be implemented just as an ignition delay model (physically and chemically based). Also spray propagation models are conceivable.

As the result, the final model will be a compromise of simplicity and complexity. The challenging requirement of the final model is to predict not only steady operation but also transient operation.

Emissions

Concerning pollutant emissions, the focus of the present work is NO_x and soot which are predominant in diesel engine.

To predict emissions which are directly related to the procedure of the combustion process at least a two-zone model is necessary. This approach divides the combustion chamber into the zone of burned and unburned mass.

The two-zone model which is used for the present work is an empirical approach of Heider [12]. The assumptions of the model are:

- No explicit mass and heat transfer between the two zones is modeled.
- Empirical function to describe the difference in temperature of the two zones.
- Maximum difference in temperature is at start of combustion which is negated until exhaust valves open.
- This behavior is described as the difference of turbulent mixing of both zones and is represented by the relation of the pressure curve during motored engine operation and fired engine operation.

The advantage of this approach is the short computational time. However, engine specific parameters are needed to fit the model based on measurement data (NO_x). Multiple alternative two-zone approaches exist, e.g. Hohlbaum [13] or Ishida [14].

The emission of NO_x is the most detrimental gaseous one from diesel engines and grouped as a composition of nitric oxide (NO) and nitrogen dioxide (NO_2). Generally three mechanism are involved in the formation of NO_x - thermal, prompt and nitrous oxide (N_2O-intermediate mechanism) [15].

Thermal NO-formation occurs at higher temperature (above 1700 K) [16] and its rate increases rapidly with higher temperature. Concerning the high temperature in the compressed ignition combustion process thermal NO is dominant and also focus of this modeling. Prompt NO and fuels NO is neglected at this juncture of model development.

Formation of thermal NO according to the extended Zeldovich mechanism [17] [18] contains the following elemental reactions:

$$\begin{aligned} O + N_2 &\xleftrightarrow{k1} NO + N \\ N + O_2 &\xleftrightarrow{k2} NO + O \\ N + OH &\xleftrightarrow{k3} NO + H \end{aligned} \qquad (7)$$

Neglecting the reverse reactions together with some additional assumptions quoted in [19] this could be summed up to:

$$\frac{d(NO)}{dt} = A_{NO}[N_2][O_2]^{0.5} \cdot \exp^{\frac{-67837}{T}} \qquad (8)$$

The applied temperature complies with the one from burned zone calculated by the two zone model.

For the modeling of soot usually two pathways are considered. The formation one and the oxidation one are, together with information about the local temperature of the burning zone, the local gaseous fuel and oxygen, of interest. The difference yields the mass of soot in the exhaust gas. In the present work the simple model of Hiroyasu [20] is used who formulated these pathways both as a single step reaction as follows:

$$\frac{dm_{PM}}{dt} = \frac{dm_{form}}{dt} - \frac{dm_{oxi}}{dt} \qquad (9)$$

$$\frac{dm_{form}}{dt} = A_{form}\frac{dm_{fuel}}{dt} \cdot p^{1.8} \cdot \exp^{\frac{-6313}{T}} \qquad (10)$$

$$\frac{dm_{oxi}}{dt} = A_{oxi} \cdot m_{PM} \cdot x_{O_2} \cdot p^{0.4} \cdot \exp^{\frac{-4.6}{T}} \qquad (11)$$

Results and conclusion

Since validation data are not available at present only an outlook can be given how prediction may look like. As an exemplary result of the current state of models development the results of a selected single cycle is presented.

The fuel mass is a demanded boundary condition of the present model. So the prediction of fuel consumption will not be a part of the discussion. Instead, only predicted emissions will be shown. Therefore, the rate of temperatures of the two zone model is shown followed by the predicted emissions of thermal NO and soot.

The two zone model is necessary to predict not only the averaged temperature of the actual volume of the combustion chamber but in addition the temperature of the burned zone. The temperature of the unburned zone is part of calculating the burned one.

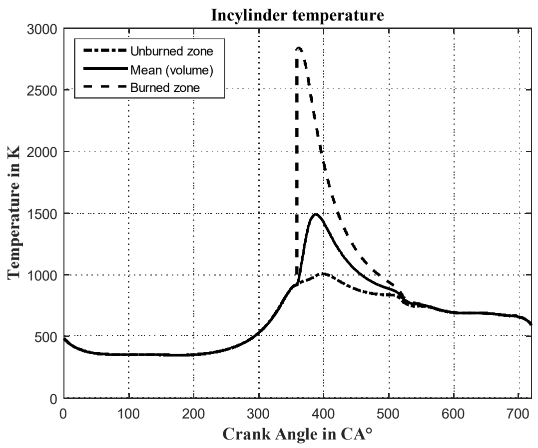

Figure 4. Volume averaged temperature of the single zone assumption and unburned and burned temperature rate of the two-zone model based on [12]

As shown in figure 4 the mean temperature is low and formation of thermal NO will not result as mentioned in the previous chapter (temperature above 1700 K is necessary) [16]. Since this is only the mean temperature in comparison the local temperature of the burned zone reaches values significantly above 2000 K. Formation of thermal NO will follow under this conditions. The formation rate and its integral as the NO concentration in combustion chamber is shown (see figure 5).

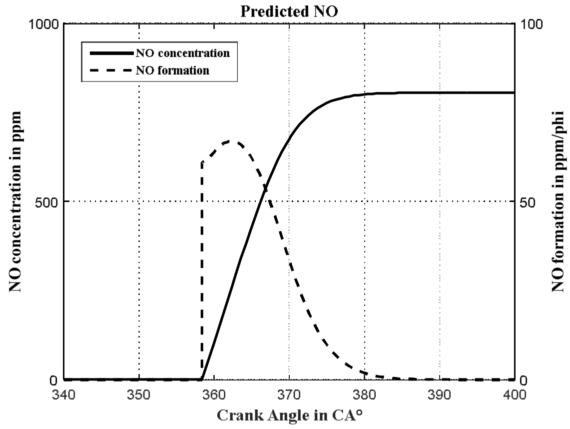

Figure 5. Predicted NO concentration and NO formation rate in the combustion chamber started with start of combustion

NO formation starts immediately as a result of the started combustion process and the first appearance of the burned zone - in the presented case with temperatures about 2800 K in the flame front. The combustion process takes place near top dead centre of the piston and NO formation rises, reaches fast its maximum peak until it falls down due to lower temperature of expanding cylinder volume and decreasing oxygen concentration of the proceeding combustion.

While evaluating the predicted NO concentration it should be kept in mind that a simple single Arrhenius equation was used which e.g. neglects reverse reaction. Consequently, the resulted NO value will be slightly overestimated.

The prediction of soot is split into formation and oxidation, whereas the oxidation depends on the formed soot mass. The difference of both yields to the net mass of soot. All the mentioned rates can be seen as exemplarily quality rates in the figure 6.

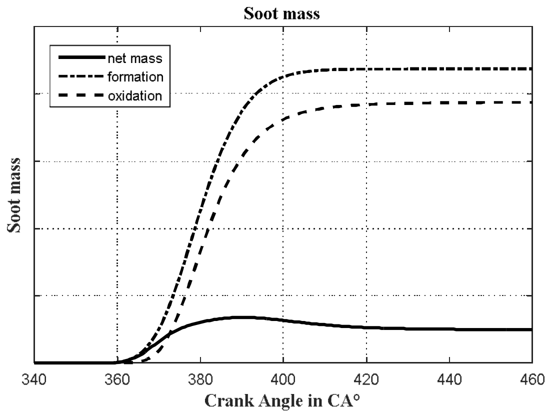

Figure 6. Qualitative rates of soot formation, oxidation and the resulted net mass

The prediction of soot is very challenging and the results should always be seen in a critical view. The used two-zone-model is only capable to calculate the temperature of a burned and unburned zone. Additional local conditions during combustion process remain unknown. However, for soot formation the local gaseous, i.e. evaporated, fuel concentration and for oxidation especially the local oxygen concentration are essential. Most probably the two zone approach is not sufficiently and more details about the spray zones considering spray breakup, evaporation and air entrainment are necessary. For further development spray cone propagation [21] and spray package multi zone models [22] are conceivable.

While prediction of emissions in steady operation is state of the art the aspiration of the future work is the prediction of emissions in transient operation. An outlook can be given by the following figure 7 which shows exemplarily transient operation.

The rising engine torque (at constant engine speed) results in a shortly increasing specific fuel consumption, i.e. efficiency decreases, predicted NO increases while predicted soot slightly decreases. Unfortunately, no soot burst occurs, as actually expected, which confirms that more complex models, especially for soot prediction, should be implemented. Nevertheless, these are results of an early stage of development and work is ongoing for further improvements. Moreover, measurement data will be generated and used for validation in the future.

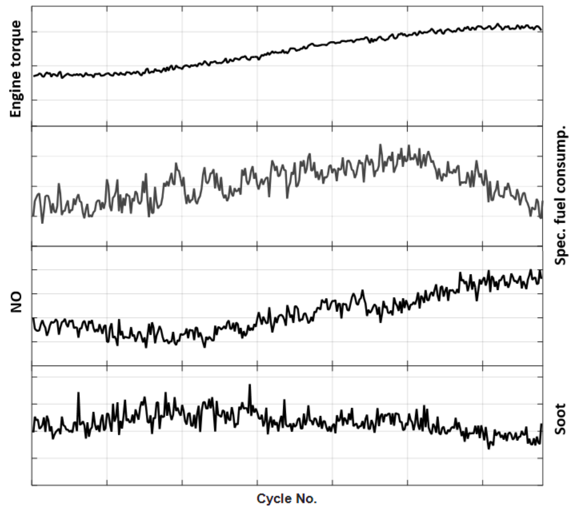

Figure 7. Exemplarily transient operation with qualitative rates of engine torque (at constant engine speed), the specific fuel consumption, predicted NO and soot

Simulator

The simulator will provide a real-time simulation environment that includes the interfaces to subsystems of main engine and that allows for conduction of scenarios according to real ship operations. RME's SES7 Ship Engine Simulator includes a main engine model that is embedded in a system arrangement consisting of control elements and supply systems. Among others control elements comprise:

- propulsion control system including control from Bridge, Engine Control Room and Engine Room
- engine governor system
- engine alarm and safety system

Among others the supply systems comprise:

- fuel supply system using different fuel qualities
- lubricating oil system
- freshwater cooling systems (high temperature and low temperature)
- starting air and control air system
- seawater system
- electrical power supply system

All systems are interconnected and simulate realistic interactions between systems and subsystems. Furthermore the SES7 includes a propeller model and a ship model based on forces acting in the centre of gravity of the virtual ship. By this means it is possible to replicate ship manoeuvring procedures with the simulator including steady operations at sea as well as transient operations in harbour areas.

The accuracy of the simulated manoeuvring behaviour can be significantly increased by using the interconnected operation with a Ship Handling Simulator (SHS). It is possible to interface the SES7 with a SHS by means of a real-time interface that connects the hydrodynamic ship model of the SHS with the thermodynamic engine model of the SES7. A corresponding simulator link is available in the simulation system of the MSCW.

One of the major tasks in this project is to replace and improve the engine model of the SES7 by a detailed thermodynamic model that will be provided by the Institute of Technical Thermodynamics of the University of Rostock. The engine model of the SES7 is based on a modular design that includes model components such as:

- combustion process
- heat transfer process
- turbo charger
- charge air cooler
- crank gear and bearings

The modular design of the engine model allows extraction of particular model components and replacement by models of a higher grade of detail. The integrated model component will be developed in a way that matches the internal interface of the replaced model component and thus can be connected to the existing model like a plug-in. In this regard all relevant model parts of the main engine can be replaced by detailed thermodynamic models provided by the Institute of Technical Thermodynamics. The result will be a highly sophisticated engine model that runs in a simulation environment of the entire machinery plant of a ship. Using the ship's bridge (SHS) for the execution of manoeuvring procedures the system will be able to replicate emissions and fuel consumption closed to reality.

Summary

During manoeuvring, as a consequence of the ships operation many changes of operation of the main engine / machinery ensue. Fluctuating and temporary higher fuel consumption and emissions result from this transient behaviour of operation. To model this fuel consumption and emissions was focus of the presented article.

Modelling and simulation of this transient operation is connected with higher requirements in comparison to steady operation. Whereas modelling is not only confined to model development itself, and also experimental data for model calibration and validation are needed, all participating section face higher requirements.

Incidentally, at first, relevant operation modes should be defined from real ship operation as the reference manoeuver with information about the main machinery operation, especially engine torque and engine speed. Only by this, the measurement data generated at the test bed could represent this reference operation as best as possible. Modified methods which handle these higher requirements and applied in terms of measurement data and their evaluation were presented in this article.

Finally, the approach of model development was described beginning with models of high simplicity and given an outlook by describing the following steps of further development with increased model complexity.

As a final result a simulation tool will be developed which is capable of model fuel consumption and emission in transient operation. Later on, the implementation for the use in a ship simulator is the aim of this work.

Acknowledgement

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NOMENCLATURE

a	Vibe parameter (degree of conversion)
A	surface area
A_{form}	model constant, soot formation
A_{NO}	model constant, NO formation
A_{oxi}	model constant, soot oxidation
$\dot{H}_{fuel}$	Fuels enthalpie
k_i	Reaction rate coefficient
LHV_{fuel}	Fuels lower heating value
M	Engine torque
m	Vibe parameter (form)
m_{form}	Mass of soot formation
m_{fuel}	Mass of (gasous/evaporated) fuel
m_{oxi}	Mass of soot oxidation
m_{soot}	Net soot mass
N_2	Nitrogen
p	Pressure
p_{emep}	Effective mean pressure
pi	Indicated pressure
p_{imep}	Indicated mean pressure
O_2	Oxygen
$\dot{Q}_B$	Reaction enthalpie of heat release
$\dot{Q}_W$	Wall heat transfer
U	Inner energy
V	(Cylinder) volume
V_h	Cubic capacity
T_{gas}	Gas temperature
T_{wall}	Wall temperature
x_{O2}	Mass fraction of oxygen
α	Coefficient of heat transfer
φ	Crank angle
φ_{BB}	Crank angle at begin of burning/combustion
$\Delta\varphi_{BD}$	Burning duration in crank angle degree

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METHOD OF TRAINING SYSTEM HARDWARE CHARACTERISTICS CALCULATING

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Abstract: tasks and challenges while optimal choosing of training systems hardware and its characteristics calculating are described.

Last 10-15 years it's become absolutely clear that Life Long Learning (LLL) conception is necessary to be realized by any engineer, developer, valuable specialist working in the field of automation, industry, transport, data transfer and control systems, etc. One of the facilities to get new knowledge, practical skill, experience is using of training equipment.

Main lack of any training equipment is big or huge cost because modern training equipment consists of high performance computers, network equipment, very expensive touch panels with big diagonals (at least 40 inches) and high resolution and so on. Typically training equipment may cost several tens of thousands, hundreds of thousands or even millions dollars depending on functionality and sphere of application. In the same time even super modern equipment becomes morally outdated very fast because of appearance of new hardware, software, technologies, network protocols, concepts, algorithms, etc. That's why from the economical point of view such training equipment has to be used 24 hours per day. Thus it's necessary to choose optimal hardware (memory volume and performance, disk subsystem type and performance, network and graphical interfaces bandwidth, central and graphic processors productivity, network technology and data transfer rate) configuration taking into consideration cost/productivity ratio.

Additionally it's very complex to realize training equipment loading during whole day in real life. Moreover very often trainees, which have to pass corresponding training, live in different cities and even countries, have different level of language speaking, work in different companies (for example, in maritime branch). These reasons quite often don't allow to get all them together. That's why very important property of training equipment is possibility to work with trainee and to be controlled by administrator and/or trainee remotely.

One more task to be solved is Internet channel bandwidth optimal choosing and analyzing and calculating of additional loading in corporate (campus) computer network. Transferring of uncompressed graphical data will be reason for unstable network condition. Fast Ethernet network technology with 100 Mbit/s data transfer rate, which is most popular in Ukrainian campus networks, will become the bottle neck. There are 2 evident ways to solve this problem.

1. Using of additional real time data compression boards which will contain own CPUs and memory.

2. Upgrading of network equipment (switches) from Fast Ethernet to Gigabit Ethernet or even to 10 Gigabit Ethernet for some network segments and structured cabling system or some its segments from category 5 twisted pair to newer twisted pair category or fiber optics.

Keywords: training equipment effective using, training system hardware characteristics calculating, training system hardware optimal choosing.

During last 10-15 years it's became evidently, that Life Long Learning (LLL) concept [1] has to be realized by any engineer, developer, qualified specialist, which works in the branch of automation in industry, at transport, with data transfer and control systems, in programming industry and so on. One of possibilities to acquire new knowledge and practical experience, to improve corresponding skills is using of different training systems (complexes). Main lack of any modern training system is very high cost, because they consist of high-throughout computers, network equipment, some high cost (very often sensitive) displays for images output with large diagonals (at least 40 inches) and high resolution (at least 1920×1080), etc. Typically cost of such training systems is tens or hundreds of thousands dollars depending on functionality and application field. In the same time even ultramodern equipment quite fast becomes morally outdated in connection with appearance of new versions of hardware, system and application software, new network technologies and data transfer protocols, changing of programming concepts, algorithms and so on. That's why from economical point of view expensive modern training systems have to be used with maximum loading, the more the better.

It's quite difficult to provide maximum loading of multi-user training system during whole day. Very often specialists, which have to pass corresponding trainings using the same training system, locate in different cities, countries or even continents, have different level of foreign language (in the majority of cases English) knowledge, work in different companies (for example, in maritime branch). All these reasons often enough don't allow to get trainees together. That's why very important feature of modern training system is to give the possibility for trainees to work with these training systems remotely and allow to administrators to control them remotely by means of Internet and corresponding protocols as well. In this regard for maximum training systems loading realization it's possible to use effectively different time zones and to attract trainees, which are physically located even on different continents. This approach is very actual in conditions of world business globalization and existing a lot of subdivisions in different countries in big companies. So, German company Phoenix Contact has more than 15000 employees and subdivisions in more than 100 countries [2]. One of the biggest developers and manufacturers of training systems for maritime transport, Norwegian company Kongsberg Maritime, conducts trainings for more than 7000 trainees per year on its training systems in 17 world wide training centers [3]. Using of training systems with possibilities of remote access and control allows to intensify Industry 4.0 concept implementing [4].

For development of training system it's necessary to chose optimal configuration of hardware (volume and productivity of memory subsystem, interface and productivity of disk subsystem, data transfer rate for graphic interfaces, productivity of central and graphic processors of computers, network interfaces, technology and data transfer rate), taking into consideration price/productivity ratio.

When developing of multi-user training system it's also necessary to make optimal choice of Internet connection bandwidth, analysis and computation of additional loading at corporate computer network (CCN). Big volume of uncompressed graphical data transferring can cause instability of CCN. So, Fast Ethernet network technology with 100 Mbps data transfer rate, most popular in CCNs of Ukrainian organizations, may become the "bottle neck". There are two ways for solving of described above problems are proposed.

1. Usage of additional video data compression hardware boards with necessary compression coefficient in real time, which contain own high productive processors and memory.

2. Upgrading of network equipment (primarily switches) from Fast Ethernet to Gigabit Ethernet or even 10 Gigabit Ethernet for some network segments of CCNs and structured cable system or some its segments from twisted pair Cat.5 to more modern twisted pair categories (6 or 7) or fiber optics.

In modern conditions of fast multi-user training systems development the task of theirs hardware characteristics choosing, bandwidths of CCNs and theirs corresponding segments and Internet channels is very actual.

METHODOLOGY

Method of graphic and central processors productivity calculating in multi-user training systems, choosing of additional video compressing hardware boards productivity, loading of CCNs segments and Internet channels, calculating of transferring data volumes is proposed.

In modern multi-user training systems use extensively liquid-crystal displays (flat panels), which have following typical diagonal sizes: 40, 42, 43, 46, 47, 48, 49, 50, 55, 58, 60, 65, 70, 75, 80, 84, 90, 98 inches. In them may be used following main frame frequencies: 75, 100, 120, 144 Hz. Most popular ratios of theirs heights and widths are 16:9, 16:10, and very perspective for future training systems development ratio 21:9 as well.

In the Table 1 are shown source data and results of calculating, which determines required bandwidth W of video interface, segment of CCN or Internet channel for uncompressed video data transferring. Calculations were made by formula (1) for variety of specified above most commonly used ratios of modern displays widths and heights and frame frequencies:

$$W = \frac{RFn}{2^{20}} \text{ MBps,} \qquad (1)$$

where R – resolution of display (TV, liquid crystal panel), pixels;

F – frame frequency, Hz;

n – memory volume for pixel color data storing (color bit depth), Bytes.

For pixel color data storing (color bit depth) 16 bits (2 bytes) is assumed. It allows to get $2^{16} = 65536$ colors; this value is quite satisfied at present time. Division by 2^{20} is executed to get final measurement unit MBps (1 kB = 2^{10} B, 1 MB = 2^{10} kB = 2^{20} B). Also for color encoding may be used less color bit depth values (8, 10 or 12 bits instead of 16). This will allow to decrease required bandwidth significantly depending on available hardware and network characteristics but will cause some losses of image or video quality.

Obtained results are shown in the Table 1. The names of columns are: 1 – Standard name; 2 – Resolution R, pixels; 3 – Frame frequency F, Hz; 4 – Required bandwidth of video interface, CCN segment or Internet channel W, MBps. The names of standards (rows in the Table 1) are: 1 – HDTV (Full HD); 2 – WUXGA; 3 – QWXGA; 4 – WQXGA (WQHD); 5 – WQXGA; 6 – WQXGA; 7 – WQXGA+; 8 – WQXGA+; 9 – WQXGA+; 10 – 4K Ultra HD; 11 – WQUXGA; 12 – 5K Ultra HD +; 13 – 8K Ultra HD; 14 – WHUXGA.

Table 1 – Bandwidth of network or graphic interface at uncompressed video and graphic data transferring

1	2	3	4
1	1920×1080	75	296
2	1920×1200	75	329
3	2048×1152	100	450
4	2560×1440	100	703
5	2560×1600	100	781
6	2560×1080	120	633
7	3440×1440	120	1134
8	3200×1800	120	1318
9	3840×1600	120	1406
10	3840×2160	120	1898
11	3840×2400	120	2109
12	5120×2880	144	4050
13	7680×4320	144	9112
14	7680×4800	144	10125

Calculations made using formula (1) and are actual for computation of video interface bandwidth between computer graphic board and display (liquid crystal panel), required bandwidth of internal computer interfaces (buses) and graphic subsystem processor throughput. Obtained result values are really huge, that's why in actuality video data in most cases have to be compressed with quality loss, which is acceptable, nearly invisible or fully invisible for human eye. For example, for transferring of standard TV signal required bandwidth about 3.8 Mbps, and for transferring of HDTV (High Definition TV) signal required bandwidth is about 15-25 Mbps with compressing at MPEG-2 (H.262) standard or 8-12 Mbps with compressing at MPEG-4 (H.264) standard [5]. The newest compression standard H.265 (High Efficiency Video Coding, HEVC) supports resolutions up to 8192 × 4320 pixels, offers about double the data compression ratio at the same level of video quality, or substantially improved video quality at the same bit rate [6].

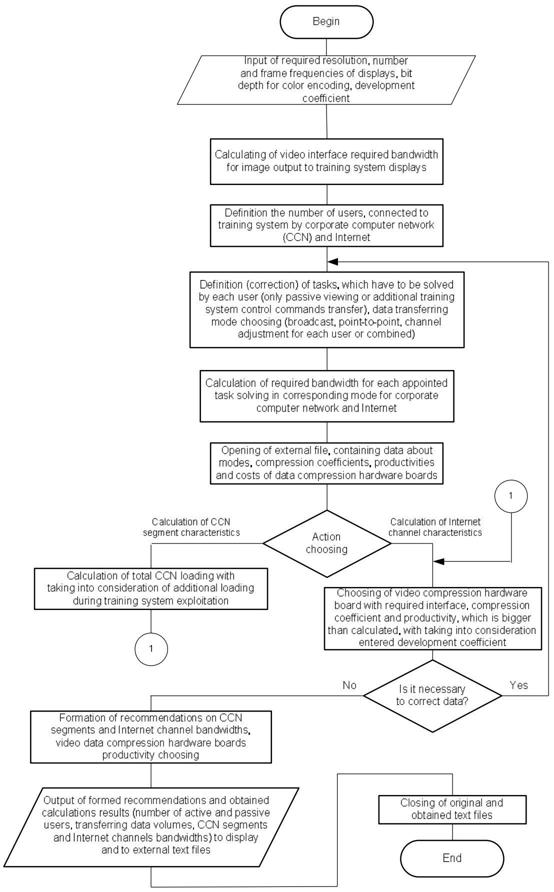

Figure 1. Algorithm scheme of training system characteristics choosing

Algorithm scheme, which allows to execute computation of required CCN segment and Internet channel bandwidths at uncompressed and compressed graphic and video data in different work modes, to calculate data transferring volumes and make choice of additional hardware video compression boards characteristics is shown at Fig. 1.

As physical interfaces for displays (liquid crystal panels) connecting may be used Display Port (newest version is 1.4 with 32.4 Gbps bandwidth and triple hardware data compression) [7], HDMI (newest version is 2.1 with 48 Gbps bandwidth) [8], Thunderbolt (newest version is 3 with 40 Gbps bandwidth) [9].

Proposed method and algorithm, which is its component part, may be used for choosing of training system characteristics during its designing or updating, determining of transferring data volume between training system, CCN and Internet when organization of remote access of users and administrators in different work modes, bandwidths of corresponding segment of CCN and Internet channel, choosing of characteristics and productivity of additional video compression hardware boards (processors productivity, memory subsystem productivity and volume, interface type).

Conclusions

1. Mathematical relation, which allows to calculate volume of uncompressed transferring video and graphic data and bandwidths of CCN segments, productivity of central and graphic processors, additional hardware video compression boards is proposed.

2. Algorithm of additional hardware video compression boards characteristics and displays connection interfaces choosing in training systems is proposed.

3. Recommendations on choosing of CCN segments and Internet channel bandwidths at users connections to training system are given.

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SELECTION OF COMMANDED OUTPUTS FOR A SHIP PROPULSION ENGINE WITH A CONTROLLABLE PITCH PROPELLER

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Abstract: Operators of all types of ships are interested in decreasing their operational costs associated with consumption of material resources, e.g., fuel consumption by ship propulsion, and operational losses, e.g., excessive travel time to the destination. Therefore, there is a need to manage these resources effectively.

In the case of a ship equipped with a controllable pitch propeller (CPP), its propulsion system can produce the desired thrust or achieve the desired ship speed at many combinations of the outputs: commanded torque and pitch ratio. Most commercial vessels use a shaft speed/pitch ratio controller. In this controller, the commanded torque is controlled to maintain a certain shaft speed.

However, there are ships (tugs, sailing vessels) that are not equipped with such controllers and in which combinations of the outputs are selected manually. In such cases, due to diverse conditions at sea, selecting output values is extremely difficult because of the uncertainty of meteorological conditions on the waters where navigation takes place.

As a rule, vessel operators select the appropriate settings for the ship propulsion system using their own experiences and rules of conduct for certain weather conditions. They make decisions which can sometimes be irrational or inappropriate. To avoid such situations, a computer-aided system supporting selection of these commanded outputs for sailing vessels equipped with engine powered propulsion systems with a CPP has been developed.

Based on this system, it is a possibility to develop a simulator allowing to vessel operators for selection of the appropriate settings of the commanded outputs (commanded engine speed and pitch ratio). Such a simulator could be used for training of the future operators of these kind of vessels.

Keywords: ship propulsion, commanded outputs, decision-making system, operator.

Introduction

Ship-owners and operators of merchant, passenger and sailing ships are interested in decreasing their operational costs. These costs involve consumption of following resources:

- material, e.g. fuel consumption during engine ship propulsion,
- human, e.g. work of the ship crew connected with loading/unloading cargo or passengers, work with sail on tall ships,
- time, e.g. sailing time to reach destination, time of standstill on the roads, time of taking turns on tall ships carrying sails.

Therefore there is a necessity to manage these resources in an effective way.

This poses the problems of optimal selection of operating parameters of the drive system consisting of engines and propellers; selection sailing ship's course to the wind and the set of sails for sailing vessels. Due to varied conditions of navigation, decision taking is extremely difficult, especially because of the uncertainty of meteorological conditions on the waters where navigation takes place. For this reason, it would be useful to support such decisions. This requires obtaining the data necessary to build a decision support system. These data may be obtained by carrying out appropriate tests, preferably on a real ship, for which these parameters:

- often change,
- affect the efficiency of navigation

significantly,

- do not contribute to incur substantial operating losses.

Tall ships comply the following requirements. There are three essential options of sailing on these ships depending on the meteorological, nautical and operational conditions:

- sailing with sails as the essential source of propulsion,
- sailing with the engine as the main source of power (without support for sails),
- hybrid sailing - sailing with sails supported by an engine (concurrent power sources).

Sailing with the engine as the main source of propulsion (called further: under engine) is characterized by some distinctive features, among others, sensitivity to weather conditions changes, and relatively low/small seaworthiness. The tall ship greater sensitivity to changes in weather conditions arises from the fact that air resistance force, which depends on the wind and sea waves, affects their engines considerably more than those of big merchant ships. This is due to the fact that high masts cause increased air resistance, which in turn are strongly dependent on the strength and direction of wind, and the sailing hull shape is very sensitive to the direction, steepness, and height of waves.

The low seaworthiness of a tall ship is associated with relatively low power of its propelling engine. In adverse weather conditions and in heavy seas, especially in the case of sailing upwind, a sailing ship's course-keeping stability and steerability are reduced.

In the case of sailing under engine, a captain's principal decision problem is to select parameters of ship propulsion system in such way that:

- estimated time to reach destination,
- a vessel's efficient fuel consumption,
- can be ensured.

The propeller rotational velocity is a determining parameter in both cases. There are two types of propellers: variable pitch propellers (fixed pitch) and controllable pitch propellers (CPP) in tall ships' drive line system.

The presented decision problems which mean ensuring the established time to reach destination and ensuring a vessel's rational fuel consumption are opposed. Hence there is a need to look for a compromise solution, which enables to plan shipping in more flexible way. In the case of tall vessels with a controllable propeller, these parameters are chosen by selection of engine rotational speed, and propeller pitch.

Modelling the decision-making problem of selecting commanded outputs for ship propulsion system with CPP

The problem of selecting optimal commanded outputs of the ship propulsion system is connected with the efficient usage of energy which is supplied to the propeller. In literature there are two essential phases of ship life cycle, which can affect the efficiency of energy supplying for the purposes of ship propulsion efficiency: design phase and working phase. In [0] the authors singled out broad set of design and working factors which affect efficiency.

The issue of ship resistance, which means the force opposed to drive, is the most important for ship propulsion. The ship velocity, displacement, and the shape of its hull made up the ship resistance [0,0]. To determine the ship resistance, it is crucial to select an appropriate thruster, and therefore select the main propulsion engine.

In the case of tall ships using the ship propulsion system with CPP, the area of feasible solutions is limited by maximum velocity attainable for the propulsion system and minimal speed for their maneuvrability. It is obvious that this range is not constant and depends mainly on weather conditions.

As a rule, the captain of a tall ship selects the appropriate parameter settings of the ship propulsion system himself, using his own experience and rules of conduct for certain weather conditions. In general, such a procedure has no theoretical justification and is based only on the captain intuition.

Therefore, the captain has to analyze all available information independently. Based on the received information, he has to choose the settings of the ship propulsion system, which sometimes can be irrational or inappropriate. In order to avoid such situations computer decision aided systems are used in lots of different applications.

The use of such system in decision-making process may limit the situations in which decisions are irrational or generate the increase of operating costs. The basis for such system are appropriate mathematical models. The existing methods do not include models for formalization of heuristic knowledge, which could help to reach destination on time with a reasonable fuel consumption. Therefore there is a necessity to build a computer-aided system that would allow to select the optimal commanded outputs for ship propulsion system with CPP for certain meteorological and nautical conditions.

Building such a system requires:

- the concept of decision-making system developing i.e. drawing up its informal description that means to define sets of system elements, their attributes and relations,
- defining variables of models of the ship propulsion system with controllable propeller (parameters, decision-making variables and output variables),
- determining how to acquire input data and parameters necessary to build these models,
- building black-box models using the method of artificial neural networks (ANN),
- building a decision-making model using multi-criteria optimization methods.

From the standpoint of physics the ship is a solid object located on the border of water and air, partly immersed in each of them and typically remaining in relative motion. While sailing with the engine a ship is affected by some factors which are connected with movement of water, air, and the ship itself (Fig. 1).

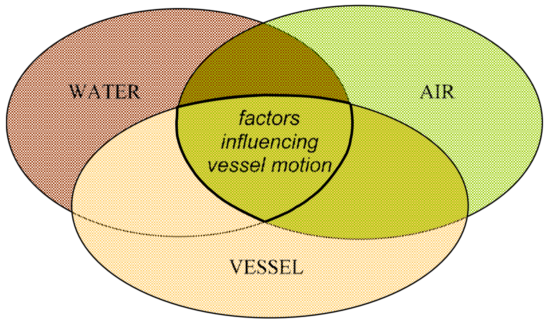

Figure 1. Factors influencing the vessel movement

In each of these elements and in each relation between its components there may be the group of factors which affect the movement, such as:

- in the case of the ship: type of ship propulsion system (structure of the energy system); type of hull (hydrodynamic shape, fineness); displacement of the ship; shell planking smoothness (no protrusions); type of propeller (the number of its lobes); design of the rudder; superstructure aerodynamic shape with the rig masts, etc.,
- in the case of water: tides; ocean currents, water temperature, water density, etc.,
- in the case of air: wind, temperature, etc.,
- in the case of relation tall ship-water: ship waves caused by the movement of the vessel,
- in the case of relation: tall ship-air: wind tilt and trim of the vessel caused by the wind acting on the rigging,
- in the case of air-water relation: wind waving (structured, waving and slightly progressive movement of subsurface water layers caused by wind).

The mentioned elements, as well as the relationships between these elements are general character. In order to determine the set of factors that affects ship movement it is required to decompose these relations. It can be done by grouping of the relations into the following groups:

- relations that cannot be observed or controlled,
- relations that can be are observed but cannot be controlled,

- relations that can be observed and controlled,
- informative relations.

Relations that cannot be observed or controlled are established or imposed parameters, which result from ensuring other more important properties, such as power, speed, etc. These parameters are preset and their value is constant in the modelling process. In some cases, the factors of this group may include:

- factors associated with the construction of tall ship which values were determined during the design process,
- operational factors that cannot be observed but their appearance affects the movement of a ship.

The first group of factors include the size and hydrodynamic shape of the hull; ship displacement; the number of lobes and hydrodynamic shape of the propeller; the size and hydrodynamic shape of the rudder; the size and aerodynamic shape of the ship 's superstructure along with rig masts, etc. The second group of factors include immersion (depending on the loading condition of the ship and the salinity of seawater), changes in the shape of the underwater part of the hull (shell deformation associated with the impact of other objects), the quality of sails folding, and extra stuff placement on board which can affect air turbulence above the deck), etc. It is obvious that these groups of factors are not taken into account during the modelling, because their observation may be very difficult, and sometimes even impossible.

Relations that can be are observed but cannot be controlled are the group of factors that are altered during ship movement, but there is not possibility of impact on their values. They include the following factors: direction and speed of sea currents; temperature and salinity of the water; wind direction and speed; air temperature; height, length and period of ship wave; height, length and period of wind wave; hull fouling condition.

Relations that can be observed and controlled are the group of factors which provide desired ship motion parameters while sailing under engine. These factors include the propeller operating parameters, i.e. the value of its rotational speed and pitch setting.

Informative relations are the group of factors which help to determine the effectiveness of decision support for selection of commanded outputs for engine ship propulsion. These are the factors which characterize the fuel consumption and time to reach destination during the ship movement. As the ship route is imposed it is convenient to take the ship speed as the other factors characterizing the consumption of resources.

In general, the decision-making problem model can be presented in the form of so-called. 'black box' that is a subject to a variety of factors (Fig. 2). Factors for ensuring desired motion parameters of a tall ship with the engine as the main source of propulsion are the decision-making input variables of XD in the model (relations that can be observed and controlled). In this case there are the propeller operating parameters, i.e. its rotational speed and pitch setting.

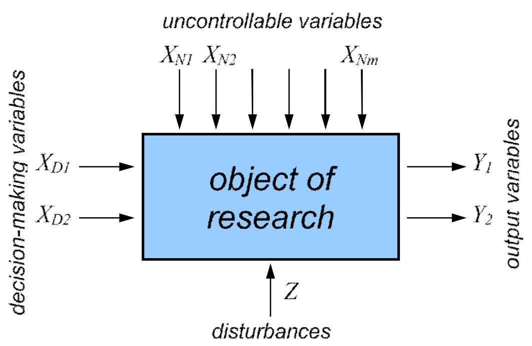

Figure 2. Decision-making model in a form of 'black box'

A group of model uncontrollable input variables XN is created by a variety of factors affecting the movement of the ship. These values may change as the result of meteorological, nautical and ship's operating conditions. In this case, it is possible to observe them but there is no possibility of direct impact on their values. They can be factors counteracting the movement (e.g., wind constituent directed contrary to the wind) as well as conducive (e.g. sea current constituent consistent with the direction of the vessel).

Other factors affecting the movement of the ship which are difficult and sometimes even impossible to observe, and there is no possibility to impact on their values are the model disruptions *Z*. In this case they are a tall ship design parameters and operational factors, which are not the subject of observation.

As the model output variables Y is assumed factors characterizing the consumption of material and time resources during ship movement, i.e. consumption necessary for propulsion and ship speed.

Taking these factors into consideration the general form of the model of decision-making selection of commanded outputs for ship propulsion system with CPP can take the form:

$$Y_j = (X_{Dn}, X_{Nm}, Z) \qquad (1)$$

where:

Y_j – output variables,

X_{Dn} – input decision-making variables,

X_{Nm} – uncontrollable input variables,

Z – disturbances.

Developing the computer-aided system supporting selection of commanded outputs for ship propulsion system with CPP requires building a mathematical decision-making model. The essence of this model would be the right combination of factors affecting the parameters of the drive system settings.

The problem of decision-making can be formulated as follows:

what should be the value of the decision-making variables X_D (rotational speed and pitch setting) to provide the desired values of output variables Y (consumption needed to drive the ship, and ship speed) for model given values of uncontrollable input variables X_N (nautical, meteorological and operational conditions at the moment of observation).

The solution to the problem requires solving the following partial tasks:

building two ANN models which bind selected model input variables (decision-making variables X_D and uncontrollable variables X_N) with selected separately output variables Y,

building a decision model which allows to set values of the decision input variables X_D to fulfil the objective i.e., the desired consumption of material resources (fuel consumption needed to drive the ship) and time resources (ship speed) during movement.

Decision-making variables X_D for this model included:

factors providing the desired parameters of ship movement during sailing with the engine as the main source of propulsion, i.e. the propeller operating parameters (engine speed and pitch setting),

factors affecting the movement of the ship, which values can change as a result of changes in nautical, meteorological and operational conditions.

The choice of uncontrollable input variables X_N was conducted with the following assumptions:

- selected variables must be characterized by a large, possible to register, range of variation,
- variables value measurement should be, if possible, carried out using measuring instruments that are conventionally installed on a tall ship,
- in the absence of such devices there should be installed additional specialist measuring instruments.

Both the assumptions made and the experience gathered while sailing, allowed to preselect output variables Y_i and input variables X_j (decision-making X_D and uncontrollable X_N variables) of decision – making model. List of model decision variables is presented in Table 1.

In order to collect the data necessary to create the required models, an experiment on the tall ship “Pogoria” was conducted, during its normal operation. A series of measurements was taken in various nautical, meteorological and operational conditions, registering a total of 315 measuring series.

Table 1. Decision model output and input variables

variable name	variable identifier	unit
rotational speed of the engine	X_1	[rpm]
pitch of the propeller	X_2	[pitch scale]
angle of wind direction in relation to the longitudinal axis of the ship	X_3	[o]
speed of the wind	X_4	[knot]
state of the sea	X_5	[degree]
angle of tidal current direction in relation to the longitudinal axis of the ship	X_6	[o]
speed of the tidal current	X_7	[knot]
time since the last docking of the ship	X_8	[months]
hourly fuel consumption rate	Y_1	[dm^3/h]
instantaneous speed over the ground	Y_2	[knot]

'Pogoria' is equipped with an auxiliary drive engine (VOLVO PENTA - 255 kW), which through a reduction gear ratio 1:4.5 drives controllable biplane propeller with nominal speed 356 rpm. The selection of commanded outputs for engine rotational speed (and thus the propeller rotational speed) and its pitch is performed by two levers located on the navigation bridge (Fig. 3).

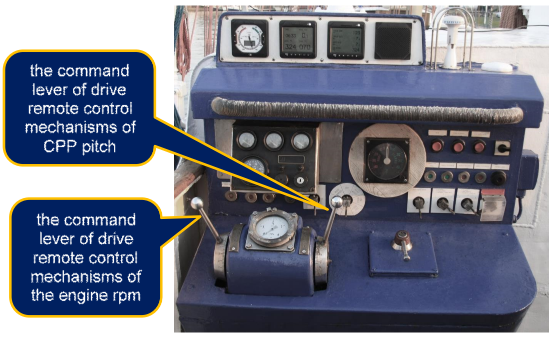

Figure 3. Command levers of the navigation bridge

The obtained results from the preliminary research carried out on the particular ship have been contributed and given reason for the selection of the method of ANNs to build black box models of ship propulsion system with a CPP. These models, developed on results of this research, have been utilized in the multi-objective optimization with limitations. Their output variables characterizing engine ship propulsion work (the hourly fuel consumption and the ship speed) have been taken as objective functions of the dual-objective optimization. Results obtained from the carried out research have validated the adopted idea. The detailed description of issues connected with building both the ANN models using the method of artificial neural networks and the decision-making model using multi-criteria optimization methods are presented in [0] and [0].

Models developed using ANN

To build ANN models of the decision-making process for setting the commanded outputs of ship propulsion system with CPP, an artificial intelligence computational-statistical technique, known as artificial neural networks (ANN) was used. In this case, the input and output variables presented in Table 1 and the values of these variables obtained during an experiment on a tall ship "Pogoria" were used.

The first step was an assessment of the quality of collected data set intended for the construction of ANN models. The evaluation was carried out using cluster analysis of the appropriate STATISTICA software module. To analyze the correctness of the factor space structure, the central agglomeration procedure and six combinatorial methods were used. The dendrograms obtained with the help of these methods have a similar structure. The data are practically separated by every method and every metrics, and in a similar way - with the exception of specific numeral values of similarity. Based on the correct clustering it was agreed that the choice of input variables is appropriate for the collected data set for the considered issue.

In the case of developing ANN models,

the linear normalization with 10% of supply was used in the range of 0.1 to 0.9 for the data in the range of positive values of the variables (X_{D1}, X_{D2}, X_{N4}, X_{N5}, X_{N7}, X_{N8}, Y_1, Y_2), and in the range of -0.9 to 0.9 for the data in the range of positive and negative values of the variables (X_{N3}, X_{N6}). Such a way of normalization allows extrapolation of the data, i.e. going beyond the range of observed values, which built up the training set, e.g. greater than the observed values of the force of wind or sea state.

In order to improve the efficiency and quality of training the neural network, the data collected to build the networks was divided into three separate subsets:

training set for teaching (training) networks;

validation (verification) set, which is used in the process of training to check if there is no deterioration in quality of the training process and to enable an interrupt of the training process when certain parameters established at the outset are exceeded;

test set used to check the results of network training at the end of the training process.

After analyzing the available methods, a pseudo-random division of the input data specified by the 'dividerand' function was selected from the MATLAB "Neural Network Toolbox". The data vector prepared for the network training was divided into three subsets in the following ratio: training set - 70% of the data; validation set - 20% of the data; test set - 10% of the data.

The decision-making process in question is non-linear, which was agreed upon during preliminary tests [0]. Therefore, for the building of ANN models of the process a non-linear neural network was selected. It was decided to build two separate networks, obtaining two ANN models connecting the decision-making process input variables for optimizing the commanded outputs of ship propulsion system with a CPP. We separated distinctive output variables, namely fuel consumption needed for the ship propulsion and speed of the ship. Such a course of action should enable an optimal adjustment of the network to calculate these outputs.

The next stages in the selection of network architecture is the choice of the number of hidden layers, the selection of the number of neurons in the hidden layers and the selection of the form of the activation function. In the given case, a 'feedforward' functions was chosen to describe the network structure. By the use of these functions, the parameters for the network structure and the subsequent process of its learning are determined. In particular, the number of hidden layers, the number of neurons in the hidden layers, and also the neuron activation functions for the hidden layers are decided upon.

When building a network, one should check the variability area of the analyzed series, as the form of the activation function results from it. For non-linear problems one of the non-linear functions is chosen, e.g. a sigmoid, a hyperbolic tangent or another. The next parameter is specifying the desired quality of the network adjustment to the empirical data (acceptable error of the network). Another parameter is the learning step. It is the extent of the weight changes of neurons in each step of learning. A step which is too big will cause problems with network convergence.

A significant stage in creating a neural network is the process of its learning. In the case of the obtained network structures for selecting the commanded outputs for a ship propulsion system with CPP both inputs and outputs of the ANN model are known. This corresponds to the supervised network learning method. For this reason, the construction of ANN involved a principal ANN supervised learning algorithm, namely the error backpropagation algorithm.

After the completion of the presented activities, the appropriate calculation scripts were prepared, using the functions contained in the "Neural Network Toolbox". Next lengthy computational experiments for two separate networks were created for output variables, i.e. Y_1 "hourly fuel consumption rate" and Y_2 "instantaneous speed over the ground". In both cases, the Multi Layer Perceptron (MLP) network of the following structure was used:

8 neurons in the input layer representing the input variables of the model,

2 hidden layers with different numbers of neurons,

1 neuron in the output layer representing the output variables of the model (separately for each of the ANN models).

The basic architecture of the developed ANNs is presented in Fig. 4.

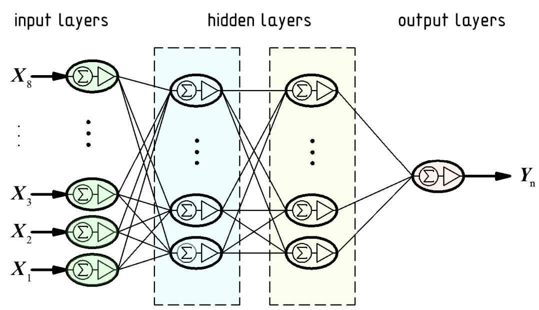

Fig. 4. The basic architecture of the developed ANNs

In the process of network learning the number of the neurons of hidden layers as well as transfer (activation) functions for the neurons were modified. The neurons of the input layer and the output layer use the default linear transfer function - purelin, in order not to cut the essential information. Eventually the best results were obtained using the tansig transfer function for the neurons of both hidden layers.

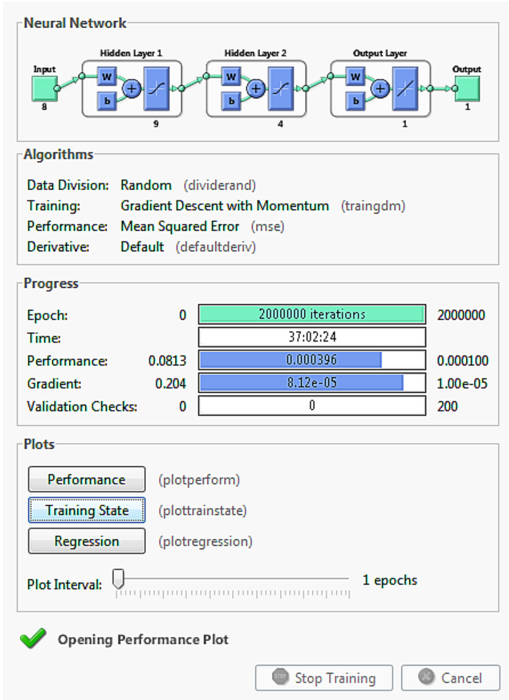

Fig. 5. MATLAB custom network diagrams for the ANN model (hourly fuel consumption rate)

For network learning, after many experiments, traingdm function, which uses the momentum backpropagation method, was chosen. MATLAB custom network diagram with functions of the selected neural network toolbox for ANN model ise shown in Fig. 5.

An example of the individual relations between output variables and decision-making variables and selected examples of meteorological and operational conditions are shown in Fig. 6.

All obtained graphs are characterized by a significant curve smoothing, which also proves a good adjustment of each ANN models to the real data. In conclusion, it needs to be stated that although the measurement data have inherently discrete values, the MLP-type neural networks provide continuous functions as results. Thus, the created neural networks forming ANN models of the decision-making process can be successfully employed for the development of a multi-criteria optimization model of the ship propulsion system.

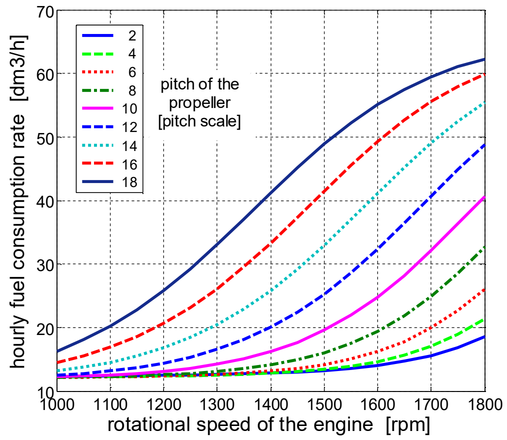

Figure 6. MATLAB custom network diagrams for the ANN model (hourly fuel consumption rate)

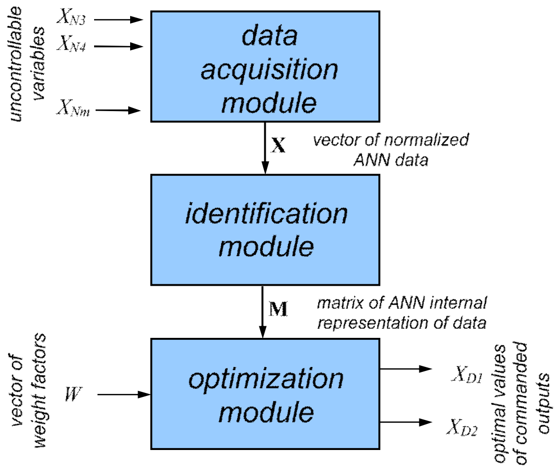

Figure 7. The block diagrams representing the relationships between the main components of the computer-aided system supporting selection of the commanded outputs of the ship's propulsion system

Two-objective optimization of the ship engine propulsion using ANN

The computer-aided system supporting selection of the commanded outputs of the ship's propulsion system consists of the following components (Fig. 7):

- data acquisition module that records and converts information acquired from actual observation of sea conditions, where the following are true:

- inputs are values of uncontrollable variables XNm,

- the output is the vector of normalized ANN data X,

- identification module that builds ANN models, where:

- inputs are the vector of normalized ANN data and two vectors of all values of decision-making variables XDn (ranges of the commanded outputs of the ship's propulsion system),

- the output is a matrix M representing ANN internal representation of data,

- optimization module that allows the selection of the optimal commanded outputs of the ship's propulsion system, where the following are true:

- inputs are the matrix representing ANN internal representation of data and the vector of weight factors W of the two-objective optimization model,

- outputs are the optimal values of the commanded outputs (the engine rotational speed – XD_1 and the propeller pitch – XD_2).

Both outputs constitute the criteria for the given multi-criteria optimization problem. Since their number was reduced to just two, the problem comes down to the two-objective optimization issue. The value of the first criterion should be as small as possible, because it is associated with the consumption of material resources (the economic criterion). The value of the second criterion should be as high as possible, as it is associated with the consumption of time resources (the time criterion).

The substitute criterion, being the weighted sum of the criteria, was adopted as the objective function. The essence of this criterion consists in assigning appropriate weights and summing the products of the weights values and the individual criteria values:

$$Z = w_{q1} \cdot Y_1 - w_{q2} \cdot Y_2 \rightarrow MIN \qquad (2)$$

and

$$w_{q1} + w_{q2} = 1 \qquad (3)$$

where:

Z – the objective function of the dual-criteria optimization as the substitute criterion,

Y_1 – criterion 1 - fuel consumption needed for the ship propulsion,

Y_2 – criterion 2 - the instantaneous speed of the vessel relative to the seabed,

w_{q1} – weight factor for criterion 1, i.e. variable Y_1,

w_{q2} – weight factor for criterion 2, i.e. variable Y_2.

The basic and most important advantage of the presented method is its simplicity. The disadvantage of this approach is the difficulty of determining values of the individual weights a priori. In the case of employing this method, the calculations are carried out by gradual changing the values of the weights, which leads to a better understanding of the relations between the criteria.

The decision-making variables of the multi-criteria optimization process as well as the constraints imposed on the acceptable operating range of the propulsion engine will belong to the set of the acceptable solutions.

The range of possible commanded output parameters of the engine rotational speed constitutes the first inequality constraint, whereas the range of possible commanded output parameters of a pitch propeller is the second inequality constraint of the optimization model. The maximum and minimum drive shaft torque value was adopted as the upper limit of the scope of the propulsion system operation and it constitutes the third of the inequality constraints. Another significant constraint which was included in the optimization model is the minimum ship maneuvering speed.

Based on considerations relating to, among others, the concept of a decision system of dual-criteria optimization of selecting the commanded output parameters for the ship propulsion system, the chosen optimization criteria and their mathematical description, as well as the determined inequality constraints, an algorithm of the two-objective optimization was designed.

To determine the optimal commanded output parameters, the complete review method was used. This method was chosen because of the small number of possible combinations of decision-making variables. Optimization calculations were performed using MATLAB with its standard mathematical functions and mathematical operations on matrices.

Conclusions

The developed decision-making system:

- supports selection of commanded outputs for the ship's propulsion system with a CPP that ensure arrival within the established time to reach a destination with a reasonable fuel consumption,
- enables the selection of these commanded outputs in the dialogue between the ship operator and the computer,
- ensures cooperation with other systems used during ship navigation, e.g., systems collecting current meteorological data,
- provides multiple uses, including the ability to select new commanded outputs as weather conditions change,
- enables continuous updating of the decision-making system as new data are acquired.

This methodology can be used on other types of vessels with a similar ship propulsion system. It requires the conduct of a new experiment and acquisition of new data specific to the vessel.

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IDENTIFYING TRAINING REQUIREMENTS TO ENHANCE BASIC SKILLS FOR MAINTENANCE 4.0 IN MARINE ENGINEERING THROUGH ENGINE ROOM SIMULATOR

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Abstract: Ship machinery maintenance is a critical shipboard operation performed in accordance with technical, economical and regulatory considerations. The designed procedures to execute maintenance operations have been targeted to ensure system availability, reliability and efficiency. To achieve the mentioned performance indicators, the ship operators also seek for implementing the advance maintenance approaches (i.e. condition based maintenance (CBM), reliability centred maintenance (RCM)) instead of/in addition to existing planned maintenance system. In this context, maintenance 4.0, initiated in the fourth industrial revaluation, can be considered as a new concept in marine engineering field. Through shipboard integrity of maintenance 4.0 in forthcoming years, this paper introduces the training requirements to enhance basic skills for system design and application of maintenance 4.0 in marine engineering taking the advantage of engine room simulator. Consequently, this study offers additional functions to develop an existing full mission engine room simulator in order to support cyber physical systems awareness and required basic skills of marine engineering graduates in maintenance 4.0 concept.

Keywords: Engine room simulator, maintenance 4.0, industry 4.0, skill assessment, marine engineering.

1. INTRODUCTION

The maintenance issue is currently undergoing a fundamental change initiated by maintenance 4.0, which lies at the core of industry 4.0. As industry 4.0 is still in the early stages, researchers and manufacturers have already been attracted by potential benefits of this phenomenon and denominate it as the fourth industrial revolution [1].

The first industrial revolution was come as a result of mechanisation of machinery units which were processing with steam engine. The second was made true with the integration of electricity utilization. Internet technology enabled the third industrial revolution in human life and increase momentum on globalisation. Today, identification of Internet of Things (IoT), Internet of Services (IoS) and Internet of People (IoP) have made possible another revolution; industry 4.0.

The main objectives of industry 4.0 areestablishing more efficient system productivity, operational capability and more automated activity supported by cyber physical systems (CPS) in an organisation [2]. Expectations from industry 4.0 is thought to be high as CPS based activities are made enable smart machines and systems which are capable of autonomously exchanging actual data, triggering operations and controlling each otherin facilities [3]. In other words, equipments, sensors, machines, products, supply chain elements and customers get connected with each other, so a system's critical elements could share actual information with the purpose of conduct control operations autonomously by IoT [4]. According to Kagermann (2014) [3], CPS is an integration of real life into virtual environment. Indeed, considering the basic elements of industry 4.0, CPS has also some potential benefits such as decentralizing system data. Case studies such as Stock & Seliger (2016) [5], they have wide information regarding implementation process of CPS. They have proposed a human-machine interaction via CPS integrating into their project and highlighted a smart production factory model. In industry 4.0, big data approach could be utilised depending on the amount of obtaining data from systems. For this issue, Lee at al. (2014) [6] put emphasis on the importance of big data environment in order to achieve more effective CPS implementations. In this context, a case study over Komatsu smart bulldozer has been widely examined and remote controlled self-maintenanceability is tested in the scope of industry 4.0. However, CPS implementations are very dependent on quality of utilised technologic data acquisition equipment and communication systems. Carlos at al (2015) [7] experienced a communication delay problem in their case study and this problem caused uncertainty. Therefore, they highlighted the importance of reliable middleware and share their findings elaborately in the study. Different aspects of CPS integration into industry 4.0 is widely discussed in the literature; see also [8], [9], [10], [11], [12], [13], [14], [15] and [16].

Thus, the term of industry 4.0 has come into prominence as the most popular subject among industry and academia in the studies who aims to constitute marginal improvement on the process management, production quality, enhanced manufacturing and system reliability. In this industrial transformation, the maintenance concept has an essential role for manufacturers, as always been in history. In the literature there are various maintenance methods such as corrective maintenance (CM), preventive maintenance (PM), predictive maintenance (PdM) etc.

In CM activities, repairing, mending or overhauling composes for an improperly working machinery system [17]. As another method; run to failure (RTF) maintenance approach,a system element is just allowed to breakdown. If the problem which arise from relevant system element begins to interfere system functionality, repairing & replacement process is conducted [18]. This approach is generally made when operational shutdowns have no serious effect on system process and/or equipment costs are not important.

PM is a time schedule based systematic inspection in order to detect any malfunctions which may lead system failures [19]. By PM, unexpected shutdowns are tried to be avoid with the purpose of increase system availability [20], [21]. However, the main disadvantages of PM implementations are; some catastrophic failures threatens the system functions and PM activities are labour intensive actions due to involvement of unnecessary maintenance tasks. For this reason, PdM strategies are implemented on industrial facilities in order to eliminate disadvantages of PM activities. The PdM focuses on the actual condition of specified parts of a system notwithstanding a planned schedule. Thus, failure modes and critical physical parameters such as vibration, pressure, flow, or voltage etc. are monitored by maintenance experts [22]. The most famous PdM methods are condition based monitoring and reliability centred maintenance methods in the literature.

By the technologic development such as remote diagnostic systems, e-maintenance concept has been intended in 2000. E-maintenance utilizes information and communication technologies (ICT) in order to provide a vast of statistical information and actual system data.The main objective of this strategy is zero downtime performance for both customers and suppliers in system or manufacturing process [23].

Today, by the industry 4.0, most of the industrial environments consider maintenance 4.0 as one of the most futuristic subjects. By means of maintenance 4.0, higher availability performance, reduced downtimes, optimized energy consumption and savings on general maintenance costs could be achieved by interoperability of machines supported with (IoT), (IoS) and (IoP) [35].

However, despite the advantages of industry 4.0 concept, new technologic developments require new human skills and contributions to this issue. In this regard, Erol at al. (2016) [25] highlights the complexity of the industry 4.0 and discussed required competences for future of production. In order to achieve, they proposed a scenario and task based training practice for different types of roles as manager, engineer and worker from different angles such as personal, social, action and domain based competences. In personal competence requirements, solution oriented attitude, creativity and out of the box thinking skills are examined, while in social competence; team work ability, consensus finding ability, compromising, role taking and role making ability, in action competence; problem analysis, solution development, data analysis, method selection and use skills are demonstrated and finally in domain competence; application of Lean thinking and methods, application of conceptual modelling methods, application of ICT for material tracking and worker tracking skills are analysed.

Hecklau at al. (2016) [26] similarly highlighted the same challenge and proposed a detailed competence and skill list in their paper comprehensively from human resources management point of view for organisations involved in industry 4.0. In contrast, Gehrke at al. (2015) [27] also compiled a list of skill requirements for workers in industry 4.0. In parallel, Blöchl & Schneider (2016) [28] investigated training of employees and made a discussion for a learning factory, a factory which enables to practice training activities by simulation based learning techniques. For this issue, a case study on learning factories has been studied by Reuter at al. (2017) [29] and Wank at al. (2016) [30]. In addition, for proper training of human workers for industry 4.0; Quint at al. (2015) [31] suggested a system architecture for a learning environment as combination of CPS via augmented reality approach.

2. THE ROLE OF THE ENGINEERS IN MAINTENANCE 4.0

Whilst the fourth industrial revolution aims zero downtime for machineries in a system, traditional system infrastructure transforms into more enhanced and more autonomous interoperable CPS. Contrary to the expectations, human activity still plays an important role in industry 4.0. However, requirements for this new phenomenon have differences from previous engineering skills, naturally. At this stage, according to Windelband (2016) [32], there are some issues need to be considered on the perspective of industry 4.0;

- Maintenance actions of production facilities involved in interactive virtual instructions:

For the optimization of the process, virtual reality technology is involved in order to prepare an operation plan and workflow effectively.

- Monitoring of processes and quality control processes and provide sensitive information in contrast with CPS:

The monitoring of a system is generally con-ducted by human for many stages in a work process.

- Planning and simulation of production activities such as pre-determining of CPS behaviour:

Virtual reality enables an image of a system to simulate the behaviour of CPS and in order to examine it properly

- Use of lightweight robots in close cooperation with the workers:

This technology is currently implemented for automotive industry related facilities. They are to be managed by skilled employees via manual interaction, smart phones or tablets etc. Simple programming skills are necessary for these tasks.

Furthermore,to conduct maintenance operations in industry 4.0 environment, skilled workers' adaptation into the different roles and tasks must be provided. If an organisation matches infrastructural developments through industry 4.0, workers would make data based decisions. As networking and digital data processing has important role, planning, data analysis and visualisation skills are involved. Moreover, in addition to the traditional troubleshooting skills, enhanced troubleshooting skills are needed especially for new and complex systems. Furthermore, enhanced assessment skills for IT systems to reveal error proneness must be noted. At times, smart systems may fail to notice a system disorder and may not show a malfunction. At this point, skilled workers should think with industry 4.0 vision and they always must keep an eye open for such cases (i.e sensor malfunction, broken data connection) [32].

The above mentioned skills are focused on the overall system availability. However, according to Erol at al. (2016) [25] and Hecklau at al. (2016) [26], engineers of the future must also deal with individual and social responsibilities such as sustainable self-learning (lifelong learning), creativity for develop innovative solutions, team work ability, language skills, communication skills, leadership ability for maintaining proper implementation of industry 4.0.

In addition, Prifti at al. (2017) [33] also proposed a list of skills regarding industry 4.0 competences. They categorised the competences in their research as; leading & deciding, supporting & cooperation, interacting & presenting, analysing &interpreting, creating & conceptualising, organising & executing, adapting & coping, enterprising & performing. They interrogated this issue from a wide perspective by integrated behavioural oriented approach into three variants of industry 4.0: information systems, information technology and engineering.

While required skills and competences have been studied in different industrial fields, specific requirements could be dependent on the type of a sector. As there are many challenges ahead especially for marine maintenance engineering, requirements for industry 4.0 must be thoroughly analysed.

3. SKILL REQUIREMENTS FOR MARINE MAINTENANCE 4.0

Comparing with other systems, some discrepancies of engine room could be listed as:

- A ship is often larger, complex and sometimes difficult to operate.
- Repairing process can be time-consuming, costly.
- High pressured and high temperature system elements have no tolerance for omissions.
- Noisy, high temperature and high vibration environment.
- Communication is difficult, so workers tend to use sign languages.
- Depending on global location, the temperature and humidity changes.
- Enclosed area
- Narrow paths
- Restricted social environment
- Depending on shipping processes, work schedule may be irregular

So, for such working environment, additional skills should be considered when a training activity is conducted. For instance, in addition to mentioned skills in Chapter 2, engine room awareness skill could be considered as narrow paths in such an enclosed and noisy area may lead falling downs and cause injuries. In addition,difficult communication environment may lead misunderstanding of engineers with each other on an actual machinery tasks. Use of sign languages could be added into the above mentioned skills for marine maintenance engineers. As a consequence, skill requirements are derived from these studies in the scope of industry 4.0.

The specific marine engineering skills considered to be necessary are also integrated by authors. Thus skill requirements for marine maintenance engineers are listed in the Table 1.

The descriptions of skills in Table 1 as listed below:

T1: Basic CPS knowledge in the scope of industry 4.0. Comprises CPS, IoT and IT knowledge.

Table 1. Marine maintenance engineer skills for maintenance 4.0.

Category	Skills	Code
Techni-cal	CPS based knowledge	T1
	CPS Process monitoring & manag.	T2
	Data analysis and interpretation	T3
	Problem analysis and structuring	T4
	Solution development	T5
	Data based decision-making	T6
	Maintenance techniques	T7
	Method selection and use	T8
	Troubleshooting skills	T9
	Enhanced troubleshooting skills	T10
	Technical Communication	T11
	Engine room technical skills	T12
	Engineering ethics & legislation	T13
	Source Management	T14
	Machine Learning	T15
	Visualisation & Media integration	T16
	Cloud computing	T17
	IT Security	T18
	Coding & system development	T19
	Recording & Reporting	T20
	Maintenance 4.0 vision	T21
Personal	Creativity	P1
	Solution oriented attitude	P2
	Conflict solving	P3
	Efficiency orientation	P4
	Resistance	P5
	Safety culture	P6
	IT & Technologic Affinity	P7
	Adaptation	P8
	Time management	P9
	Mentality & psychology	P10
	Emergency situations	P11
	Engine room awareness	P12
	Researching & motivation to learn	P13
Social	Team work ability	S1
	Intercultural skills	S2
	Language skills	S3
	Taking Responsibility	S4
	Communication skills	S5
	Environmental awareness	S6
	Leadership	S7
	Compromising	S8

T2: CPS monitoring and management skill in order to monitor and response abstractness interoperations of CPS.

T3: Data analysing skill. Depending on system characteristic it may comprises big data knowledge.

T4: Problem analysis and detection in certain situations

T5: Solution development for system ambiguities and software errors.

T6: Decision making skill for whole engine room management includes CPS data.

T7: Knowledge for advanced maintenance methods.

T8: Decision making skill for maintenance approach selection depending on the certain situations.

T9: Troubleshooting skill for marine engineering.

T10: Enhanced troubleshooting skill towards CPS and data flow regarding maintenance 4.0. Subsidiary of T14.

T11: Skill for using technical marine engineering terminology and proper language on duties.

T12: Technical skills for engine room operations.

T13: Necessary knowledge on regulatory requirements and engineering ethics of shipping activities

T14: Skill for correct use of resources on engine room.

T15: Machine learning knowledge to conduct enhanced machinery systems.

T16: Virtualisation competence to deal with human machine interactions, CPS, remote controls (including mobile devices) and simulation knowledge.

T17: Cloud computing skill including big data knowledge.

T18: Knowledge for avoiding cyber-attack or another threats to system software.

T19: Coding skill for a certain situation to manage CPS and other smart systems.

T20: Correct recording & reporting shipping operations and critical data logbook.

T21: Even the most reliable equipment may fail. This skill necessary to detect sensitive malfunctions in sensors or data transformation processes.

P1: Creativity is required for suggesting internal or external system improvements or innovations.

P2: Solution oriented attitude especially critical on engine room of a ship.

P3: Tendency to peacekeeping actions on-board ship.

P4: Efficiency orientation deals with energy economy in ships.

P5: Resistance for ever changing conditions including different environmental situations.

P6: Tendency to take safety measurements in engine room.

P7: Tendency to deal with technologic equipments and computers.

P8: Adaptation for different ships and their system characteristics.

P9: Timing skill while executing operations in certain situations.

P10: Ship environment needs strong mental state especially for a place such engine room.

P11: Self preparedness for emergency situations including knowledge level on relevant procedures and actions.

P12: Awareness for both machinery system and safety for human movements during conducting maintenance duties.

P13: Desire for maintaining individual development & learning.

S1: Team work ability for operational efficiency of ship crew.

S2: This social skill is needed such a global working environment. Besides ship crew constantly changes by time.

S3: Language skills. This is required for smooth communication of ship crew.

S4: Tendency to not to evade responsibility.

S5: Basic communication skill for other people.

S6: Environment friendly consciousness.

S7: Leadership skill to organise ship crew in certain situations.

S8: Tendency to the finding consensus and healthy results.

4. ENGINE ROOM SIMULATOR FUNCTIONALITY ON MARINE MAINTENANCE 4.0 SKILLS

Engine room simulators are capable for conducting training practices for marine engineering students and widely used in most of the maritime training institutions. Currently, ERS plays essential role on skill improvement, student assessment and evaluation in marine engineering educations. In this chapter, marine maintenance 4.0 skill requirements are linked with ERS functionality. To determine the relationships between identified skills and simulator functions, a typical full mission engine room simulator includes workstations, instructor room, control room and mimic panel is used. Existing full mission simulator enables many engine room functions in order to practice key crew competences. In practices, trainees can understand whole engine room systems and their operational process in detail, in this highly realistic training tool which based on actual ship specifications and performance data. Moreover, discharge and loading operations and emergency situations for overall shipping operations are suitably functional.

At first, trainees study in working stations in order to understand and monitor how simulator must be commanded by users on a desktop based system demonstration. In following to this system familiarisation stage, trainees are introduced with mimic panel which makes enable to conduct full mission operational tasks on a custom panel supported by real-like ship equipments. As this panel is synchronised with instructor’s room and engine control room; various scenarios are executed flexibly and trainees able to take different watchkeeping officer roles. Instructor’s room is very capable to manipulate ongoing scenario’s data and trainees can be confronted by single or multiple different system malfunctions on purpose to evaluate their engineering skills in emergency situations. These ERS functionalities also include some critical aspects such as fouling & wear of equipments, combustion performance monitoring etc.

The Table A-III/1 of the updated STCW contains the minimum standard of competence for officers in charge of an engineering watch in an engine room. In this table, required competencies are clearly specified (i.e: “maintaining a safe engineering watch”, “using internal communication systems”, “operating main and auxiliary machinery and associated control systems” etc.). To meet competence requirements, desired background knowledge, understanding and proficiency also identified under the second column of A-III/1 which is prepared for each competency standard. This section includes detailed explanations of routine duties, maintenance principals, safety precautions, relevant system components etc. The third column is: “Methods for demonstrating competence” comprises the evidences for valid platforms for how to make assessment of required competencies. For exemplify, if simulator based assessment practices are essential, it is described as “approved simulator training”. In conclusion, the fourth column of STCW AIII/1 (Criteria for evaluating competence) describes criteria for each competence for standardising evaluation techniques for relevant competences [24], [34].

As demonstrated in Table 2, there are four section to indicate the engine room simulator’s functionality level if skill requirements towards maintenance 4.0 on marine engineering is properly met or not. Fully supporting section describes that used simulator in this study well capable for the given skill requirement. In “partly supporting” column presents incapability of the ERS functionality despite supporting some levels of a given skill requirement.

Third column shows that if a substantial development is needed in order to meet certain skill requirement in ERS environment. In the final section (not applicable) if a skill requirement is not possible in any simulator environment or it

Table 2. ERS functionality on marine maintenance 4.0 engineering skills.

Code	Fully Supporting	Partly Supporting	Need Further development	Not applicable
T1			^	
T2			^	
T3		*		
T4	+			
T5		*		
T6		*		
T7			^	
T8			^	
T9	+			
T10			^	
T11	+			
T12	+			
T13	+			
T14		*		
T15			^	
T16			^	
T17			^	
T18			^	
T19			^	
T20	+			
T21			^	
P1		*		
P2	+			
P3	+			
P4	+			
P5		*		
P6		*		
P7		*		
P8			^	
P9	+			
P10				-
P11		*		
P12		*		
P13				-
S1	+			
S2	+			
S3	+			
S4	+			
S5	+			
S6		*		
S7	+			
S8	+			

is not healthy way to train a student due to hazardous aspects of required qualifying conditions. If proper scenarios and tasks are prepared by instructors for a simulator practice, 6 of 21 technical skills can be fully practiced on ERS environment while 4 of them partly supported. The rest of 11 technical skills need further development as they require substantial technologic infrastructures in context of maintenance 4.0.

Followingly, 4 of 13 personal skills are currently able to be conducted in the ERS practices without any additional improvements. Besides only “adaptation” skill needs further development in personal skills section of the table. In social skills, 7 of 8 are fully supported in the ERS if scenarios and task assignments are suitably prepared to involve practising these skills. Only “environmental awareness” could be partly supporting as functionalities of utilised simulator has limited availabilities to conduct this skill.

Summarily, the ERS which is used for shows that; most of the technical skill developments need further development for executing maintenance 4.0 oriented training activities. However, most of the social skills are fully supporting and can be effectively practised without any modification. Finally, personal skills also need some developments but they would not be marginal, predominantly.

5. CONCLUSION

As it is early stages for industry 4.0 concept, researchers have already conducted studies on this fourth industrial revolution. In this sense, most of the industrial fields have been identified regarding potential challenges and benefits for the implementation phase of this new phenomenon. As other industrial fields, there are challenges for maritime such as; ever changing and unstable conditions, numerous strict norms for maritime transportation, involvement of classification societies and other organizations, already overloaded crew, unskilled crew, additional training requirements for industry 4.0, uncertainties in software development process, unwillingness of ship owners towards innovative integrations, different ship characteristics would retard the know-how from different ships etc. [35].

Nevertheless, the maintenance concept is crucial for system availability, reliability and efficiency in maritime engineering. If newly intended effective maintenance methods are integrated on a ship, marginal benefits are gained such as great cost savings on maintenance, substantially reduced downtimes, smooth and swift inspections etc. In this regard, maintenance 4.0 can be considered as a new concept in marine engineering field. In order to integrate maintenance 4.0 into shipboard for forthcoming years, this paper identifies the training requirements to enhance basic skills for system design. For this reason, this study identifies for skills which are in need of further developments to an existing full mission engine room simulator to raise CPS awareness in marine engineering within the scope of maintenance 4.0.

For further studies, obtained skill lists of this research can be developed and technologic requirements for further modifications of current ERS could be clarified. Moreover, experimental studies can be conducted through maintenance 4.0 oriented simulators in the future to detect specific functionality level in sensitive way.

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REQUIREMENTS FOR FURTHER IMPROVEMENT OF ENGINE ROOM SIMULATORS IN THE EDUCATIONAL, TRAINING AND RESEARCH SYSTEM

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Abstract: the paper is devoted to the new directions of development of engine room simulators related to the improvement of the adjustment possibilities of electrical power plant equipment as well as empowering users of these simulators with the aim of gaining additional knowledge, understanding and proficiency.

Engine room simulators are the essential training aid for the study of marine engineers and electrical engineers, as required by the STCW Convention, as amended. There is the challenge for marine engineers both in the proper operation of the ship systems and mechanisms, and their setup and adjustment at the management level. Modern engine room simulators in most cases do not provide the opportunity to change the electrical and electronic control devices operation parameters, as well as protective equipment of most systems and, consequently, do not allow to acquire the proficiency in their adjustment.

The article proposes the implementation in future generations of engine room simulators of the number of tasks: functional testing and protections adjustment of power generating and other equipment; generators synchronizing process parameters adjustment; active and reactive load sharing process parameters adjustment; diesel generator starting and stopping process parameters adjustment. In the paper there have been proposed two level electrical power plant control system diagram with a number of program modules. Such modules reconfiguration enables for the trainees to gain necessary skills in power plant control equipment adjustment and operation modes optimization.

Keywords: electrical power plant, parameters adjustment, modes optimization, protection equipment.

Modern ship is a technical complex with high automation level of technological processes based on such areas of science as mechanics, hydromechanics and thermodynamics.

It causes versatility of marine engineering personnel, legalized by The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers with amendments (STCW) [1] in standards called "Specification of minimum standard of competence" which defines necessary volume of knowledge, understanding and proficiency for performing duties on each function.

Engine room simulators are the essential training aid for the study of marine engineers and electrical engineers, as required by the STCW Convention, as amended. One of the approved methods of demonstrating competence according to the STCW Code is "Approved simulator training". The engine room simulators available on the market today sufficiently enable to acquire the skills of operating the ship systems and mechanisms, fulfilling the function "Marine engineering". However, from a practical point of view, this training adapts the trainee to the introduction to the real analogues of the ship systems and mechanisms and doesn't provide in most cases possibility to strengthen acquired theoretical and practical knowledge.

Application of new technologies, complex equipment, computer and microprocessor control systems on modern ships issues the challenge for marine engineers not only in the proper operation of the ship systems and mechanisms but also in their setup, adjustment and troubleshooting.

Modern Engine Room Simulators (ERS), with the exception of rare cases, doesn't give a possibility to adjust electrical and electronic control devices parameters as well as protection equipment parameters of most systems and as therefore doesn't enable to gain skills in their adjustment. Moreover, for most of competences, given in STCW functions "Maintenance and Repair", "Electrical, electronic and control engineering" at the management level modern simulators neither completely fit, nor are sufficiently developed. Here are just a few of them: "Troubleshooting electrical and electronic control equipment"; "Function test of electrical, electronic control equipment and safety devices"; "Inspection and adjustment of equipment" etc.

First of all it relates to ship's electrical power plant as one of the most important ship's installation from the navigation safety point of view, since its failure leads to a complete loss of the vessel control. In this regard the main tasks of electrical power plant are providing uninterrupted power supply, required engineering-and-economical performance of its devices and operation modes optimization. Therefore among the tasks necessary for implementation in ERS, choose following: function test and protection adjustment of generating and other power equipment; synchronization process parameters adjustment; active and reactive load sharing process parameters adjustment; diesel generator start/stop process parameters adjustment.

The facilities of two widely distributed Full Mission Engine Room Simulators: Transas ERS 5000 (Model LNG dual fuel engine) and Kongsberg ERS Neptune (Model Container vessel RT-FLEX engine) were analyzed in this paper. Taking into account that most of tasks necessary for implementation in ERS are common for both simulators, further in work will be not specified separate problems belonging to one or another simulator.

Separate attention must be paid for electrical power plant dynamic processes as integral part of marine Electro Technical Officers education program and also important element of scientific researches. At present time powerful consumers starting processes, sufficient load-on/load-off processes are not presented realistically neither relating the time of transient process nor relating the behavior of the analyzed parameter in most of ERS.

Generating and other power equipment function tests and protection adjustment could be fulfilled by getting the access not only to protection devices parameters but also by getting the access to parameters of the protection objects. In modern simulators of leading manufacturers such parameters generally are completely disabled or enabled only for instructor. In this connection it is offered to implement adjustment possibility of the following parameters both for instructor and operator access level: generator Short Circuit protection tripping current (I_{SC}) and time delay (t_{SC}); Under Voltage protection tripping voltage (U_{UV}) and time delay (t_{UV}); Reverse Power protection operating power (P_{RP}) and time delay (t_{RP}); Preferential Trip protection current (I_{PT}) and time delay (t_{PT}) for non-essential consumers disconnecting; Over Current protection tripping currents (I_{OC}) and time delays (t_{OC}).

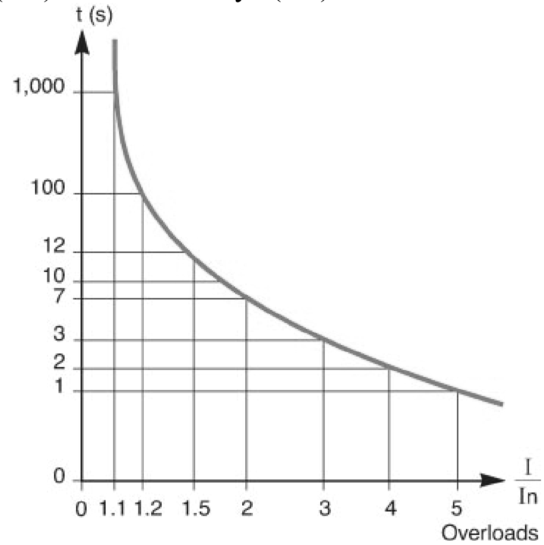

Figure 1. Generator overcurrent protection time-current characteristic

In mentioned above simulators Over Current protection realized just for one point (usually 110% of rated current) that is not correct, therefore in future for this protection it's offered to provide time-current characteristic, fig. 1, with the possibility of its adjustment as applied to electrical motors thermal ability different values.

Not less important from electrical power plant operation reliability point of view is correct adjustment of synchronization process parameters. Especially it relates to the power plants with the shaft generators where electrical power parameters stochastic fluctuations are typical under influence of external perturbing factors, caused by variable load or rough sea, what can sufficiently delay or even make impossible an automatic synchronization with default settings of its parameters. Ship's electrical power plant synchronization processes at normal and abnormal conditions are investigated in details in work [2], the number of synchronization process parameters reference values is defined, adjustment method and objective function $F_{SY} = f(\Delta f_{\max}, \Delta U_{\max}, \Delta f_{\min}, T_{s\min}, T_{s\max}, t_{GB})$ are offered for the case of variable external and technical conditions, where $\Delta U_{\max}$ – maximum acceptable voltage difference between synchronizing generator and network; $\Delta f_{\max}$ – maximum acceptable frequency difference; $\Delta f_{\min}$ – minimum acceptable frequency difference; $T_{s\min}$ – minimum synchronization time based on stability conditions; $T_{s\max}$ – maximum synchronization time based on system performance requirements; t_{GB} – generator breaker operating time.

During synchronization process studying using ERS it is reasonable to set the number of tasks, among which should be marked response speed tasks, i.e. control tasks fulfilled in shortest time, control tasks fulfilled in prescribed time and control tasks fulfilled in prescribed conditions. For this purpose it is reasonable to implement control tasks with assignment of objective function $U = f(K_1, K_2, K_3)$ on such optimality criterions for response speed tasks as:

$$K_1 = \min_u T ,$$

where T – control time; u – synchronizing object control;
for control tasks fulfilled in prescribed time:

$$K_2 = \min_u (T_{set} - T_{act}) ,$$

where T_{set} – required control prescribed time; T_{act} – actual time, elapsed for control task fulfilling;
for control tasks fulfilled in prescribed conditions:

$$K_3 = \min_u (\Delta p_{prm} - \Delta p_{act}) ,$$

where Δp_{prm} – maximum permissible deviation of parameter p_i from its permissible value p_{prm}; Δp_{act} – actual deviation of p_i from p_{prm}.

Based on presence or absence of external disturbances and synchronization process requirements, as usual, it's applied two automatic synchronization methods: with generator breaker constant closing angle and with generator breaker closing constant lead time. In case of synchronization with generator breaker constant closing angle in most of modern systems generator breaker switching phase angle range is from +/-0.1 till 20.0°, as shown on fig. 2.

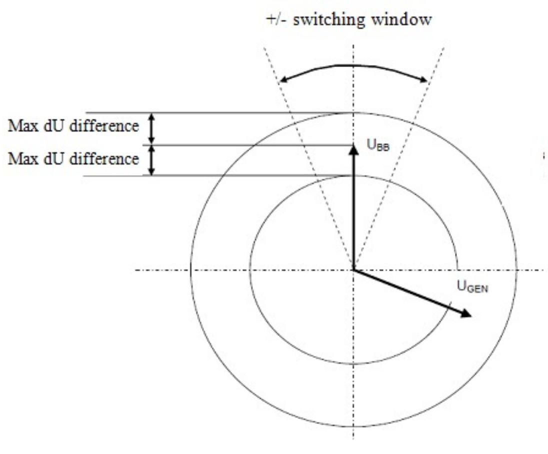

Figure 2. Generator breaker switching window

Synchronization method with generator breaker closing constant lead time is applicable when important criterion is response speed and electrical power parameters fluctuations are present. At the same time for each frequency difference value is defined pulse supply angle α_{CL} (point of time) for generator breaker closing according to expression:

$$\alpha_{CL} = 360 \cdot t_{GB} \cdot \Delta f .$$

With such synchronization method the maximum $\Delta f_{\max}$ and minimum $\Delta f_{\min}$ frequency difference settings are very important from the points of stability and response speed taking into account wide range of generator breakers closing time.

New electrical power plant simulators must be fit not only for operative personnel (bachelor level, ship's electro-technical officer/engineer) but also for more comprehensive study of power plant objects and processes as a part of master's education and scientific researches. Thereto it is necessary to provide new simulators with the synchronous and induction machines reliable models suitable for various generators and motors control modes modelling.

In ship's synchronous machine model it is advisable to provide possibility of assignment the following functional:

$$F_{SM} = f(R_s, R_f, L_d, L_q, L_f, M, p, F, J, T_L),$$

where R_s – stator winding resistance; R_f – rotor (field) winding resistance; L_d, L_q – stator windings inductances on d and q axis; L_f – rotor winding inductance; M – mutual induction of rotor and stator; p – pairs of poles number; F – combined rotor and load viscous friction; J – combined rotor and load inertia; T_L – motor load torque.

Similarly, in ship's induction motor model it is advisable to provide possibility of assignment the following functional:

$$F_{IM} = f(p, \gamma_s, \gamma_r, \theta_m, \omega_m, \theta_s, \omega_s, \theta, R_s, L_s,$$
$$R_r, L_r, M_{s0}, M_{r0}, M_{sr0}, J_m, b_m, \tau_m, \tau_e),$$

where p – pairs of poles number; γ_s, γ_r – rotor and stator phase angles; θ_m, ω_m – rotor angle position and angle speed; θ_s, ω_s – stator voltages angle position and frequency; θ – electrical angle; R_s, L_s – stator phases resistance and inductance; R_r, L_r – rotor phases resistance and inductance; M_{s0}, M_{r0} – stator and rotor mutual inductance maximum coefficients; M_{sr0} – mutual inductance maximum coefficient between stator and rotor phases; J_m, b_m – moment of inertia and linear friction coefficient of the rotor; τ_m, τ_e – electromagnetic torque and external load torque acting on rotor.

When modelling three phase electrical machines could be useful the results of work [3], which offers with some allowances (proportional currents and flux, constant air gap, windings symmetry) electromagnetic and mechanical process control in differential and matrix form with its transformation to Park-Gorev system.

Taking into account that nonmeasurable parameters can vary in wide ranges during electrical machine operation, it is important to provide electrical machine model with a special observer needed for control process correction. At the same time for simulator observer it is enough to define such parameters as R_r, L_r, R_s, L_s. Observer modelling detailed study for parameters evaluation tasks is given in work [4].

Merchant and specific fleet ships' electrical power plants' power growing and its equipping with large number of generating sets and with nonuniform characteristics consumers, actualized the necessity of gaining new skills by marine engineers in power plant control [5] and operating modes optimization using full mission engine room simulator. At the same time the most important tasks are: electrical power plant control tasks in normal and emergency conditions, where special attention must be paid out to correspondence between generating and requested power; transfer from one generating power level to another subject to efficiency (optimality) criterions;

generating set (GS) configuration control taking into account power plant condition and operator orders; GS on/off processes management taking into account GS emergency conditions and operator control actions.

In capacity of electrical power plant control system structure could be used two-level structure, applied in [6], and taking into account above mentioned tasks the following program modules and control command could be applied: SBCNT – GS number counting program; PRNRY – program which defines necessary number of GS; PRSEL – program for selecting GS from standby; PRST – GS starting program; PRSP – GS stopping program; PRSY – synchronization program; PRSH – load sharing program; PRUNL – stopping GS unloading program; ST(i) – GS number i starting command; SP(i) – GS number i stopping command; PH(l) – upper (high) load threshold for l GS working in parallel; PD(l) – down load threshold for l GS working in parallel.

On the basis of applied two-level control system structure, SBCNT, NRY, PRSEL, PRSY and PRSH modules are referred to the system's top level – local coordinator (LC), and PRST, PRSP and PRUNL modules are referred to the system's bottom level – local subsystem (LS).

In this case coordinator program in each technological cycle T_{TC} must: define number of GS connected to main switchboard, i.e. fulfill GS counting subprogram SBCNT, which cause predicate WRK(l)=T (T – true), if l GS are working; in accordance with load calculate necessary GS number, NRY(l ± 1), i.e. fulfill subprogram PRNRY, which cause predicate NRY(l ± 1)=T if power plant requires l ± 1 GS working in parallel and choose standby GS using PRSEL program for GS start PRST or for GS stop PRSP.

Generally, GS configuration control block diagram, which meets the stated requirements, is given by pic. 3, where $GA(N_{GA}) = \bigcup^{m} GA(i)$ – set of GS, installed in power plant.

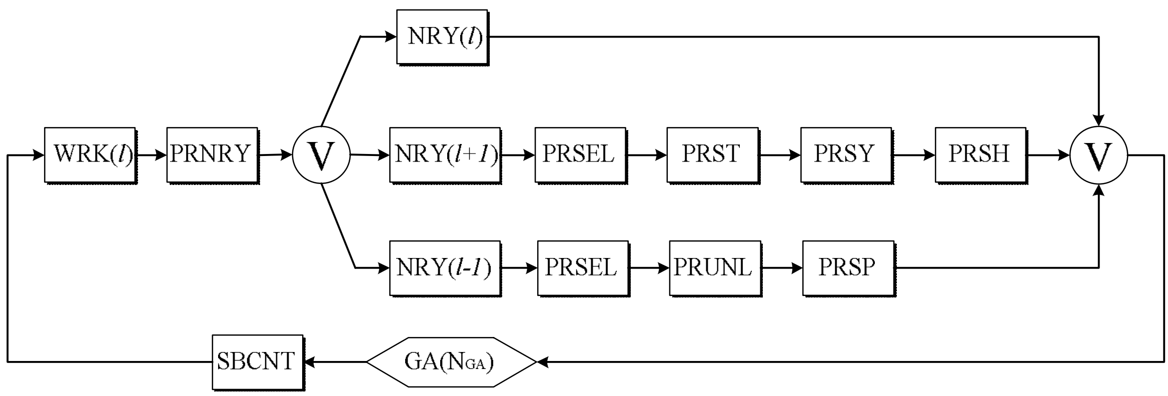

Figure 3. Generalized GS configuration control block diagram

Generalized GS configuration control block diagram, pic. 3, covers just limited set of power plant control tasks and is only part of multiunit power plant control system, where in the capacity of full software structure could be used the diagram of fig. 4.

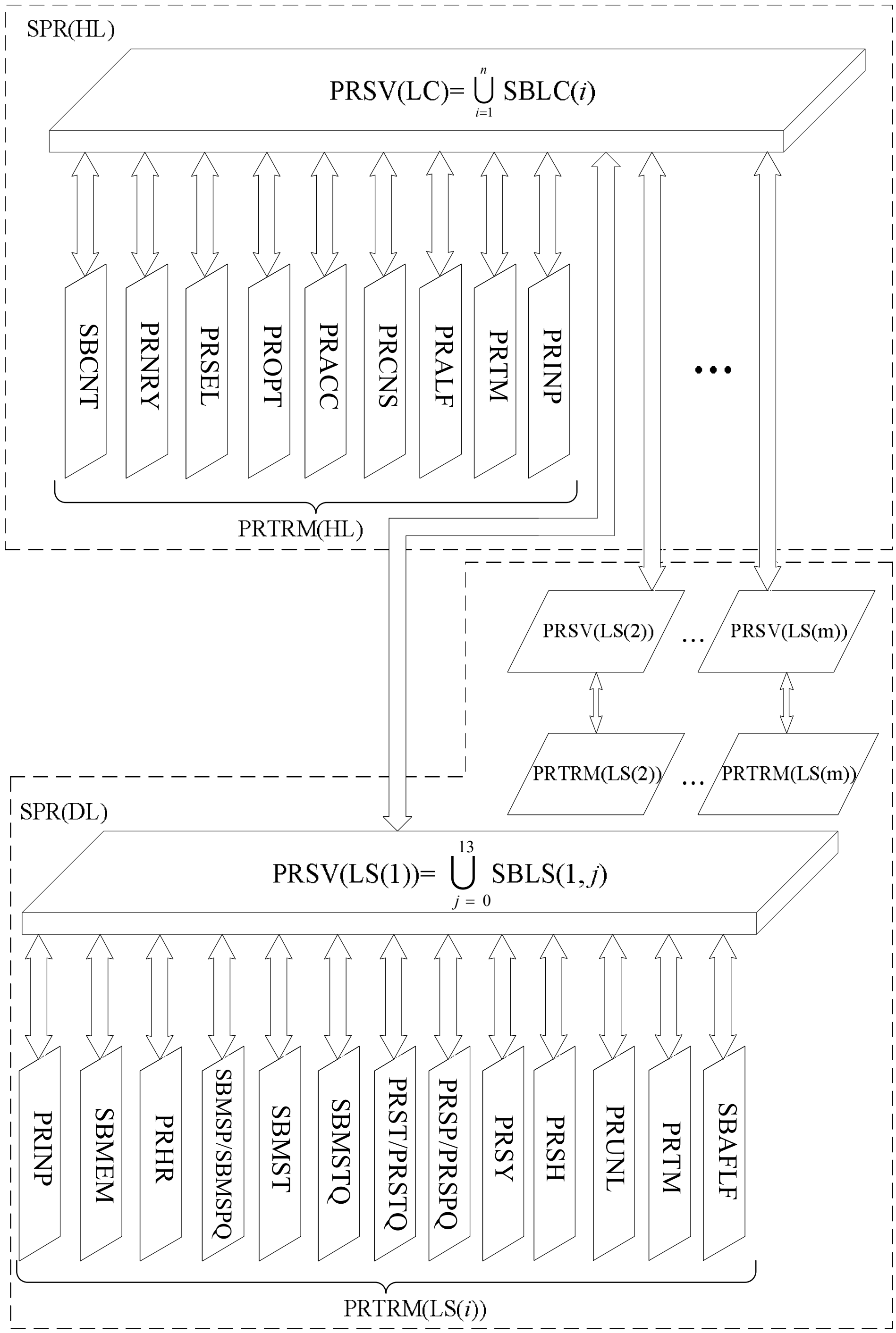

Figure 4. *m*-units electrical power plant control system software block diagram

On the diagram on fig. 4, except earlier described, the following program modules and control command are applied: SB – subprogram; M – message; STQ, SPQ – quick (extraordinary) start and stop; SPR(HL) – top level programs; SPR(DL) – bottom level programs; PRTM – timer program; PRHR – hot standby control program; PRINP – data acquisition and input program; PRSV(LC) – local coordinator supervisor program; SBLC – local coordinator subprogram; PRSV(LS) – local subsystem supervisor program; SBLS – local subsystem subprogram; SBMEM – emergency condition service program; PRCNS – consumers disconnection program; PRACC – energy storage system connection program; SBALF – air-fuel ratio deviation calculating program; PROPT – electrical power plant operation modes optimization program; PRTRM – application program packets. A number of program modules on fig. 4 diagram, is already developed by us and could underlie in creation of new engine room simulators.

Approbation of the most of offered tasks was conducted on electrical power plant equipment physical imitation models in the laboratories of National University "Odesa Maritime Academy" and Odesa Maritime Training Center.

Offered directions of engine room simulators improvement will allow significantly extend the scope of their application, covering not only operators training, but also maintenance engineers, service technicians and scientific manpower in this field.

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APPLICATION OF ENGINE ROOM SIMULATORS WITH 3D VISUALIZATION FOR DUAL FUEL SOLUTIONS

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Abstract: This paper describes two examples of application of new 3D visualization engine room simulators based on a modern Dual Fuel solutions, developed by UNITEST company:

- *W-Xpert RT-flex50DF Engine Room Simulator*
- *LNG DE3D Engine Room Simulator*

These two simulators are designed for training all marine engineers, students of maritime academies as well as can be used by different types of marine vocational training centres. Those simulators, developed in close cooperation with shipyards and manufacturers of marine equipment have universal features and enable a realistic experience in ship environment. This feature is particularly significant in complex modern electronically controlled main engines and dual fuel solutions. Maritime educational and vocational centres have to address the new challenge of preparing students to be familiar with the newest engine room solutions.

Keywords: 3D engine room simulators, dual fuel solutions

W-XPERT RT-FLEX 50 DF (Dual Fuel) ENGINE ROOM SIMULATOR DESCRIPTION

W-Xpert RT-flex50DF Engine Room Simulator is based on typical solutions and presently used in medium engine rooms such as LNG carriers, handy size tankers and bulk carriers, as well as feeder container vessels. The propulsion machinery is based on Dual Fuel Electronically Controlled Winterthur Gas and Diesel RT-flex50DF, low speed, 5 cylinder configuration, 2-stroke, turbocharged engine with Controllable Pitch Propeller (fig. 1,2 and 3). The technology is based on the low pressure gas system concept which fulfils IMO Tier III emission. The electric power plant includes three (3) diesel generators and one (1) emergency generator (fig. 4).

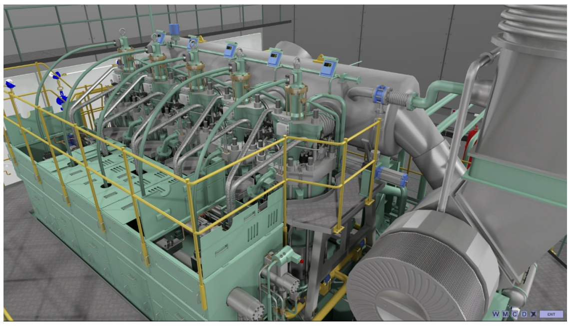

Figure 1. W-Xpert RT-flex50DF simulator upper part

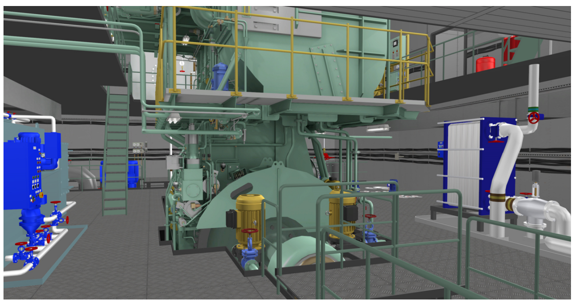

Figure 2. W-Xpert RT-flex50DF simulator lower part

W-Xpert simulator offers a detailed simulation of Dual Fuel engine behaviour with respect to its operational aspects, functionality and performance. The simulator includes a Power Management System which contains all standard functions, such as load dependent start/stop, load sharing, synchronising, and load shedding.

Figure 3. Engine Control Room – general view

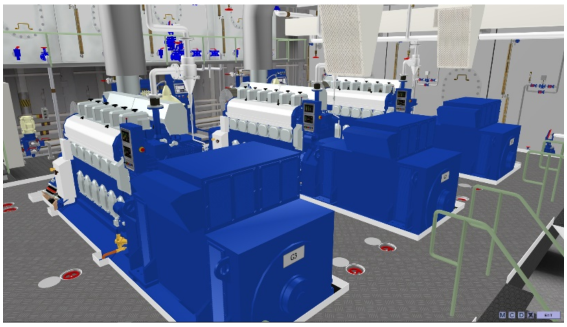

Figure 4. Auxiliary Diesel Generators

The Alarm and Monitoring System allows the operator to control all propulsion system equipment parameters (fig.5).

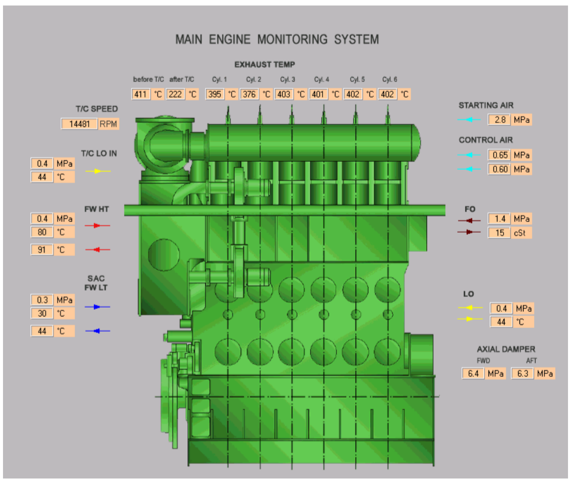

Figure 5. Main engine monitoring system

The Intelligent Combustion Monitoring system for continuous pressure measurement and analysis of NOx emission level and FOC (Fuel Oil Consumption) with primary features includes: graphic presentation of PT, PV and Balance Diagrams, together with Mean Indicated Pressure and Maximum Pressure deviation limits. Calculated values of Effective Power, Mean Indicated Pressure p_i, Compression pressure p_{comp}, Maximum pressure p_{max} and Scavenge pressure p_{scav} include values for fuel injection and exhaust valve adjustment (fig. 6).

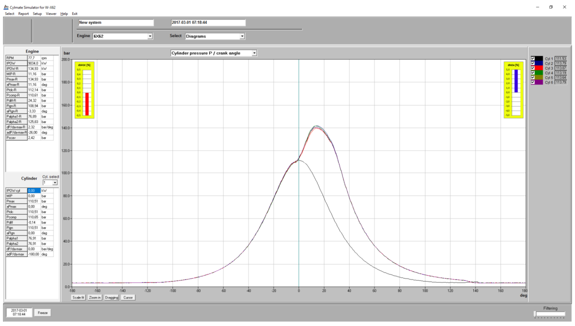

Figure 6. An example of display of the virtual Intelligent Combustion Monitoring interface - the screen shows one cylinder not firing. Barographs are visualised and calcutated by the thermodinamic model of specific fuel consumption and NOx emission deviation in relation to the reference conditions

The simulation and scenario editor mode can be enabled for training emergency operating procedures when faults occur on low-speed main engine, supporting systems and auxiliary machineries.

The main purpose of the simulator is the practical preparation of the trainee for engine room operation, and more particularly (1,2):

- familiarization with electronically-controlled common-rail technology and flexibility of the fuel injection and exhaust valve operations
- familiarization with the engine room installation (electric power plant system, compressed air system, fresh and sea water cooling system, lubricating and fuel oil system);
- acknowledgment with diesel generators and auxiliary equipment starting procedure;
- propulsion system manoeuvring;
- power management system operation PMS.

LNG supply diagrams, supply unit with GVU Gas Valve Unit and bunkering station are presented on fig. 7, 8 and 9.

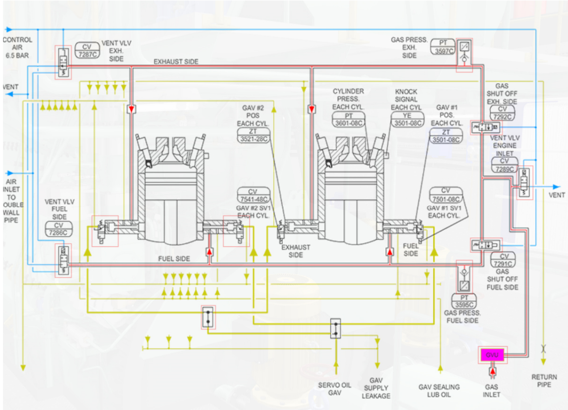

Figure 7. Main engine's LNG supply system

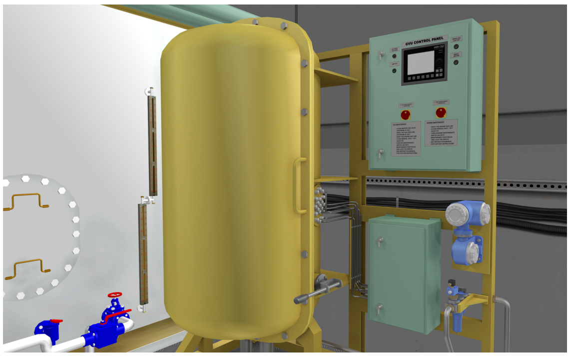

Figure 8. LNG supply unit with Gas Valve Unit GVU control panel

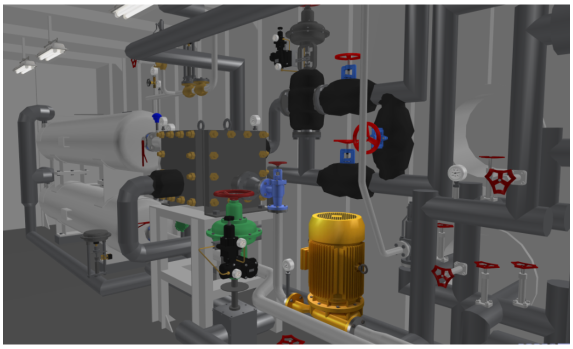

Figure 9. LNG bunkering station

LNG DE3D ENGINE ROOM SIMULATOR DESCRIPTION

The UNITEST LNG DE3D Engine Room Simulator has been based on engine room equipped with diesel electric dual fuel propulsion system powered by Liquefied Natural Gas and Diesel Oil. This type of propulsion is widely used in modern propulsion system on various types of vessels (3). The following simulator has been based on a Ferry vessel which is used for carrying vehicles and passengers. Generally, the propulsion system includes three (3) DF Diesel Generators 3x1489 kW and two (2) Azimuth Thrusters 2x1750 kW.

General view of Engine Control is presented on fig. 10.

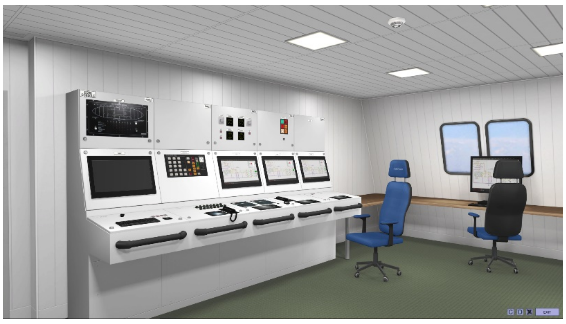

Figure 10. Engine Control Room - General view

The simulator includes an Integrated Automation System which fully integrates all significant data into a single platform. The IAS allows the operator to go through LNG bunkering process (fig. 11). The Power Management System contains all the standard functions, such as load dependant start/stop, load sharing, synchronising, and load shedding. The Alarm and Monitoring System allows the operator to control all propulsion system equipment parameters. Emergency operating procedures can be trained by fault simulation and scenario editor mode.

The main purpose of the simulator is the practical preparation of the trainee for engine room operation, and more particularly:

- LNG bunkering (fig. 13 and 14) and Diesel Generator/ Boiler supply process.
- familiarization with the engine room installation (electric power plant system, compressed air system, fresh and sea water cooling system, lubricating and fuel oil system);
- acknowledgment with diesel generators, thrusters and auxiliary equipment starting procedure;

- propulsion system manoeuvring;
- power management system operation PMS

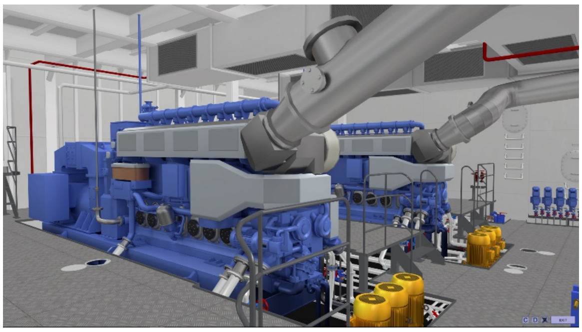

Figure 11. Main Diesel generators

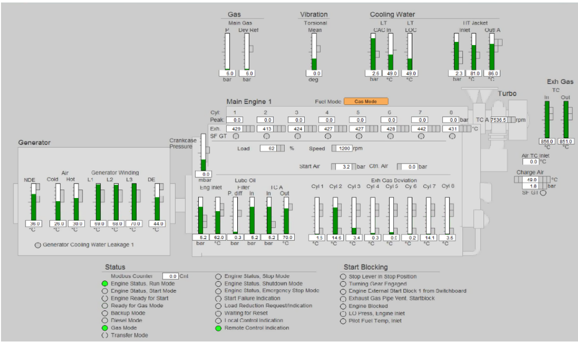

Figure 12. Integrated Automation System- DG1 overview

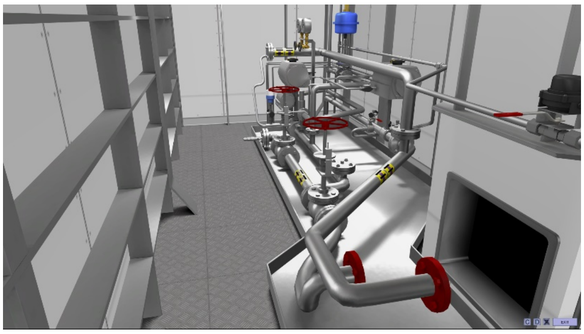

Figure 13. LNG & Fans/ Bunker station

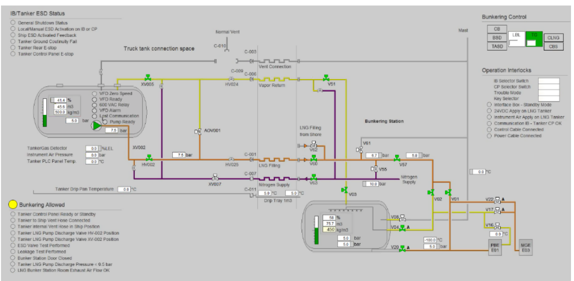

Figure 14. LNG/Bunkering plant overview

CONCUSIONS

It is now well established that the application of engine room simulators with 3D visualization in maritime education leads to an enhanced understanding of the marine machinery and results also in increased emergency preparedness and in consequence, leads to hazard mitigation and reduces the risk of human error in the operation and maintenance of marine equipment (4).

This is especially important in modern electronically controlled main engines and dual fuel solutions. The described engine room simulators were based on customized projects:

1. W-Xpert RT-flex50DF for Winterthur GAS And Diesel, Winterthur, Switherland
2. LNG DE3D for Remontowa Shipyard, Gdansk, Poland – project for BC Ferries

As a result, the users of engine room simulators may now be familiarised not only with one specific type of engine room but have the opportunity to get acquainted with a variety of configurations.

Due to the specificity of operating marine equipment in real life conditions, the didactic goals in marine education are directly linked with achieving preparedness for emergency situations. Such preparedness may only be achieved if the trainee is familiar with both the equipment and its operating modes, including emergency situations.

Application of 3D solutions constitutes a very positive development in maritime educational schemes and should be applied continuously and widely in engine room simulators' design.

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SOFTWARE FOR EDUCATIONAL DISCIPLINE "SIMULATION OF SHIP REGULATED ELECTRIC DRIVES"

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Abstract: The necessity of studying the discipline "Simulation of ship regulated electric drives". Prescribes the software and content guidelines for settlement and graphic works for the time-affairs of the discipline associated with controlled asynchronous electric drive. Carried out the development of the structure of interactive educational and training complex for this innovative discipline, which is a computer learning tool in the form of software and methodical support, as well as data and knowledge bases and consists of functionally related multimedia learning systems, interactive learning, automated control of the learning process. Made the development of multimedia teaching system comprising electronic textbooks and teaching aids for the course in the form of media, as well as various manuals. Carried out the development of interactive learning system, which is a computer simulator, with which you can perform a number of settlement-graphic and virtual labs. To perform an interactive learning system developed by multi-level software, allows the analysis of electromagnetic electromechanical, power, thermal, mechanical, vibro-acoustic processes in the engine and on the basis of this analysis, to carry out an automated selection and design optimization motors. The opportunity of communication developed software with other commonly used in the industry and computing facilities. Made the development of an automated control system, which serves for the input, current and final control, and includes testing programs, a database of test questions and answers, registration and accounting log, temporary training statistics in graphic form. It is proposed to review the technical solutions for the optimization of ship controlled asynchronous electric drives.
Keywords: academic discipline, a ship controlled asynchronous electric drive, ensure software-set, guidelines, computational and graphics performance, optimization work.

The use of variable speed drives (VSD) which are the basis of modern high technology in transport makes it possible to improve the technology processes, provides comprehensive mechanization and automation, enhances increase productivity, improve the reliability and life of the equipment.

In this connection it is necessary to teach the discipline "Simulation of ship regulated electric drives" in teaching marine electricians.

Widespread use has led to VSD what a modern electric drive is not only energy-power basis capable of supporting production mechanisms necessary mechanical energy, but also a means of process control as well as tasks for the implementation of the quality of production processes currently in the majority of cases are assigned to the adjustable control system actuators in conjunction with systems technological automation. Of particular importance is the use of energy-saving aspects of the VSD. In connection with the increase in energy prices, in particular for electricity, and limited increase in power generating capacity problem of energy saving systems, including the reduction of power consumption, it is of particular relevance. Energy conservation has become one of the priority directions of technical policy in all developed countries. This is due, firstly, to the limited and non-renewable primary energy, and secondly, with the continuously increasing complexity of production and the value in the third to global environmental problems.

Electromechanical systems with adjustable induction (IM) and electronic (EM) motors in which the union of energy and information processes takes place, ensure maximum use of the opportunities and achievements of electronics for converting electrical energy into mechanical energy. This is achieved by increasing the service life of equipment, reducing operating losses, high reliability [1].

Insufficient knowledge of the operation of the main unit controlled electric drive - IM or EM - does not allow the drive to improve due to the modernization of this link. A comprehensive analysis of IM and EM in VSD systems based on a systems approach and systems analysis methods makes it possible to design a electric drives with improved adjusting, launchers, dynamic and vibroacoustic performance, reduced mass, size and cost characteristics. The demand for professionals possessing knowledge gained in the process of studying the discipline is observed in all areas of water transport, which are used electromechanical energy conversion devices.

Modern teaching techniques should be adapted to the new principles of the organization of educational process is provided by the introduction of the industry has problems raising the level of preparation of students to engineering. Fixed assets should include measures for the development and implementation of information technology education, the development of research and scientific and technological activities in the education system. Innovative engineering discipline should be provided with modern methodological and software development, allowing not only the conduct of full-time, but also in absentia, remote, post-graduate training. Using the European educational trends in Ukraine will bring the national standards of teaching to the standards of European education. One result is the establishment of a working relationship between the training activities, scientific research, production and social practice.

To solve the above was carried out as follows:

• satisfied formation (development) of innovative technical discipline, training material that is the most relevant topics, and that topicality confirmed the latest developments in the electrical industry. The relevance of the discipline "Simulation of ship regulated electric drives" supported by the extensive use of VSD in all branches of industry and transport for sustainable management process while minimizing energy consumption;

• carried out the development of the structure of interactive educational and training complex for this innovative discipline, which is a computer learning tool in the form of software and methodical support, as well as data and knowledge bases and consists of functionally related multimedia learning systems, interactive learning, automated control of the learning process;

• made the development of multimedia teaching system comprising electronic textbooks and teaching aids for the course in the form of media, as well as various manuals;

• carried out the development of interactive learning system, which is a computer simulator, with which you can perform a number of settlement-graphic (analysis of the serial general-purpose IM in different systems of VSD, designing special controlled IM and EM to work in VSD) and virtual labs for study It features the work of IM and IM in different systems of VSD. To perform an interactive learning system developed by multi-level software, allows the analysis of electromagnetic electromechanical, power, thermal, mechanical, vibro-acoustic processes in the engine and on the basis of this analysis, to carry out an automated selection and design optimization motors of VSD. The opportunity of communication developed software with other commonly used in the industry and computing facilities;

• made the development of an automated control system, which serves for the input, current and final control, and includes testing programs, a database of test questions and answers, registration and accounting log, temporary training statistics in graphic form;

• providing support to developing individual educational trajectories, using the system, open and distance education in remote access via the global Internet network, which has interactive and differentiated approach to learning;

• quality education is possible by this innovative technology discipline everyone access to all comers methodical and program materials;

- possible formation of an active dialogue between the users in the study of this discipline and communities with an interest in this technical discipline

• data can be provided and the sharing of knowledge required for new educational and research approaches for the presentation and dissemination of results, preparation of research presentations.

Computer code DIMAS-Drive [2] performs mathematical modeling of physical (electromagnetic, electro-mechanical, thermal, mechanical, vibro-acoustic) processes in static and dynamic modes of induction motors, regulated electric drives with matching transformers and gearboxes, with semiconductor converters, different types, species and management methods, frequency control laws (fig.1). Mathematical models take into account the structural features of the motors (closed and secure version) and cooling (self-cooling and independent cooling, ventilation ducts), squirrel cage design. Taken into account the impact on the physical processes of magnetic circuit saturation, displacement currents in the windings, the presence of the highest space-time harmonics.

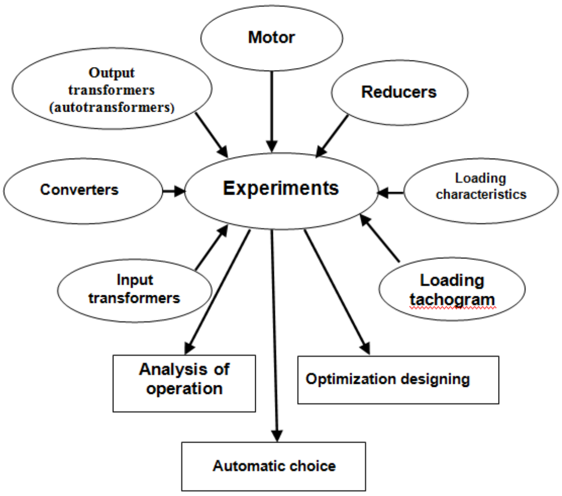

Figure 1. Scheme of program

We consider the mechanical and vibro-acoustic performance in dynamic conditions. On the basis of multiple targeted simulation taking into account the nature, size and mode of operation of load in a certain range of control is carried out design (structural and parametric optimization) special controlled asynchronous motors with different formulations of the problems (designing a predetermined control range, design, taking into account the duration of the work on specific speeds, projecting a predetermined tachogram considering transitions) The program modules are presented in fig.2.

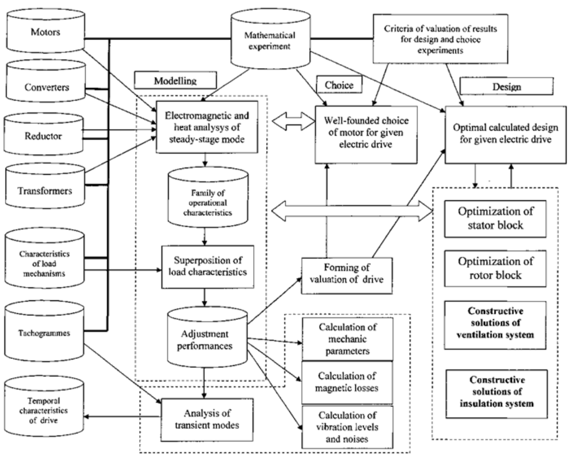

Figure 2. Composition of programme modules of the complex

Developed guidelines [3-9]: for laboratory work on the experimental stands or virtual laboratory works; to the settlement and graphic works: a study of electromechanical and power characteristics of the controlled induction motors; analysis of the thermal state of the controlled induction motors; analysis of the vibro-acoustic performance of controlled induction motors; Study the performance of electric rolling stock traction with induction motors; analysis of electronic motors.

Performing by students laboratory work on experimental stands or virtual labs to study the characteristics of motors and drives at the phase and frequency control makes it possible to fix in practice theoretical principles.

The knowledge gained as a result of studying the discipline "Simulation of ship regulated electric drives" can be used when the final works on the Bachelor and Master levels.

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THE USE OF EMOTICONS IN ALARMSYSTEMS

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Abstract: This article discusses if it advisable to use emoticons in SCADA (Supervisory Control And Data Acquisition) systems. A part of the SCADA system is the alarm system, where interactions between the installation and the engineer take place. Currently the information consists mainly of text embedded in different colours, to indicate the status of the alarm. This research will focus on the possibilities to change or add different symbols to the human interface to clarify information, the engineers in this way better judgement can be made on the status of the different alarms..

The current automationsystems are so complex that it is not possible for the engineer to know the state of the complete technical installation, this is however not necessary, because the current SCADA systems are capable of controlling the system with the ICS (Integrated Control System) between set limits. In case the system is out of limits, the engineer has to step in and make manual changes or override the ICS (Integrated Control System). He has, figuratively spoken, become a part of the ICS therefore the engineer has to make a good situational assessment (SA).

To get an impression on the different possibilities, a research has been done in areas not particularly related to SCADA systems. Other human interfaces like Microsoft Windows and Apple, and different software have been looked into.

Common used symbols are emoticons, defined as [1] *graphical presentations of emotions in a text message. They are used worldwide by millions* [2] *in whatsapp and facebook to express emotions in text messages. Hsieh & Tsengeir conclude the following in their research; "Taking into account the popularity of this type of new communication, the immediacy of the messages they convey, and the fact that they are language-free, leads us to believe that emoji might represent a new way to assess personality differences across populations different for language and literacy level"* [3] *So these emoticons can play a role to improve situational assessment of the engineer in the engine room.*

In the research the emoticons have been added to the alarm system of the Kongsberg K-Sim M11-CNTR Engine room simulator of a feeder container ship equipped with a 4 stroke MAK engine. The alarm system has been partly redesigned . Then a predefined exercise was run with different test persons with and without emoticons, the results will has been analysed and concluded.

Keywords: SCADA system, Alarm system, Emoticons, Emoji, Situational Assessment.

1. Introduction

As part of the study Maritime Shipping and Innovation a research is conducted on alarm systems in the engine room and especially the interaction between the operator and the system and how this can be approved. Currently systems consist mainly of text messages enhanced and with colours. In this research solutions from other different branches where interaction between man and machine is used, are looked into like mobile phone and computer software. From these applications some parts are selected and will be implanted in the alarms system. This is done by using the 10 steps of innovation of the Massachusetts Institute of Technology (MIT). These steps are used to create new innovative designs.

2. Problem description

The information at the user side is presented via text or via a schematic representation, or so-called mimic's. In shipping SCADA systems are commonly used in control rooms, alarm monitoring is a part of the system. Research shows that the current alarm systems have some downsides, not technically but during the interaction with the engineer. An example is the flooding of the engine room of the Emma Maersk on the 1st of February 2003 near the Suez canal. A leakage caused by a mechanical break-down of a stern thruster situated at the aft part of the ship's shaft tunnel was flooded. The bulkhead between the shaft tunnel and the main engine room could not withstand the hydrostatic water pressure and eventually the main engine room was also flooded. During this event the alarm system was functioning as it should, but due to the amount of alarms an overflow of information between the system and the technicians occurred and this had a very negative influence on the technicians [4] Throughout the entire course of events, the officers and crew were constantly disturbed and highly stressed by the sound of countless alarms, which made it extremely difficult to concentrate on the many challenges that appeared one after another. Even though the alarms were acknowledged continuously on the bridge and in the engine control room, it was not possible to keep paying attention to the incoming alarms. It became necessary to concentrate on basic observations and to act manually accordingly. Although it was not the case in these events, it may limit the crewmembers' cognitive capabilities and the prioritizing necessary for handling an emergency situation. In other publications this flooding was also investigated [5] Alarms associated to these process variables are triggered and may overload engineers, who will not be able to properly investigate each of these alarms [6]. This undesired situation known as alarm flood has been recognized as a major cause of most industrial incidents. A difference between ships and industry is the fact that the amount of alarms on board is much lower than in most industrial plants, but nevertheless this flooding can occur.

3. Theory

What is the core of the problem? The point is that people perceive things and take decisions based on these observations. This seems simple, but it, however, turns out, that effective observation is not that simple. Through wrong perception of observations, wrong decisions can be made with disastrous consequences. We see things and interpret them differently. What is observation or perception? Observing is defined as: "As soon as possible giving meaning to the world around us [7]". Based on different stimuli who reach us, this is interpreted as quick as possible. Three important factors are important.

First, our senses such as eyes, ears, skin, nose, mouth and tongue, the sensors of our body. The signals that are sent to our brains. The quality of our senses is called 'absolute threshold'. By combining, selecting and organizing the different signals we can efficiently process signals. For the problem we are addressing, the visual sense is dominant[7].

Second, the person (meaning grantor). The observer, a person is limited in what can be processed as information, but some information (e.g. acute danger etc.) cannot be ignored. Everyone has his own interests, personality, knowledge, experience and motivation etc. which influences the perceptive of information. Physical condition, like emotions and fatigue, also play a role.

Third, the situation is also an important contributor perception. Especially when related to special situations. If the situation is perceived as dangerous, this creates stress and makes the observer focus on certain stimuli which can cause tunnel vision. When this theoretical support is related to alarm information, the information can be misinterpreted when the optimal senses are not triggered.

4. Existing technologies

Focus is on existing technology of the subject; in our case the SCADA system and especially the alarm systems. I have used the SCADA system from the engine room simulator. This SCADA system is almost equal to the KCHIEF600 system of Kongsberg Automation systems.

4.1 SCADA system

The SCADA (Supervisory Control And Data Acquisition) system is an alarm and monitoring system for the technical installation of ships equipped with power management system and access control.

The operating station is very important, because interaction takes place between the user and the system.

The operating stations are normally located in the control room of a ship, but may also be placed elsewhere, e.g. on the bridge in the loading office, etc. The system consists of a colour monitor with an operator panel on it. The system is Windows based and adapted to marine use. Basically all stations are the same but can be set to different functions and accessibility for each station can be customized. Messages can be split in three different types, warnings, alarms and critical. Every type of alarm has its own colour (see figure 1). This colour indicates the urgency of the message. The alarms are also divided in groups depending on the type of machinery they are linked to.

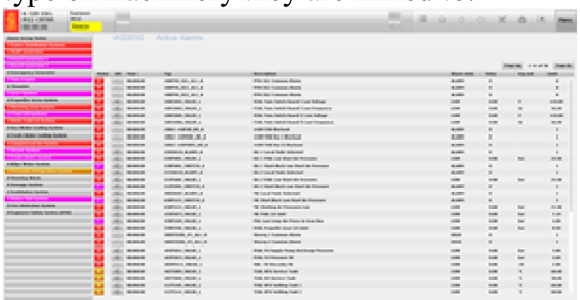


Figure 1. Kongsberg K-Chief 600 alarm system

The goal of the research is to find a way to make the interaction between the alarm system and the engineer more intuitive, resulting in better decisions. At the moment the status of the readings is not always clear. This problem can be improved on two sides namely on the engineer side or on the alarm system side. In this research we will focus on the alarm system.

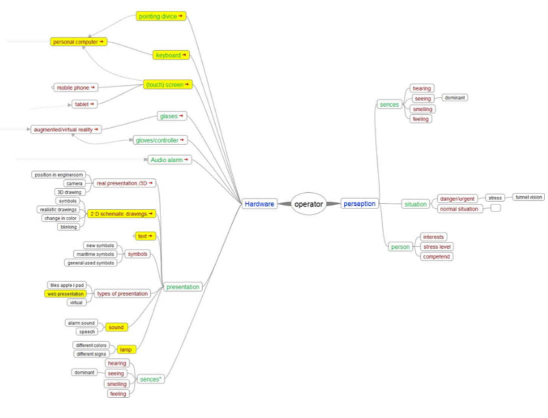


Figure 2. Mindmap on interaction between engineer and alarm system

In figure 2 the operator is located in the middle. On the left you find different kinds of hardware possible and the various ways the system sends information to the operator. Hardware can be computers, mobile phones and goggles. Visually, text, 2D like mimics and 3D virtual reality are an option. To add extra attention, sound and colours and symbols can be part of the system.

On the right you find the way this information is processed by the engineer (perception).

Training of engineers can improve perception. but also less stress and interest plays a role in perception.

5. Presentation

Presentation of the hardware plays an important role in the interaction as well and the focus is on this item. In alarm systems text is used from the first development of the system and from the moment colour monitors are used. Colours are also part of the system and experiments [8] have shown that colours have a positive influence on the situational awareness of the engineer. Also the use of symbols are a positive influence on making decisions according to Hoekstra [9] " *Pictograms accompanying textual messages have proved to be useful for drivers to identify possible risks, warnings, and prohibitions*“ and this is also proven in medical applications [10]. By the way, the use of symbols does not always improve this and can even have a negative effect, especially when symbols are unfamiliar to people [3].

6. Emoticons

Walther & D’Addario [1] define emoticons as "graphic representations of facial expressions used in electronic messages". The use of emoticons, or simply called emoji is an emotion display at nonverbal communication on various virtual platforms such as email, facebook, etc. Kaye, Wall, & Malone [11] have developed it further and say the following about the use of emoticons: "*The use of emoticons helps to show expressions on virtual platforms, with the same intention as nonverbal expression in face to face communication*". According to a study of Lakin, Jefferis, Cheng, & Chartrand,[11] Facial expressions can result in the adoption of these emotions and temper of another. In January 2017 1.2 billion people used whatsapp software with emoticons so the use of emoticons is obvious. To what extent this also applies to the present study will be further investigated. So the question is; can these emoticons draw the attention of the engineer and will it be easier to prioritise, thus resulting in better and faster decision making?

7. Research design and accountability

The investigation will be conducted based on an experiment.

The research is a Quasi-Experiment because it cannot meet all requirements., as the allocation of random subjects will not take place. In this study, a group of students, seafarers and teachers are selected. The selected persons are divided into two groups and put into these categories randomly. The first group will be tested with the present system and a second group is tested using a customized system.

7.1 Practical implementation

The research is conducted on the engine room simulator of the Maritime Institute Willem Barentsz on Terschelling. In this simulator, an initial condition is being installed, and in this initial condition a fault is created. After some time this will be displayed on the alarm monitor. The participants have to solve the problem. The fault is applied in the simulator using a standard scenario and can be replayed exactly the same way over and over again. With the evaluation tools present in the simulator, various parameters may be defined. During the experiment the scenario will be played with a group with the current alarm system and a group with the modified alarm system. The test groups will also get some questions afterwards about the way they have experienced the modified alarm system. These results can be compared with the results of the experiment.

The test group will consist of a total of approximately 50 people, divided into two groups (25 people per group).

8. Modification

As a base the current alarm system is used and is modified for the use of emoticons.

Which emoticons to use is investigated in a survey of 179 peoples who were asked which emoticon and which colour had the highest feeling of urgency. From this survey the result of the colours red, purple and yellow are in that order of urgency.

Figure 3. Following order of urgency colours

Looking at the emoticons the following order was picked as shown in figure, from left to right from not to very urgent.

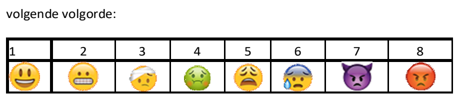


Figure 4. Emoticons arranged from not urgent to very urgent

From these emoticons 3 of them are selected in the alarm system depending on the severity of the message. So for *Warning* yellow and , for *Alarm* purple and , and for *Critical* . In the alarm group system three emoticons are selected for the amount of alarms in a group:

- 0 alarm no emoticon
- 1 to 5 alarms
- 5 to 9 alarms
- 10 and more

An extra item was added in the alarm system called the total system status bar.

Figure 5. Total system status bar

This system is also based on the amount of alarms in the same order as the alarm groups:

- No alarm
- 1 to 5 alarms
- 5 to 9 alarms
- 10 and more

All these items are implemented in the alarm system with the following result:

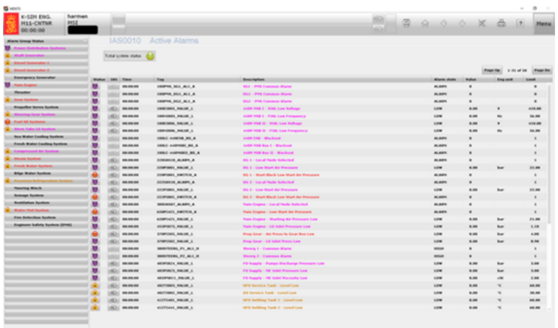


Figure 6. New alarm system layout

For test purposes both alarm systems can be used in the simulator and results can be compared.

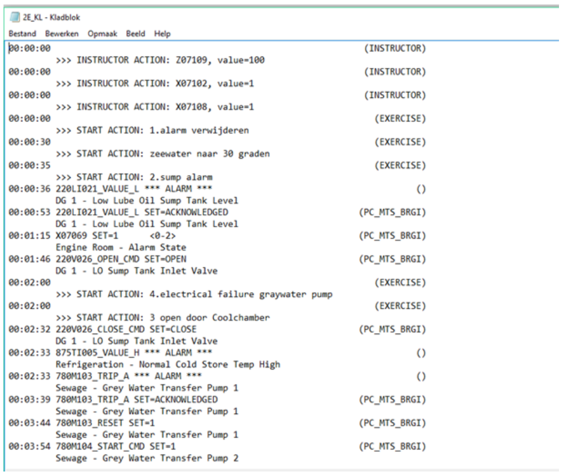
9. Practical research

The research was conducted on a Kongsberg part task simulator consisting of one PC and two colour monitors. On the simulator a pre-defined exercise with scenario was loaded. So every test person got exactly the same scenario with one of the alarm systems. The scenario took about 10 minutes. Before the exercise the test persons were shortly briefed on the system and then the exercise would start. After 50 seconds a single alarm occurred, after 3 minutes 2 messages occurred at the same time (one warning and one alarm). Then after 6 minutes an alarm and a critical alarm would come in and after 10 minutes there is was to be a blackout.

None of the students were familiar with this simulator and they did not know on which version of the alarm system they were tested.

A mix of persons were picked with different kind of experience, like 2nd year students, 4th year students and qualified engineers.

In the experiment two types of variables were tested during the exercise namely 'Time to acknowledge the alarm' and 'Following order in excepting the messages'. These times can be found in the logfiles of the simulator.



```
2E_KL - Kladblok
Bestand  Bewerken  Opmaak  Beeld  Help
00:00:00                                                  (INSTRUCTOR)
         >>> INSTRUCTOR ACTION: Z07109, value=100
00:00:00                                                  (INSTRUCTOR)
         >>> INSTRUCTOR ACTION: X07102, value=1
00:00:00                                                  (INSTRUCTOR)
         >>> INSTRUCTOR ACTION: X07108, value=1
00:00:00                                                    (EXERCISE)
         >>> START ACTION: 1.alarm verwijderen
00:00:30                                                    (EXERCISE)
         >>> START ACTION: zeewater naar 30 graden
00:00:35                                                    (EXERCISE)
         >>> START ACTION: 2.sump alarm
00:00:36 220LI021_VALUE_L *** ALARM ***                             ()
         DG 1 - Low Lube Oil Sump Tank Level
00:00:53 220LI021_VALUE_L SET=ACKNOWLEDGED                 (PC_MTS_BRGI)
         DG 1 - Low Lube Oil Sump Tank Level
00:01:15 X07069 SET=1      <0-2>                           (PC_MTS_BRGI)
         Engine Room - Alarm State
00:01:46 220V026_OPEN_CMD SET=OPEN                         (PC_MTS_BRGI)
         DG 1 - LO Sump Tank Inlet Valve
00:02:00                                                    (EXERCISE)
         >>> START ACTION: 4.electrical failure graywater pump
00:02:00                                                    (EXERCISE)
         >>> START ACTION: 3 open door Coolchamber
00:02:32 220V026_CLOSE_CMD SET=CLOSE                       (PC_MTS_BRGI)
         DG 1 - LO Sump Tank Inlet Valve
00:02:33 875TI005_VALUE_H *** ALARM ***                             ()
         Refrigeration - Normal Cold Store Temp High
00:02:33 780M103_TRIP_A *** ALARM ***                               ()
         Sewage - Grey Water Transfer Pump 1
00:03:39 780M103_TRIP_A SET=ACKNOWLEDGED                   (PC_MTS_BRGI)
         Sewage - Grey Water Transfer Pump 1
00:03:44 780M103_RESET SET=1                               (PC_MTS_BRGI)
         Sewage - Grey Water Transfer Pump 1
00:03:54 780M104_START_CMD SET=1                           (PC_MTS_BRGI)
         Sewage - Grey Water Transfer Pump 2
```

Figure 7. Logfile K-sim engine room simulator

After running the scenario the test persons had to fill in a questionnaire with general questions and different items in the simulator like colours, alarm systems and emoticons in a scale from I disagree to I totally agree. All data were collected and analysed.

10. Analysis of the data collected

For analysis the data collected were first loaded in Microsoft Excel and imported in IBM SPSS [12] statistics for windows. A total of 49 people were involved; 23 persons tested the original system (emo-) and 26 persons tested the changed system (emo+). This resulted in the following outcomes:

In phase 1 only one alarm the emo- (M=11,83; SD= 8,02) reacted in average quicker to the alarm than emo+ (M=12,88; SD=5,54). With the T-test t (47) = -1,542, p = 0,590 there is no significant difference between the groups.

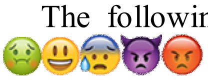
In phase 2 with a warning and an alarm both groups accept the alarm first emo - (P= 61) and emo+ (P=69). emo- (M=32,70; SD 33,70) reacts quicker again than emo+ (M= 36,95;SD=39,96). The warning takes longer to accept for both groups emo- (M=76,10; SD=68,18) as emo+ (M=88,23;SD=79,297) but also emo - is quicker to accept. The results of the T test show for the alarm " t (47) = -0,360 p = 0,721, as for the warning t (40) = -0,529, p = 0,60 There is no significant difference.

In phase 3 with a critical and a warning message only emo+ accepts the critical first emo+ (P= 54) and emo- (P= 79) accepts the alarm first. When looked at the time to accept the alarm emo- (M=52,46; SD 62,90) needs more time than emo+ (M=38,54; SD= 32,74). The T on the critical shows " t (44) = 0,941, p = 0,354, and on the alarm t (45) = -1,777, p = 0,861, both not significantly different.

In phase 4 a blackout with a lot of alarms both groups accept alarm group 1 first emo- (P=64,7) and + (P=68,4). The average time to accept is emo- (M= 28,41; SD=19,317) and emo+ (M=24,05 ; SD= 20,17). The T-test t (34) = 0,660, p = 0,513 on the time shows no significant difference.

11. Conclusion

Adding emoticons to the alarm system improves the interaction between the engineer and the alarm system. At first the colours and the different emoticons had to be chosen. This was done with a questionnaire and the following colours were selected; red, purple and yellow. This is different from the original alarm system, but the results of the experiment indicate significantly that this improves the right choice in prioritising the messages for both groups.

The following emoticons were chosen,  and tested as the best in the following order from not urgent to very urgent and added to the different messages in the alarm system. When a single alarm occurred, there was no significant different between emo + an emo –, both groups react the same. Conclusion; the emoticon draws no extra attention. With multiple messages, like a warning and an alarm, this is also not significantly different. Both groups accept the alarm first with no significantly different average times. When a critical and an alarm occurred, it changed: emo + accepts the critical first and the emo- the alarm first this indicates that with the new alarm system the prioritizing is done better. If you look at the time to accept, this is also quicker with the new system, however not significantly quicker. In the questionnaire the students are generally positive about the use of the colours and the emoticons.

12. Discussion

Taking the results of the experiment in consideration it can be said that with a single message there is no difference between the systems. When the messages get complicated some differences in favour of the system with the emoticons are shown. Interaction has improved, but is this because of adding emoticons? This cannot be said because in the design more than one thing has been changes like the colour of the messages and adding emoticons. In this research the difference of influence of both changes is not tested. Looking at the time of acceptance of the messages, this is also faster when the messages are more critical with the new system, but not significantly faster. The reason for this can be because the time to accept takes very long when test persons are busy solving a message and not acknowledging the other messages, this shows in the high variance on these accept times. In this test time to acknowledge and following order was used as test variable. Maybe other variables, like stress indicators on the test persons, etc. can be part of the test in the future.

In message software people get responses from other persons, this response indicates a sense of urgency. For example; I want to speak to you 😡, or I want to speak to you 😃 is interpreted differently. In the future alarm system a same type of response has to be tested and looked into, but with the current design this is not (yet) possible.

Acknowledgement

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USING ENGINE ROOM SIMULATORS FOR TRAINING AND EXERCISES IN FIGHTING FIRES FOR MARINE TRAINING COMMAND STAFF IN THE VIRTUAL VESSEL TYPE FREGAT

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Abstract: There is no standard formula for fighting fires on board vessels. However, with adequate prefire planning, fire training in simulation complex, and careful size-up and by using the guidelines in this paper for the specific circumstances, a set of instructions can be developed that will be successful in most fire situations.

The exercises were developed based on the ability of the simulator complex marine engineers and specific model of boat type ANZAC. They are composed of different models for dealing with shipping powerplant similar to those used on real warship.

Keywords: ERS, diesel engine, fighting fires, exercises mechanics, virtual vessel, ANZAC.

The developed series of exercises for seafarers in the conditions of a virtual frigate military fleet in the simulation complex "ERS TehSim5000" are related to the overall firefighting organization on board the ship. It consists of several teams, with the responsibility and management of the operation entirely for the captaion [1].

Although crew duties vary for different ships, usually the senior assistant is responsible for the activities of teams in crew and passenger accommodation and deck spaces and the chief engineer is responsible for operations in and around the engine room. The crew is divided into different teams such as fire-fighting team, engine room team, technical team and first-aid team. The exercises are based on the capability of the ship mechanics training complex and the ANZAC vessel model that the simulator has. Various fire-fighting models were developed in the ship power system, similar to those used at the Drazki (41) and Verni (42) frigates.

An organization and documentation (workbook, checklist) was set up for training that was aligned with the requirments of the "Willingen" frigate ship service.

In the simulator complex is simulated the work of a ship propulsion complex of a military frigate type ANZAC analogous to the propulsion complex of the Drazki (41) frigate (a multifunctional frigate of the "Willingen" class, part of the Navy of Bulgaria, which was adopted by the Navy at 21st. October 2005, one of the three frigates in the class purchased after their withdrawal from the Belgian fleet between 2004 and 2008). The simulator sets out scenarios of real fire-fighting situations faced by engineers in engine room work on such a ship.

TRANSAS "ERS-TehSim5000" training instructor is extremely important for the training of midshipmants in Maritime Engineering. The trained has 8 workstations each equipped with two monitors and computers that are included in a local and internet network, a multimedia projector, video cameras according to the Maritime Administration Executive Agency standard, as well as a complex integrated workplace for working together – Figure 1. In the simulation complex is simulated the operation of a ship propulsion complex of a military frigate type "ANZAC", of the main engine with turbocharger aggregates and its systems, as well as a ship power station, air-compressor, pumping systems and installations of general ship systems (fire, ballast, compressed air, special systems, etc.) [3]. Scenarios are in place in the simulator where new and realistic situations are encountered by engineers working in the engine compartment compartment of such type of ship.

Modern diesel engines for the Navy are characterized with high thermal and mechanical stresses stemming from the pursuit of the highest power per unit mass of the engines at acceptable economic performance. It is also necessary to provide high reliability and safe operation in a wide speed and power range. This is achieved by creating the conditions for running the best possible working process, and the main part of this is the organization of fueling and mixing in the engine cylinders [2]. Developing specific plans for virtual engine room training for training purposes is particularly relevant as:

- work guides – built on the basis of real procedures when working in a machine room of the Verni frigate
- new approach and scenarios for working with simulation complex “ERS-TehSim5000”

Figure 1. ERS-TehSim5000

The development of specific exercises and rules for action by the naval mechanics using computer simulators using multimedia technology enables the realization of practically diverse experiments and the developments of methodologies for responding to various unregulated situations and verifying the adequacy of actions that they take. This is achieved by the integration of real models (check lists) which show the engine room of frigates 41, 42, 42 with the application of scenario models embedded in the simulation itself, as well as situations set by the instructor himself. One of the main tasks of this type of training is the effectiveness in the learning process, which is related to the presentation of the learning information, adequate to real objects, taking into account the individual features of the mechanisms of perception of the seafarers.

Leading in the exercises is the individual work and the individual experience of each participant, and the good results are related to the knowledge, habits and skills acquired in the process of their training and work on the frigates. This means that the learning problem can be formulated as a problem of mastering knowledge skill formation and accumulation of habits to best perform the assigned combat tasks– Figure 2.

Figure 2. Instruction before performing the task of preparing and starting of a main engine

The concept of preparation consists of the following sequence [4]:

- General theoretical training;
- Regulation and preparation of scenarios for action;
- Training sessions;
- Evaluation of actions.

There are several stages in the work with the simulator

1) Understanding and perception of the situation→ the knowledge accumulated over time serves to find and understand the situation;

2) Conduction, analyzing and assessing the situation → this stage is done in relation

to the criteria and constraints of the particular exercise;

3) Realization of the scenario (exercise) → implementation of the decision made in relation to habits or orders;

4) Verification and evaluation → control of skills accumulated during work.

Compared to conventional training, trainers offer a better structured method of building high levels of competence in dealing with real situations. During simulation, all subsystems for understanding and acquiring knowledge and skills in making complex decisions can be isolated and frozen. Proper simulator training is an effective way to build competency and provide marine command staff, confidence and relevant experience.

The possibilities offered by the engineers trainings are shown, both theoretical and practical exercises.

Using simulators enables every trainee to practice their actions in various situations, as well as building up a work team, where everyone is aware of carries out their responsibilities. Apart from training maritime personnel, simulators can be used for training teams for operation of electric power stations, thermal plants, etc.

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A PRACTICAL TRAINING ASSESSMENT METHODOLOGY FOR ENGINE ROOM SIMULATOR TRAININGS

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Abstract: Maritime education and training (MET) is a practical training intensive education and training system with the aim of shaping knowledge, skill and attitude of students in practical training. Within such a practical training-intensive education and training system, the assessment technique/methodology should be robust and designed to measure the application of knowledge, skill and attitude in real-life scenarios. Specially, simulator based training; with its realistic, controlled, non-risk environment; is one of the most practical intensive training in MET approach. Simulator based trainings gives students the opportunity to learn, experiment and interact with a variety of realistic situations that would be dangerous or expensive to recreate in real life. At the same time, simulator based trainings gives lecturers the opportunity to assess and evaluate the knowledge, skills and attitude of students under different real-life scenarios as long as appropriate practical assessment methodology is used. Within this direction, this paper focuses on designing an alternative novel method with the integration of the analytic hierarchy process (AHP) and simple additive weighting (SAW) for a practical training assessment methodology in Engine Room Simulator (ERS) trainings. The performance of the proposed methodology with empirical study is illustrated and the obtained outcomes from the application propound the ability of methodology in practical training assessment.

Keywords: Maritime Education and Training (MET), Engine Room Simulator (ERS), Practical Training Assessment (PTAs), Analytic Hierarchy Process (AHP), Simple Additive Weighting (SAW).

1.INTRODUCTION

Maritime simulations can provide a safe, supportive environment that allows students to learn a variety of complex skills in a stress-free environment. Regardless of content or context, simulations are designed to provide an opportunity for students to learn how to manage a variety of shipboard situations in an environment in which errors can be made without serious troubles. In a well-designed simulation, there is opportunity for students each to review their actions, evaluate their own performance, receive feedback from peers and instructor and develop alternate plans of action [1] (Prion, 2008). The goals of simulation based maritime education and training have focused on improving trainee competencies in technical and non-technical skills, knowledge, communication, team training, leadership, emergency response performance. The types of educational uses to achieve these goals have included familiarization with systems and equipment on board ship, engine room watch-keeping and operation management skills, machinery trouble solving abilities, team training with human factor performance such as communication skills, task sharing, emergency response management skills. At this insight, a new generation maritime simulators from desktop trainer to full mission, with its unique properties fulfilling the training requirements in compliance with the latest international maritime standards and regulations, have become essential tools in maritime education and training.

Simulation based exercise scenarios specifies possible various outcomes of shipboard simulation experiences which are increased knowledge or understanding, development of critical thinking abilities, enhanced skill performance, increased student self-confidence and greater learner satisfaction. However, direct measurement and assessment of these outcomes are quite difficult and equivocal. Within this direction it is understood that, assessment is an integral and key part of the learning process to obtained accurate information about discovering the fit between competency expectations for student achievement and pattern of actual student achievement in simulation based training experiences with its formative and diagnostic structure [2] (Bloxham and Boyd, 2007). Assessment provides information about student achievement which allows teaching and learning activities to be changed in response to the needs of the learner and recognizes the huge benefit that feedback can have on learning [2-3] (Black and William, 1998; Bloxham and Boyd, 2007). Hence, the design of valid and reliable assessment methodology of this complex, integrated teaching and learning strategy is of fundamental importance to its successful integration into maritime education and training curricula. Within this direction, this paper focuses on proposing a new practical training assessment methodology (PTAsM) to assess simulation based scenario applications and experiences. The proposed method is intended to aid maritime education and training (MET) instructors during assessment and evaluation of student performance in simulator based practical training applications. The proposed method is illustrated using an empirical study.

The remainder of the paper is organized as follows; section 2 is devoted to the literature review. The proposed PTAsM is described in section 3 and an empirical study is presented in Section 4. Finally, concluding remarks are made in Section 5.

2. LITERATURE REVIEW

First usage of simulation as a training method is starting with the aviation industry over 80 years ago. In 1929, Ed Link developed a simulator to train pilots [4]. This method to training and education is now not unique to the aviation industry and is evident within many individual industries and disciplines [5]. In early 1970s, the first medical simulator was created [4]. In late 1950s, a significant improvement took place in maritime simulator development with manufacturing of radar and navigation simulator [6, 7]. Today, simulators are used in wide scope of the maritime education and training (MET), from offshore operation training on vessels and oil rigs, cargo handling, engine control, crane operations, towing and anchor handling [7].

With development of simulator usage in MET, monitoring, assessing and evaluating of simulator-based training turns into a complicated process for MET instructors. In the literature, limited number of studies have been found on assessment of simulator-based training. From the studies in the literature, Kobayashi [8] studied maritime policy and documents to draw conclusions about simulators and their use for training and assessment competences involved in safe navigation. Emad and Roth [9] concentrate on identification and bridging the gap in literature and research of competency - based training and assessment in the maritime domain and provide practical solutions for improving the system. Gekara et al. [10] focuses on examines the growing adoption of CBA within the safety - critical field of maritime education and training (MET). Sampson et al. [11] referred to the maritime instructors lack knowledge and uncertainties on how to make assessments of competency in the simulator.

Respect to the conducted literature reviews, it is explicitly seen that more studies are needed in order to provide guidelines for simulator-based assessments of competency to ensure validity and reliability of the assessment methods or models. Since MET institutions train their students for one of the most safety-critical industries in the world, there is a need for to concentrate on developing competency based practical training assessment methodology to enhance the quality of training and assessment and lay the foundation for an evidence-based practice for simulation-based training of seafarers.

Within the scope of feedbacks gathering from literature review, this paper focuses on proposing a competency based practical training assessment methodology for engine room simulator trainings. In the proposed methodology the priorities of multi criteria decision making (MCDM) techniques is used.

3. METHODOLOGICAL APPROACH

The proposed PTAsM uses the advantages of analytic hierarchy process (AHP) and simple additive weighting (SAW); which are widely used multi criteria decision making (MCDM) techniques in the literature. During the design of proposed methodology, Bloom Taxonomy learning domains; (i) cognitive domain: mental skills (knowledge), (ii) affective domain: growth in feelings or emotional areas (attitude or self) and (iii) psychomotor domain: manual or physical skills (skills); are selected as domains to assess. Bloom's Taxonomy of Learning Domains was initially published in 1956 under the leadership of American academic and educational expert Benjamin Samuel Bloom (1913 - 1999) whose aim was to develop a system of categories of learning behavior to assist in the design and assessment of educational learning [12]. The generic framework of proposed PTAsM is illustrated in figure 3.1.

With respect to the generic framework of proposed methodology, the structure of AHP and simple additive weighting SAW techniques is explained briefly in section 3.1 and section 3.2 respectively to clarify the processes in the framework.

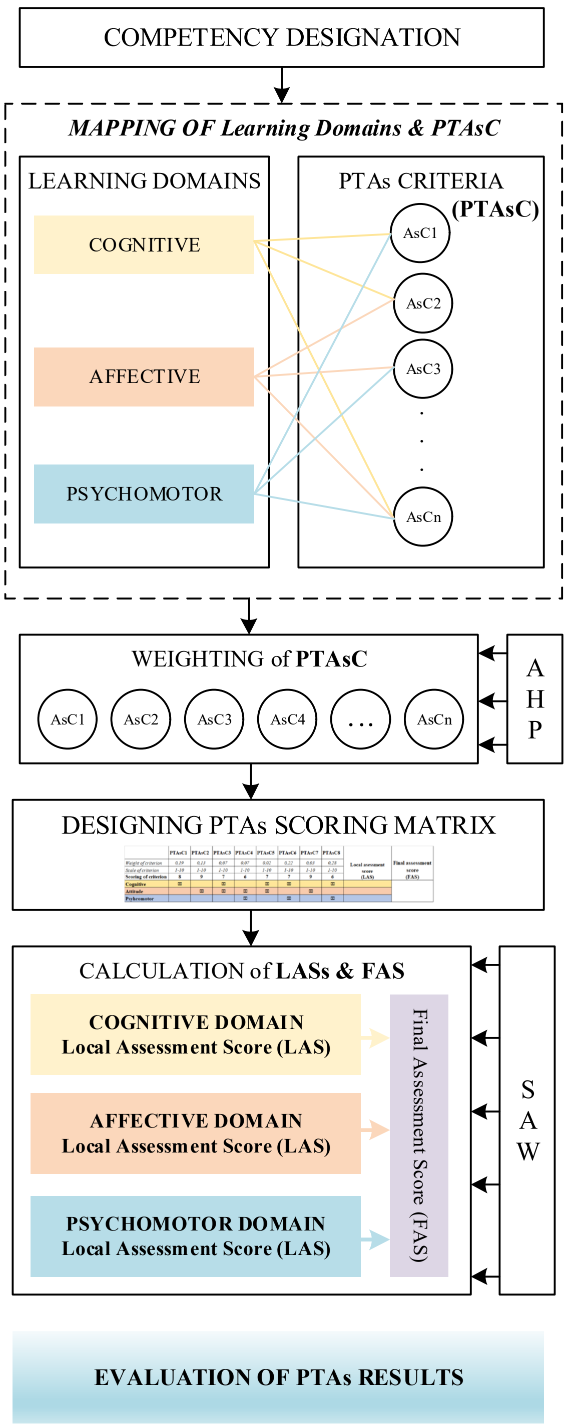

Figure 1. Generic framework of PTAsM

3.1 Analytic Hierarchy Process (AHP)

The analytical hierarchy process (AHP) is one of the most common techniques in MCDM that was proposed by Thomas Saaty [13, 14] which helps in complex decision making involving multiple scenarios, criteria and actors. AHP is a comprehensive and powerful methodology and aims to facilitate making the right decision through the use of each of subjective judgments of the decision maker as well as empirical data [15]. It combines materialistic and non-materialistic decision maker aspects in order to derive weights for the criteria [15, 16]. In typical analytic hierarchy, the numerical scale of 9-point is used. Each point equates to an expression of the relative importance of two factors, e.g., "A has the same importance of B" or "A is more important than B", etc [13-15].

In the study a scale with values ranging from 1 (equal importance or no difference) to 9 (absolute importance or extreme preference) which is illustrated in table 1 is used [13, 14].

Table 1. Scale of relative importance (according to Saaty [13, 14])

Intensity of importance	Definition
1	**Equal importance**
2	Equal to moderately importance
3	**Moderate importance**
4	Moderate to strong importance
5	**Strong importance**
6	Strong to very strong importance
7	**Very strong importance**
8	Very to extremely strong importance
9	**Extreme importance**

The process of applying AHP in the study is starting with construction of the pairwise comparison matrix to indicate the relative importance of criteria. A relative importance scale is shown in Table 1 is used for pairwise comparison judgements. Then, calculation of the priority weights of criteria according to the pairwise comparison matrix by the following equation (13-16):

$$Aw = \lambda_{\max w} w = (w_1, w_2, \ldots, w_n)^7 \qquad (1)$$

where A is a n dimensional comparison matrix, λ_{max} is the largest eigenvalue of A and w is the eigenvector corresponding to λ_{max}.

In AHP, a consistency index (C.I.) is defined to measure the inconsistency within the pairwise comparison matrix A.

$$C.I = \frac{\lambda_{\max} - n}{n-1} \qquad (2)$$

Accordingly, the consistency ratio $C.R.$ is used to measure the degree of $C.I.$ by the following equation:

$$C.R = \frac{C.I}{R.I} \qquad (3)$$

where $R.I.$ is the random consistency index, its value is related to the dimension of the matrix, listed in Table 2.

Table 2. Random consistency indices for different values of (n) [13,14]

n	*RI*	*n*	*RI*	*n*	*RI*
1	0	6	1.24	11	1.51
2	0	7	1.32	12	1.48
3	0.58	8	1.41	13	1.56
4	0.9	9	1.45	14	1.57
5	1.12	10	1.49	15	1.59

If the value of consistency ratio ($C.R.$) is smaller or equal to 0.10, the inconsistency degree of the comparison matrix A is consider acceptable and the eigenvector w is used as the weighting vector after normalization.

3.2 Simple Additive Weighting (SAW)

Simple Additive Weighting which is also known as weighted linear combination or scoring methods is a simple and most often used MCDM technique. The method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that criterion with the weights of relative importance, directly assigned by decision maker and followed by summing of the products for all criteria. The advantage of this method is that it is a proportional linear transformation of the raw data which means that the relative order of magnitude of the standardized scores remains equal.

The mathematical formulation to evaluate each alternative (Si) using the simple additive weighting method was as follows [17, 18]:

$$S_i = \sum_{j=1}^{n} w_i \times N_{ij} \qquad (4)$$

where W_j relative importance of normalized weight of criterion, N_{ij} the standardized rating value of learning domain i under criterion j and **n** number of criteria.

4. EMPIRICAL STUDY

The proposed PTAsM is implemented through empirical study to execute the reliability and validity. Within this scope, the steps of empirical study are explained as follows;

***Step 1. Competency based mapping matrix design*:** The first step of the empirical study is creation of competency based assessment matrix, illustrated in table 3, through determination of competency to be assessed, identification of PTAsC and mapping of PTAsC with learning domains.

Table 3. Competency based mapping matrix

Name of competency (obtained from A-III/1 or A-III/2 tables of STCW 2010)								
	PTAsC1	**PTAsC2**	**PTAsC3**	**PTAsC4**	**PTAsC5**	**PTAsC6**	**PTAsC7**	**PTAsC8**
Cognitive domain	☒	☒	☒	☒	☐	☐	☐	☒
Affective domain	☐	☒	☐	☒	☒	☐	☒	☐
Psychomotor domain	☒	☒	☐	☒	☐	☒	☐	☒

Step 2. Weighting of PTAsC: The defined PTAsC is weighted using the analytic hierarchy process (AHP) in reference to expert (instructor) judgements. The obtained pairwise comparison matrix is presented in table 4. Calculation of the priority weights of criteria according to the pairwise comparison matrix is enabled using equation 1.

Table 4. Pairwise comparison matrix of PTAsC

	PTAsC1	**PTAsC1**	**PTAsC1**	**PTAsC1**	**PTAsC1**	**PTAsC1**	**PTAsC1**	**PTAsC1**
PTAsC1	1	3	5	5	7	1/3	5	1/5
PTAsC2	1/3	1	3	3	5	1	3	1/3
PTAsC3	1/5	1/3	1	1	3	1/3	3	1/3
PTAsC4	1/5	1/3	1	1	3	1/3	3	1/3
PTAsC5	1/7	1/5	1/3	1/3	1	1/9	1/3	1/9
PTAsC6	3	1	3	3	9	1	7	1
PTAsC7	1/5	1/3	1/3	1/3	3	1/7	1	1/9
PTAsC8	5	3	3	9	9	1	9	1

The consistency ratio of pairwise comparison matrix is calculated **0,0765** and it is said that the inconsistency degree of the comparison matrix is c acceptable. The obtained **priority weights** of each PTAsC is; ***0.19, 0.13, 0.07, 0.07, 0.02, 0.22, 0.03, 0.28*** respectively.

Step 3. Designing PTAs Matrix: The third step of methodology is designing of PTAs matrix using the outcomes of step 1 and step 2. The designed PTAs matrix is shown in table 5.

Table 5. Practical Training Assessment Matrix

	PTAsC1	**PTAsC2**	**PTAsC3**	**PTAsC4**	**PTAsC5**	**PTAsC6**	**PTAsC7**	**PTAsC8**	**Local asessment score (LAS)**	**Final assessment score (FAS)**
Weight of criterion	*0,19*	*0,13*	*0,07*	*0,07*	*0,02*	*0,22*	*0,03*	*0,28*		
Scale of criterion	*1-10*	*1-10*	*1-10*	*1-10*	*1-10*	*1-10*	*1-10*	*1-10*		
Scoring of criterion	**8**	**9**	**7**	**6**	**7**	**7**	**9**	**6**		
Cognitive	☒		☒		☒	☒		☒		
Attitude		☒	☒	☒	☒		☒			
Psyhcomotor				☒		☒		☒		

Step 4. Monitoring and scoring of practical training: After designing of PTAs matrix, the student performance is scoring under each criterion from 1 to 10 scale on PTAs matrix via monitoring engine room simulation exercise of student. As an empirical application, in table 6 soring of student under each PTAsC is illustrated to conduct proposed methodology and to calculate local assessment score (LAS) and final assessment score (FAS).

Table 6. Scoring of student under each PTAsC

	PTAsC1	PTAsC2	PTAsC3	PTAsC4	PTAsC5	PTAsC6	PTAsC7	PTAsC8
Scoring of student under each PTAsC	8	9	7	6	7	7	9	6

Step 5. Calculation of LAS and FAS: The obtained scores under each criterion through monitoring the engine room simulator exercise of student is analyzed using simple additive weighting (SAW) technique mathematical formulation in equation 4. The mathematical formulation of SAW is slightly modified to reach meaningful results. The modified formulation to calculate LAS for each learning domain is presented in equation 5.

$$LAS_j = \frac{\sum_{j=1}^{n} AsCr_j \times w_j}{\sum_{j=1}^{n} 10 \times w_j} \times 100, i = 1,2,3 \quad (5)$$

After obtained LASs, FAS of practical training is calculated with taking of arithmetic mean of LASs with the formulation in equation 6.

$$FAS = \sum_{i=1}^{n} LAS_i \Big/ 3 \quad i = 1,2,3 \qquad (6)$$

The obtained LASs and FASs, using equation (5) and equation (6), is presented in table 7.

Table 7. PTAsM results

	LAS	FAS
Cognitive Learning Domain	68	73
Affective Learning Domain	80	
Psychomotor Learning Domain	71	

The obtained LASs and FAS provides substantial information about student performance in simulation exercise under *three different learning domains*. Also criteria based assessment show the student strengths and weaknesses. Hence, the proposed methodology provides prominent feedbacks to instructors on modification or enhancement the context of ERS course and the scope of ERS scenarios.

5. CONCLUSION

Simulators have been used as an educational tool for training and certification in MET since they first appeared in the 1950s. With The latest update of the international convention on standards of training, certification and watchkeeping for seafarers, *the Manila amendments 2010,* has a greater focus on technical proficiency and the non-technical skills of team management and resource management. The practical impact of STCW convention updates increase the tendency of using simulators for training and certification of proficiency and non-technical skills. For that reason, monitoring, assessing and evaluating the student performance in simulator based training turns into a hot topic in the scope of MET. At that point, this study with its proposed practical training assessment methodology provides a new perspective and fill the gap in literature on simulator based training assessment. Additionally, the obtained results with the demonstration of proposed methodology presents substantial information for MET instructors about student performance and proficiencies under three different learning domains. This information helps instructor to enhance accuracy, consistency and reliability of evaluation process about students. Finally, it can be said that the proposed methodology with its valid, reliable and wieldy structure is a candidate to generate a new perspective not only for simulator based training assessment but also for all types of practical training assessment in MET.

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THE EVOLUTION OF 3D AND VIRTUAL REALITY IN ENGINE ROOM SIMULATION

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Abstract: From research and development to planning and operation, products, processes and training are increasingly taking shape in the virtual world, much thanks to the growing power of simulation technologies. KONGSBERG's continuous focus on simulator development and use of new advanced technology, have enabled more accuracy and realism in maritime training.

Engine Room Simulators are acknowledged as powerful and efficient tools to build sea skills and are increasingly used at training institutes around the world. Leading the way in innovative training systems, Kongsberg Digital is providing sophisticated Virtual Reality (VR) solutions for enhanced training experiences. Our K-Sim Engine VR solutions enables engineer students to navigate through the engine room with detailed sub systems such as the boiler, compressors, pumps, pipes and coolers used on board. The student can operate the equipment in a virtual environment, which creates engagement and promotes learning.

Kongsberg has developed and sold various solutions of VR systems for almost ten years. Due to market demands, end user experiences and the constant requirement of cost effective solutions the evolution of VR has forced its way through to be a very important area of various Kongsberg Engine Room simulator applications.

VR solutions for classroom training as well as for full mission simulation, where students use an X-box controller are currently in use at maritime training institutes worldwide.

Kongsberg presented a VR solution that uses 3D Goggles and hands on experience with gloves last year; this solution is a part of our virtual reality development programme and product demonstrations has provided a constant flow of new ideas and interest from worldwide simulator users.

What is Virtual Reality?

- The word Virtual reality (VR) is in this paper used for describing 3D development of specific engine room systems as well as use of VR hardware equipment such as X box controllers and head set including goggles.
- Virtual reality (VR) refers normally to a high end user interface that involves real-time simulation and inter actions through multiple channels.
- Virtual reality means feeling of an imaginary (virtual) world rather than the real one. The imaginary world is a simulation running in a computer. The sense data is fed by some system to brain.
- Virtual reality allows a user to interact with a computer-simulated environment: real or imagined.

The beginning for Kongsberg.

The first official 3D virtual application for the Kongsberg Engine Room and Cargo Handling Simulator was launched in 2007: A new requirement for CCTV for cargo handling simulators forced Kongsberg to embed a CCTV View for all CHS in order to get DNV class A.

Kongsberg developed a 3d simulated CCTV of the manifold area that was embedded to all existing CHS models. This was a successful product for Kongsberg, and it stated a new demand for visualisation of both engine room and cargo handling simulators.

In 2010 Kongsberg released a new version of the BigView for our MAN B&W MC 90 low speed model. The version included a VR application of the main engine as an integrated part of the system. The model was presented at the Kongsberg simulators user conference in Bergen, and Kongsberg had great feedback from experienced engine room simulator users, and students.

Since 2010 Kongsberg has expanded the library with 13 additional models available with BigView, several including VR solutions. The system diagrams in BigView provide students with sufficient information to recognise interactions between systems and sub-systems, and to identify component statuses. A user-friendly interface allows students to operate the total Engine Room. Operation of valves, pumps and controllers can all be activated by pointing your finger on the screen; software based pop up panel's and\or impressive 3d models (VR) allow easy operation of the equipment. The graphical presentations provides students with visually correct, mimics of the engine room systems or sub-systems and panels that interfaces as required to interact with the system/sub-system as they would with the real equipment.

All relevant equipment commonly located in the engine room compartments are displayed as simulated in this product.

As mentioned, from the described mimics the user can also access VR view of specific equipment by clicking on a magnifier symbol on the mimic screen. A VR view of the system appears on the screen and the student can manoeuvre around for interactive operation by simply touching green fields on the screen.

In 2011 Kongsberg launched VR applications for the classroom systems that allow the users access to operational virtual engine room displays in the ERS mimic library on the desktop stations. This gave the user a possibility of operating the VR presentation in a traditional classroom set up, the functionality is consisted as an add-on to existing well-known mimic presented systems.

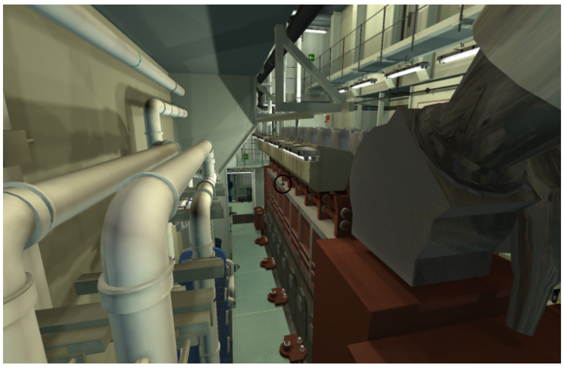

Figure 1. MaK Main Engine VR View

Walkthrough Engine Room.

Several years of close cooperation with staff at Maritiem Instituut Willem Barentsz, Netherlands, who had been a pioneer in creating virtual engine room systems for their engine room simulator led Kongsberg to a launch of a full Walkthrough Virtual Engine Room application 2014. This version based on a container feeder with a single MaK main engine includes an interactive virtual animation of the entire engine room. Students can walk around in the engine room in a virtual world and operate the machinery systems locally. The system is ideal for engine room familiarisation and gives the user an understanding of the complexity of an engine room layout and the challenges of finding the correct equipment in a real engine room environment.

Figure 2. Students Aarhus School of Marine and Technical Engineering Denmark using VR "Walktrough" engine room simulator

In this virtual engine room, the end user is able to interact with all of the vessels systems that are accessible in the engine room, as local control panels, motor starters, valves, compressors etc. The models includes operation of water mist valves in machinery spaces, ventilation dampers and local switch operation.

Engine room equipment like specific valves or pumps is often hard to find and time consuming to reach in real life, so focus on communication and case planning can be vital. The 3D walkthrough system is therefore an ideal tool for management and communication studies, since realistic time consumption is a mandatory requirement for local operation in this virtual engine room system. A second impressive full virtual engine room application for a model in the K-Sim Engine library was released in 2015; The best-selling model MAN B&W MC 90-V (VLCC) did now have a full Walkthrough Virtual Engine Room application, with a virtual animation of the entire engine room.

The new virtual engine room are capable of showing animated representations of fire and smoke and fluid leaks appropriate to the equipment, also flooding of bilge wells and light effects are important animations in the virtual engine room.

Figure 3. Visual effect: leaking engine

Simulated CCTV

The work with VR has also lead to a simulated CCTV (Closed Circuit TV) of the vessels funnel, and selected engine room areas. The funnel view allows the students to monitor the exhaust from the ship's engines. Any actions related to combustion has an effect on the smoke content shown. Also visual effects like blackout fire and water mist release can be observed from a CCTV monitor view

Typical Visual effects included:

- Main engine. Smoke. Dynamic 0-100%
- Diesel Generators Smoke 0-100%
- Incinerator Smoke
- Aux. Boiler 0-100%
- Steam Dump
- Fire in the engine room
- Black-out
- Water Mist Release
- Oil/Water leak

Figure 4. CCTV: Fire in engine room

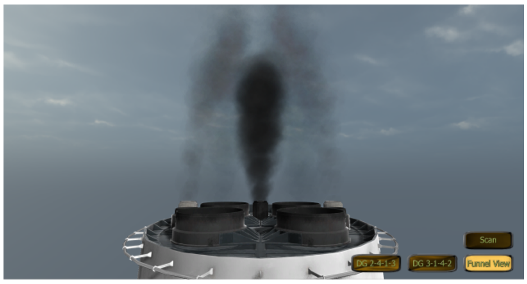

Figure 5. CCTV Funnel View

VR Goggles

At Nor Shipping 2017, Kongsberg Digital further demonstrated the ability of deliver realistic training inside a full 360 virtual engine room environment. The new K-Sim Engine VR solution is complimentary to traditional training and enables engineer students wearing a VR headset to navigate through high-fidelity virtual engine rooms and operate detailed subsystems such as the boiler, compressors, pumps, pipes, and coolers. It places the engineer in a virtual environment providing familiarisation of the systems, and equipment with a visual, interactive approach, providing increased stimulation for learning.

Figure 6. VR goggles in use

Future VR solutions

Also for K-Sim Navigation and K-Sim Offshore, new disruptive VR solutions will soon be available. A prototype of our VR solution for K-Sim Navigation was successfully demonstrated at our User Conference in Athens in October. However, the future developed product will of course offer a lot more in order to fully take advantage of the technology's powerful interactive learning potential.

In addition to training, VR can also be used to test equipment and products in a virtual environment before actually made. This will save time and money while simultaneously increasing quality and flexibility. Kongsberg Digital is ideally positioned to lead the way developing highly cutting-edge systems as well as service models that are anchored in the virtual world.

A new R&D project recently granted by the Research Council of Norway, will ensure further development of innovate simulators and methodology with the use of Mixed Reality (MR), Virtual Reality (VR), Augmented Reality (AR) and Augmented Virtual Reality. In the future, there will be possible to offer flexible, inexpensive and mobile Future Training Simulators to substantially enhance the performance of maritime operators and thus contribute to a safer and more efficient maritime industry.

Conclution

My journey with Kongsberg simulators started in 2007, same year as the first 3D VR application was embedded to our cargo-handling simulator. The quality of products, competition in market and the fact that PC and specialized hardware are getting faster and more cost-efficient leads the way forward in the use of VR technology. I believe that VR will be common also for maritime firefighting training, crises management and entire ship familiarisation in close future.

Virtual reality training has many benefits like:

- Familiarisation of environment, systems and equipment like in real life
- Exploration of virtual scenarios as experience for real world scenarios
- Visualisation of complex concepts and theories
- Building skills on how to handle risky or dangerous situations within a controlled environment
- Highly visual approach which gives increased stimulation to learning
- Generates interaction and engagement, which promotes learning
- Peer review, feedback and ongoing assessment
- Cost effective

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A NOVEL APPROACH TO IMPROVE ASSESSMENT PROCESS OF SIMULATOR BASED EMERGENCY OPERATIONS

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Abstract: Maritime simulators are training and assessment tool to attain many knowledge, understandings and proficiencies, hence identified competences in STCW Code. Particularly, beyond the training of regular activities, engine room simulators are employed for training of emergency situations and troubleshooting operations. Assessment of simulator based emergency scenarios is the challenging activity like other simulator trainings. Following the trainee's reaction step by step and forming an emergency procedures checklist could facilitate this process. In addition, a simulator instructor needs to define application sequence of each item in checklist as the most significant process rather than solely completion of the emergency checklist. In this study, we propose a prioritisation technique of each item in emergency procedures checklist. Analytical Hierarchy Process (AHP) method is employed to define correct and safe sequence of the items. Moreover, trainees' simulator performance evaluation system proposed for simulator instructors. Validation and contribution of proposed technique is discussed in case study section.
Keywords: Assessment Process, Emergency Operations, Performance Evaluation System, Prioritisation of Items.

INTRODUCTION

With the developing technology, all maritime universities and training institutions have been equipped with various kinds of simulators according to their educational needs. Marine simulators enable to reproduce practical and even more emergency situations not only for academic researches but also vocational training and educations [1-4]. In this manner, knowledge, understandings and proficiencies can be gained under identified competences in Standards of Training, Certification and Watchkeeping for seafarers (STCW) Code. Though STCW Code identify minimum standards for attained knowledge, understandings and proficiencies, there is no standard for comprehensive evaluation system for simulator training. Generally, simulator instructors evaluate the trainees by considering solely their results [5]. Moreover, assessment of simulator based emergency scenarios is another challenging activity for instructors.

Importance of emergency situations and their fidelity in the simulator is needed to be well semtinized and explained to trainees at the briefing section of simulator execution. Probable results of any mistake or skip on emergency checklists should be depicted with all realities to the trainees. Instructor should ensure that the trainees follow correct emergency procedures for certain conditions. In most cases, just fully completion of emergency checklist list is not indication of a successful scenario. Simulator instructor needs to revise and ensure all items of checklists are put in right order based on importance and safety prioritisation manner. Sequential follow up of each item in checklist is essential and vital for especially real cases. There exist some catastrophic accidents originated from incorrect sequential design of emergency checklists.

In this paper we propose a prioritisation technique for emergency checklists. Analytical Hierarchy Process (AHP) method is employed to define correct and safe sequence of the items. Bunker spill emergency checklist which is employed at simulators centre of Istanbul Technical University Maritime Faculty (ITUMF) is focused on and sequence of the items is reconstructed based on AHP methodology by making expert consultation.

Priorities of each item in the checklist are determined by using pairwise comparison as a part of the methodology. Superdecision Software (www.superdecisions.com) is utilized for employing this application [6].

METHODOLOGY

The Analytical Hierarchy Process (AHP) is one of the most referred decision making approaches. There exist other decision making method which are employed for decision making processes of different problems [7-9]. AHP was firstly proposed by Saaty, is a decision making method which enables to compute both qualitative and quantitative criteria comparison [10]. The mainstay of AHP is utilizing expert consultation [11]. AHP essentially consist of three steps: hierarchy structure, ratio of priorities and aggregation of the local weights into a global priority that measures the impact of all items.

Subsequently, the following can be done manually or automatically by the AHP software. Employed steps are given below:

1. Combinations of the pair-wise comparison matrix
2. Calculating the priority vector for factor and then overall priority;
3. Calculation of the CI, consistency index,
4. Calculation of the consistency ratio;
5. Checking the consistency of the pair-wise comparison matrix to aware whether the experts' comparisons were dependable or not. Table 1 shows relative measurement scale filled by the experts.

For AHP method, criteria are used as inputs and the matrix produces the relative weights of items, which are classified the into five sub-groups (0-2, 2-4, 4-6, 6-8 and 8-10) in addition to 0. The corresponding vector of weights and the matrix is given below:

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & A_3 & A_n \end{array} \\ \begin{pmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 \cdots w_1/w_n \\ w_2/w_1 & w_2/w_2 & w_2/w_3 \cdots w_2/w_n \\ w_3/w_1 & w_3/w_2 & w_3/w_3 \cdots w_3/w_n \\ \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & w_n/w_3 \cdots w_n/w_n \end{pmatrix} \end{array}$$

Table 1. Pair-wise comparison scale for AHP preferences

Numerical Rating	Verbal Judgement of Preferences
9	Extremely preferred
7	Very strongly preferred
5	Strongly preferred
3	Moderately preferred
1	Equally preferred

The relative weights are obtained by multiplication of A and W, where
$W = (w_1, w_2, . . , w_n)$

$$A * W = n * W$$

n is the number of the elements, n and W are eigenvalue of the matrix algebra and eigenvector of matrix A.

Due to experts are not able to produce the accurate weights of matrix, the estimation of $\hat{W}$ is obtained as shown below:

$$\hat{A} * \hat{W} = \lambda_{\max} * \hat{W}$$

Where is observed matrix, λ_{max} is the largest eigenvalue of $\hat{A}$, $\hat{W}$ is the right eigenvector which is the estimation of W (weights i.e. priority vector).

Consistency Index (CI) is calculated from the formula of:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

λ_{max} is the largest eigenvector value. Then, Consistency Ratio (CR) is;

$$CR = \frac{CI}{RI} \leq 0.1$$

Random Consistency Index (RI) is an average index of randomly generated weights given in Table 2.

Table 2. Random consistency index

n	1	2	3	4	5	6	7	8	9	10
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

IMPLICATION

Bunker spill emergency response is an important action which is needed to make preliminary simulation and exercise [12].

Related checklist is employed at ITUMF. At the beginning of the scenario trainees are supposed to make correct line connections and valve operations for bunkering. They expected to follow and observe flow of the fuel, line pressure, tank level and any spillage alarm on the system. After spillage alarm is arisen, the mentioned checklist is to be followed and filled. Table 3 indicates sequence of each item in present checklist.

AHP prioritisation of above mentioned 9 items (A-I) is executed by making expert consultation. The expert group consists of ten experienced field experts including scholars from marine engines department of universities in Turkey. Superdecision software is utilised to perform AHP application. Figure 1 indicates the AHP structured items.

After expert consultation process, essential calculations are completed.

Weights of computed priorities are given in Figure 2.

Table 3. Sequence of each item in checklist

Items of Checklist		
1	Call Master	A
2	Inform the Engine Room	B
3	Stop all cargo / bunkering /transfer operations	C
4	Inform the Company	D
5	If at sea warn ships in the vicinity	E
6	Keep continuous watch on channel 16 VHF	F
7	Ensure that firefighting equipment is available	G
8	Ready to start fire pumps	H
9	Check crew for absence / injury	I

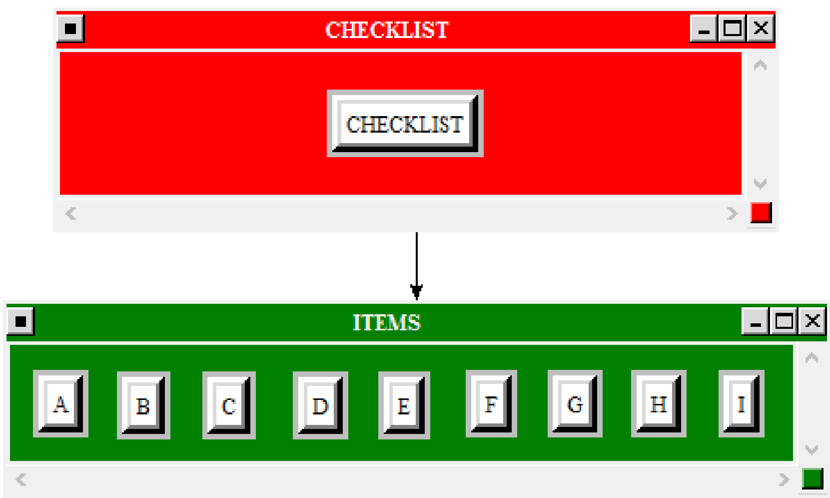

Figure 1. AHP structure of the items

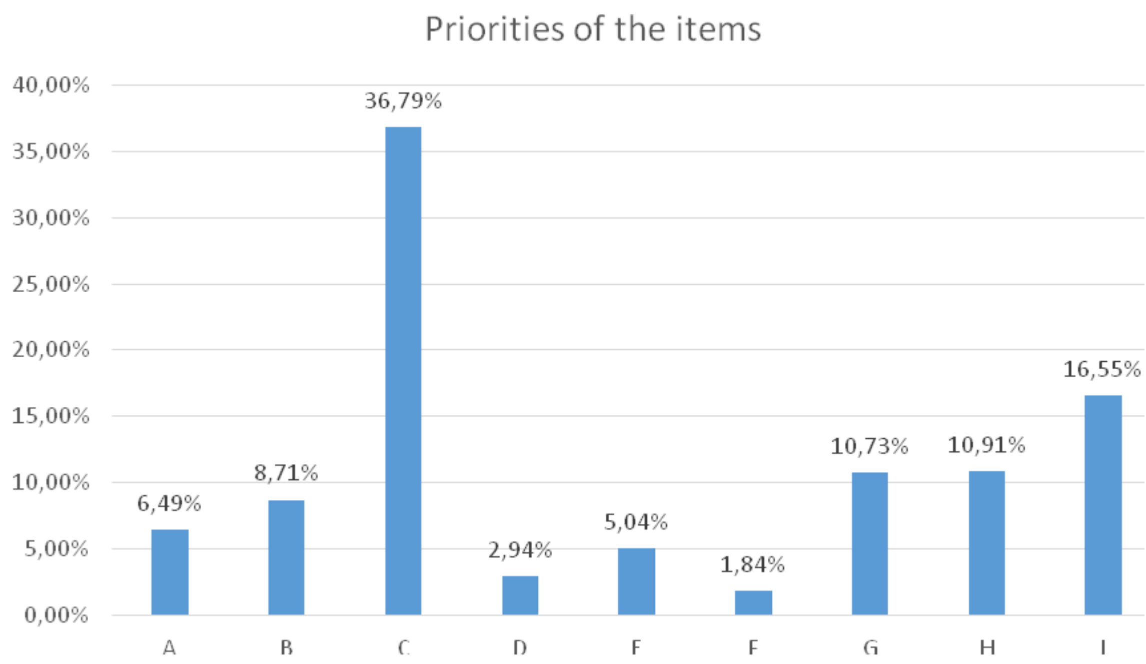

Figure 2. Weights of computed priorities

Accordingly, *"Stop all cargo / bunkering /transfer operations"* (C) item is obtained as the most prior one by % 36,79. Dramatically, *"Check crew for absence / injury"* (I) is settled as final item in the first version of the checklist, whereas field experts evaluated it as the second most prior item by % 16,55. Another remarkable result is about informing the company and warning the surrounding vessels. Field experts evaluate the emergency response should be devoted to recover root causes of the problem. Table 4 shows reconstructed sequence of the checklist.

Table 4. Reconstructed sequence of each item in checklist

	Items of Checklist	
1	Stop all cargo / bunkering /transfer operations	C
2	Check crew for absence / injury	I
3	Ready to start fire pumps	H
4	Ensure that firefighting equipment is available	G
5	Inform the Engine Room	B
6	Call Master	A
7	If at sea warn ships in the vicinity	E
8	Inform the Company	D
9	Keep continuous watch on channel 16 VHF	F

After establishing a correct and safe sequence of the items, there exist another problem faced for the scoring process. Main concern is that is the fully completion of the items enough for scoring 100/100 or correct implication sequence of items has any effect?

In this paper, we argue that there should be an effect of correct implication sequence and reflected to trainee evaluation system. For that respect, we propose a new scoring system for simulator instructors. In the proposed system total score is identified as Q.

Sequence coefficient is c where;

$$0 < c \leq 2$$

Number of items in the checklist is identified as n. Instructor identifies impact of sequence by deciding value of sequence coefficient c.

Impact of sequence is;

$$I = \frac{Q}{c}$$

Impact of sequence on each item i can be calculated as follow;

$$i = \frac{I}{n}$$

Accordingly, we can calculate maximum available score (E) when any sequence of items is not correct by given formula;

$$E = Q - I$$

Similarly, maximum available score for each item e is obtained by using the formula;

Same scenario is evaluated by proposed system and reconstructed checklist where;
General Impression is 10 pts.
$Q = 90$ pts.,
$c = 2$,

$$e = \frac{E}{n}$$

Implication of proposed system is explained in case study section of this paper.

CASE STUDY

In this section of the paper, we compare instructor's scoring results for present checklist with our reconstructed one in same scenario which is executed by same trainees. Table 5 reflects instructor's scoring table without sequence consideration. There are two references in this evaluation system as general impression and execution of items. Score distribution is assumed as follow;

General impression = 10 pts.

Total execution of items = 90 pts.

As it is seen in Table 4 trainees executed all items except item D.

Table 5. Scoring table without sequence

Items	Result	Points
A	✓	10
B	✓	10
C	✓	10
D	X	0
E	✓	10
F	✓	10
G	✓	10
H	✓	10
I	✓	10
General Impression	-----	10
Gross Total	**90 pts.**	

$i = 5$ pts.,
$e = 5$

Table 6 shows results of proposed evaluation system with same scenario.

Table 6. Scoring table with proposed system

Items	Execution Result	e	Sequence Result	i	Points $(e+i)$
C	✓	5	✓	5	10
I	✓	5	✓	5	10
H	✓	5	X	0	5
G	X	0	X	0	0
B	✓	5	✓	5	10
A	✓	5	X	0	5
E	✓	5	✓	5	10
D	✓	5	✓	5	10
F	✓	5	✓	5	10
	General Impression				10
	Gross Total				**80 pts.**

CONCLUSION

In this study, a novel approach is proposed for prioritisation of any checklist which is used in simulator training. AHP method is applied to compute prioritisation weights of each item in predefined bunker spill emergency checklist. According to the results, group of field experts evaluated the almost all items are needed to re-sequenced. Safety and urgency related concerns of the experts caused drastic changes in checklist which seems safe and well-designed at first glance.

Along with this study, also a new evaluation system is proposed for simulator instructors. According to case study, there exist differences of approximately % 10 on total available score between conventional assessment method and our proposed system. Consideration of execution sequence of items will assist to make more sensitive and academically supported assessment of simulator trainees.

The proposed system enables the simulator instructors to make fair and standardized assessment who follow a checklist for evaluation of trainees' performance.

As our future research, we plan to determine the importance and essentiality of items and define different e values for each item based on their essentiality in the light of safety aspect.

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ENHANCING THE EFFECTIVENESS OF ENGINE ROOM SIMULATOR TRAINING WITH APPLICATION OF AUGMENTED REALITY TECHNOLOGY

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Abstract: In this paper, we briefly reviewed advantages and disadvantages of modern engine room simulators that further revealed a necessity to enhance the effectiveness of those with respect to degree of reality. Such an important indicator is not excellent when it comes to simulation of emergency situations (e.g. machinery fire, flooding, technical failure, etc.), as these conditions physically could not be fully perceived, using standard graphical human-machine interface.

This problem is partly solved by implementation of augmented reality technology that we found proved to be able to provide higher degree of reality and help to obtain a certain flexibility in operation of a simulator, allowing to enrich educational content without additional hardware. With help of advanced augmented reality technology (e.g. adding computer vision and object recognition) the information about the surrounding engine room model (or real one) space of the user becomes interactive and digitally manipulable.

Keywords: engine room simulators, augmented reality, training of marine engineers.

1. Introduction

Today, approximately 80% of the world volume of goods is transported by seagoing vessels [3].

Following a rapid expansion in the size of the cargo fleet by 38% between the start of 2005 and 2012 to total 31000 units over 100 GT, annual fleet growth has since slowed falling to around 3.7% in 2014 and 2015, limited by firmer demolition activity and generally lower deliveries (Fig. 1) [1].

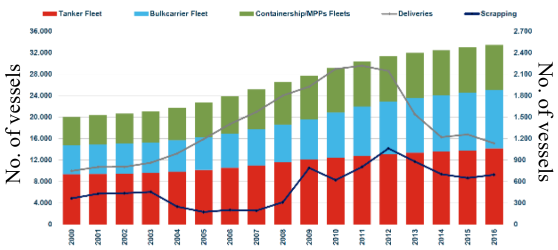

Figure 1. Historical cargo fleet growth development.
Note (1): Includes all vessel in these categories above 100 GT
Note (2): All fleet totals are on the left hand axis deliveries and scrapping figures are on the right hand axis

At the start of July 2016, the global fleet totalled 91,773 ships of a combined 1,237 million GT.

Expanding global fleet constantly requires a significant number of professionals. Moreover, in the last decades, shipboard technology has changed extensively, mainly in the form of automatic controls which demand higher and updated skills and knowledge from seafarers.

Technology has shaped and influenced the way in which crew make errors. It has also affected the crew's opportunities to detect or recover from the errors they make and thus, in certain cases, accelerated their journeys towards breakdown.

Nearly 85% of accidents onboard have been attributed to the human error [8]. Notwithstanding, a comprehensive view of the circumstances of these accidents depends on many different actors. But still, imperfection of official procedures, rules and regulations is rarely the root cause in those.

Basically, human error is a result of improper education, use of unqualified personnel and reluctance to use the right training techniques.

Despite specific training is probably only known efficient tool to deal with human error, operations with reduced shipboard personnel, stringent regulations, competitiveness and commercial pressures which are common onboard do not leave much time for it [8].

Therefore, both International Maritime Organization (IMO), certain classification societies and state authorities address special attention of educational establishments on the quality and uniformity of marine simulator training [3-5, 8, 9, 14].

Furthermore, the STCW (Standards of Training, Certification and Watchkeeping) 87/95 Convention strongly recommends the application of both bridge and engine room simulators in the teaching/learning process, as they are very powerful resources for students to develop their cognitive skills due to presence of certain degree of reality [9, 14].

The objective of this paper is further enhancement of effectiveness of engine room simulator training, using augmented reality technology that allows to enrich cognitive learning process.

2. Synopsis of simulators

The simulator is defined as a mechanical, electro-mechanical, or computer device for producing a realistic representtation of an event or a system. It is used where the real equipment is very expensive and inaccessible, and to train operators in safety.

The DNV placed the simulators into classifications due to the limitation in tasks that each simulator can perform. The important training role marine simulators can play in raising safety standards has been given increased recognition through the incorporation of this advanced technology in the recently amended STCW Convention [6, 8, 9].

It can be said that any dynamic process or complex operational equipment is a suitable model for a simulator system. Some of the types of simulators in use in the maritime and related industries include: navigation equipment simulator, communication equipment simulator, ship handling simulator, dynamic positioning simulator, ballast control simulator, propulsion plant simulator, refrigeration plant simulator and drill technology simulator.

The levels of simulator systems that can be distinguished are suggested in the design drafts and are categorized as [8, 9]:

– Category 1 which is the Full Mission type (FM);

– Category 2 is the Multi-Task type (MT);

– Category 3 is the Limited Task type (LT) and

– Category 4 is the Special Task type (ST).

However, the purpose of the classification of a simulator is to ensure that simulations provide an appropriate level of physical and behavioural realism in accordance with training/assessment objectives as stated in the STCW Code Section A-I/12 [9].

Category 1 (FM) are used for full immersion training with maximum possible control of the simulation environment. They have a complete engineering systems installed, including sound and realistic visuals, and are capable of advanced training in management of both and critical emergency conditions.

Category 2 (MT) are capable of simulating a total environment of the technical operation, but excluding the capability for advance training.

Category 3 (LT) are capable of simulating an environment for a certain engineering system to provide advance training in specific tasks.

Category 4 (ST) are appropriate to provide multiple trainee stations for familiarization training in preparation of a more comprehensive simulator.

However, under the mandatory part of the STCW Code, parties are required to ensure that the aims and objectives of simulator-based training are defined within an overall training program with the emphasis on objectives and tasks relating as closely as possible to shipboard practices.

Table 1 below indicates the tasks that can be performed by the various simulators as stipulated in STCW 95.

Table 1
Simulators tasks as stipulated by STCW 95

Type of simulator	STCW 95	IMO model course
Full Mission	Table A-III/1 Table A-III/2 Table A-VIII/2	2.07
Multi Task	Table A-III/1 Table A-III/2 Table A-VIII/2	2.07
Limited Task	Table A-III/1 Table A-III/2	2.07
Single Task	Table A-III/1	-

3. Learning methods

It has been learnt through experience that the application of simulation in teaching complex control systems leads to a better understanding of the principles of operation of both the equipment and the systems, in comparison with traditional education methods.

Moreover, it reduces the cost of training and increases the effectiveness of engineering educational scheme.

Trainees not only acquire the knowledge concerning the operation of the equipment in normal exploitation conditions, but are also familiarised with emergency situations. As a consequence, trainees are better prepared to deal with potential emergencies during operations on board [4, 5].

However, it is worthwhile mentioning that, apart from several benefits, engine room simulators have also some basic drawbacks and disadvantages.

First of all, simulators involve many simplifications, abbreviations and schematic presentations of machinery systems. As a result, trainees with even a perfect knowledge of the simulator operation can have serious problems while operating a real ship power plant, primarily because the graphical presentation and operating procedures of a simulator are different from the real environment that the trainee is normally being confronted with [4, 5].

This problem is partly solved by utilising computer-based training (CBT) as a preparatory stage, prior to the use of *full mission* engine room simulators. The basic role of CBT interactive programs is the familiarisation with individual auxiliary machinery and associated systems, prior to the commencement of the operation with the whole engine room plant [3-5, 8].

The experience gained in the educational process shows that it is extremely important to combine the schematic diagram with the real presentation of a determined part in the form of a photograph [4, 5]. An example of the relationship between the graphical presentation and real field components is presented in Figure 2.

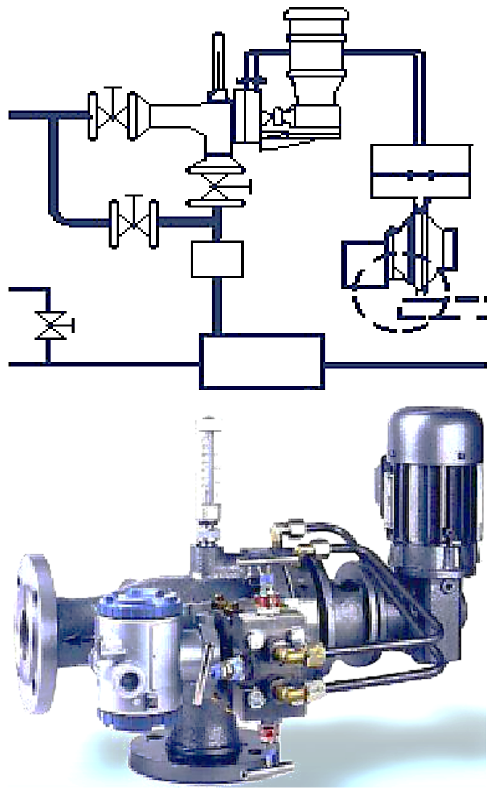

Figure 2. Schematic and real image of the viscosity sensor

This educational effect can be further enriched and strengthen with use of technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view. This technology is called augmented reality (AR) because the objective information, abstracted through real-time visualization, overlies images captured from camera(s) and augments the experience of a user in that he or she can view and explore better contextualised content.

With respect to engine room simulators, augmented reality technology should be utilised in the following forms:

– displaying any additional features or possible operation procedures of the real equipment, not included in the original setup;

– displaying the three-dimensional visuals of the elements shown in any printed diagrams or placards;

– enriching training videos that describe real environment with digital interactive content;

– simulation of dynamic digital visuals (like smoke, fire, water, etc.) to produce emergency scenarios on a real (even installed on board) equipment.

Thanks to AR, information used can be both virtual and real, thus making it possible for the learning process to be more inter-active with manipulable content [10, 11, 13].

These new properties are directly related to the person's cognitive learning and help trainees to learn an information faster and, what is more important, remember it loner due to created associations and internal reflections.

For example, seeing other real sensed or measured information such as electro-magnetic or mechanical waves overlaid in exact alignment with where they actually are in space (Fig. 3).

AR displays can be rendered on devices resembling eyeglasses. Versions include eyewear that employ cameras to intercept the real world view and redisplay its augmented view through the eye pieces and devices in which the AR imagery is projected through or reflected off the surfaces of the eyewear lens pieces.

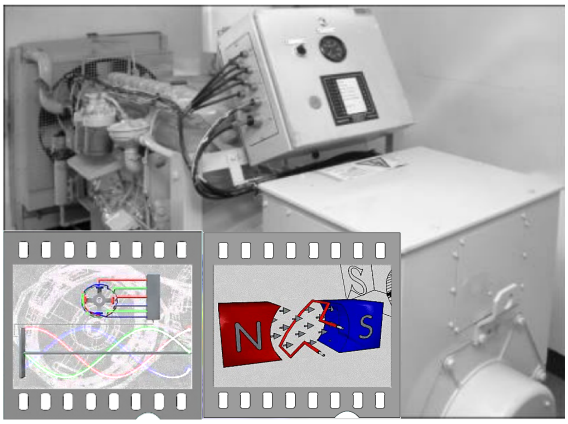

Figure 3. Example of augmented visual of diesel driven generator

4. Evaluation of learning effectiveness

One of the vital functions of an engine room simulator is evaluation of the professional skills of a trainee in virtue of the training platform. Evaluation items are set with accordance to the seafarers' competency standard stipulated in STCW Code, included but not limited to: task and workload management, effective resource management, knowledge and ability to apply decision-making techniques, and others.

An objective evaluation is achieved by dividing each of evaluating items into two types: one is "Operation Type", and the other is "State Parameter Type" [7], the "Operation Type" represents the operations of interactive entity such as valve, switch, *etc.*, and the operation result is "True" or "False". "State Parameter Type" belongs to numeric indicators representing the marine machinery running state, such as pressure, flow, frequency, *etc.*

Since the operation result for "Operation Type" is true or false, single-point member-ship function based on fuzzy set theory can be adopted to implement this function.

The single-point membership function, which grade is 1 or 0, can be then defined as

$$\mu_A(x)=\begin{cases}0 & x=x_i\\ 1 & others\end{cases}. \qquad (1)$$

For the “State Parameter Type”, a membership function $\mu_A(x)$ takes the form

$$\mu_A(x)=\begin{cases}0 & x \text{ doesn't belong to } A \text{ totally}\\ (0,1) & x \text{ belongs to } A \text{ partly}.\\ 1 & x \text{ belongs to } A \text{ totally}\end{cases} \qquad (2)$$

If the evaluation element x doesn’t belong to A totally, its membership grade is 0; if the evaluation element x belongs to A totally, its membership grade is 1; if the evaluation element x belongs to A partly, its membership grade is a continuous value in the closed interval $\{0,1\}$.

Considering the characteristic of each state parameter and the suggestions of experts in this domain, four kinds of membership function are defined for the “State Parameter Type” variables. The first three types are “Peak Type”, “Ascending Type” and “Falling Type”.

As shown in Figure 4, the “Peak Type” is appropriate for the state parameter that has the optimal value in a certain section; the “Ascending Type” is appropriate for the state parameter which is bigger and better in a certain section; the “Falling Type” is appropriate for the parameter which is smaller and better in a certain section [7].

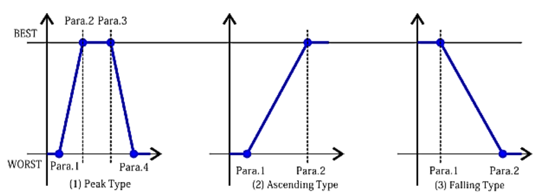

Figure 4. Membership function [7]

The membership function of the fourth type is used to evaluate the time element.

This function can be written, using following expression [7]:

$$\mu(t)=\begin{cases}0 & t\le t_1\\ \frac{1}{2}-\frac{1}{2}\sin\left[\frac{\pi}{t_2-t_1}\left(t-\frac{t_2+t_1}{2}\right)\right] & t_1\le t\le t_2,\\ 1 & t\ge t_2\end{cases} \qquad (3)$$

where $\mu(t)$ represents the time membership function; t is the time consumed by the trainee; t_1 is the standard evaluation time; t_2 is the regulated maximum evaluation time.

Described above theoretical background of learning progress evaluation can be successfully utilised to determine the effectiveness of engine room simulator of new or upgraded type (e.g. enhanced with augmented reality technology).

5. Discussion

AR is a promising technology that is being successfully applied in many contexts as diverse cultural heritage, education, geographic visualization, environmental monitoring, as well as emergency management and search and rescue [2, 10-13].

There is real demand for such augmented reality software that promotes its rapid development and makes financially profitable.

Implementation of AR technology in all types of engine simulator can significantly improve effectiveness of professional training. Knowledge and skills gained through such training will be essential to make full use of the human and equipment resources in the engine room, clarify the duties and responsibilities of the daily work, operation and maintenance of all kinds of machinery in engine room correctly, ensure safe voyage, reduce and/or eliminate the potential human error, perform well in all the emergencies. [7].

6. Conclusions

Today’s ship owners, managers and operators are under constant pressure to demonstrate that the vessels, which they operate, are safe both in the material sense and with respect to the ability of the crew to operate them safely.

Engine room simulator training remains essential part of education with regards to safe operation of marine vessel and its propulsion plant. This training should not be stopped after graduation, but repeatedly con-tinued in the form of additional or refresher courses and computer-based training.

It is expected that, after proper field evaluation, implemented in marine simulators augmented reality technology will allow to significantly improve effectiveness of training.

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IMPROVEMENT OF ENGINE ROOM SIMULATOR VISIBILITY FOR MARITIME EDUCATION TRAINING

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Abstract: Watch keeping marine engineers constantly gaze at the control consoles where many gauges and meters are installed and depend on the readings of those for the proper running conditions of machinery.

In ergonomics and psychology, when a person process at a given instant the information, that upper limit number of information is known as 7 ± 2 [1]. Humans can increase the memorized number of numerical value which is displayed on a meter panel by forming causalities and chunks or rhyming game etc., against a numerical value. It is a method to give a meaning and a value for meaningless number, and to increase the capacity that people can memorize. However, at the real work environment, engineer should be able to monitor the meters with moving needles that indicate the operating condition of the machineries that changes every moment and discriminate whether it is normal or abnormal. It needs not only remembering the numerical value, but also understands their meaning. Otherwise, they will not be able to manage the machinery and plant properly.

As a characteristic of the marine engine console panel, the location of the meters on panel and the painting are different by the manufacturers' intention according to ship owners' requests. It is necessary to select proper colors for panels and suitable placement of gauges and meters, in order to reduce physical fatigue and mental stress and improve the visibility and readability. However, if color selection is not harmony to each other, there is also the risk of causing discomfort to engineers.

In this study, we focused on the color scheme of the control console of the marine engine room. The meter panel color is changed, and it objectively evaluate by participant. The specific tendencies were found in engineer group, also student's group too.

Keywords: Visibility, Inductivity, Readability, color difference.

1. Introduction

The marine engineer's task is to keep the machinery which are installed in the engine room, in proper working order. In order to maintain the efficient and effective operation of equipment, it is important not only the maintenance such as strainer cleaning, but also monitoring the state of running machinery. In watchkeeping work, the engineer should patrol the engine room and monitor the console panels, etc., to understand the condition and health of machinery. During manoeuvring of the of maine engine such as entering port and going through a narrow channel, as the engine load suddenly changes, it is imperative to accurately grasp the engine condition very quickly.

In Japan, there are some engine malfunctions in marine accident judgment arbitration record. These engine malfunctions have led to damage of engine by uncertain actions at the engine operation. [2] [3] These accidents are caused by operating the engine without clear reading of the lubricating oil pressure, when the oil pressure has been decreasing.

Meanwhile, the engine control console should confirm to the users' needs as a minimum requirement. In console design, it tends to be selected according to the intention of the manufacturer reflecting regionality or owner's requirement. After the accident mentioned above, the engine console panel maybe improved by modifying the lubricating oil pressure gauge to a larger size by the owner's request.

In this study, we have considered the visibility of gauges in the PC display of the engine room simulator, which is developed for marine engineer training and education. The intention was to assure that the readability of the meter was such that it will give a clear view of the reading without a causing any fatigue to the engineer.

2.Materials and methods

2.1 Illustration image of meter

An engine room simulator was installed at Kobe univeristy Fuculty of Maritime Sciences as a ship operation simulator in March 2010. The class room lesson has been conducted as an exercise using the engine room simulator for second, third and fourth grade students of marine engineering course. The engine control console which installed in the engine control room is shown in Figure 1.

In actual engine control console, the visibility of meter on the console panel will affect by difference in brightness or saturation between the two parts which are adjacent to each other. It is common knowledge that the lightness and saturation of the part are affected by several factors, such as indoor lighting, its material of parts and its surface roughness. In addition, it depends on personality and characteristics such as the visual functions and the physical condition of the user who evaluates the console panel.

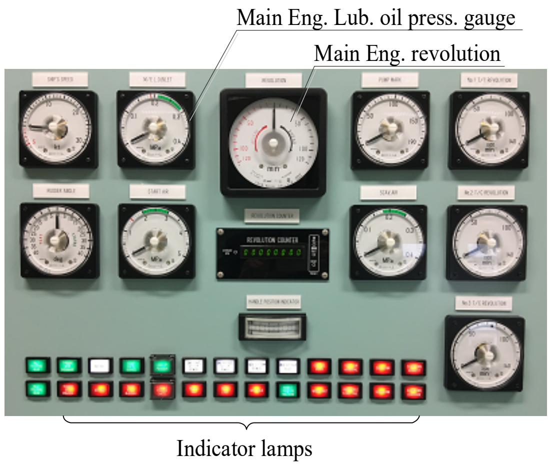


Figure 1. Control panel of Engine console in Engine room simulator at Kobe university

In this study, we consider the meter design of the engine room simulators which is aimed at improving the actual design of engine control consoles.

The illustration image is created by using software (Flash professional mx, Adobe systems) for creation of Web contents, based on photographs which taken the main engine revolution meter. Figure 2 shows a photo (a) and an illustration image (b).

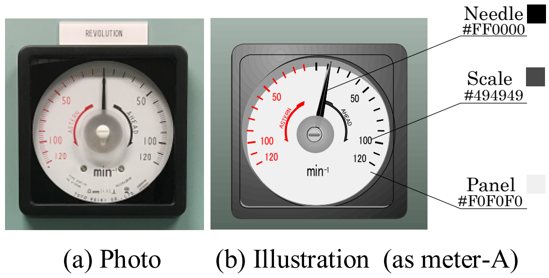


Figure 2. (a) Photo and (b) Illustration image with colour code of Main engine revolution meter

2.2 Measurement of color

Using the L*a*b* colorimetric system, lightness (L*), and chromaticity index Chromanetics indexs (a*, b*) of photo were able to measure by photo analysis softwere (ImageJ,pubric domain software). And Chroma is calculated by using these factors. The lightness represents that black as 0 value to white as +100. The red color is indicated as positive value and green color as negative value in Chromanetics index a*, and yellow color as positive value and blue color as negative value in Chromanetics index b*. Table 1. shows representative color values of each elements of the main engine revolution meter.

Table 1. L*a*b* Value of meter elements

	Parts	Hexadecimal	Lightness L*	Chromatinecs index a*	b*	Chroma C*
meter-A	Needle	#000000	0	0	0	0
	Panel	#F0F0F0	95	0	0	0
	Scale	#494949	31	0	0	0

2.3 Illustration image

The illustration image is created, it is based on Figure 2 (a). In this report, the red ,blue and black were used as color of needle. Also, off white and pale yellow were used for panel color. Kansaku [4] explained, red is conspicuous in the case of white background, and conspicuous are according to large difference area between background and object in brightness as well as hue.

If the panel is white, it presumes that red will be conspicuous. By same reference, red, yellowish red, yellow and blue are order of conspicuous. And the difference in brightness as well as hue, contribute to the inductivity between background and target. Therefore, the off white and pale yellow which is warm color are adopt as panel. As needle's color, red and blue were adopt with black too.

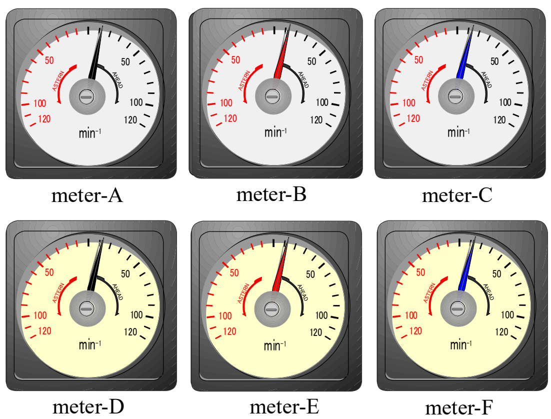


Figure 3. Meter images for eveluation research

Figure 3 shows illustration images of six type of main engine revolution meters. Meter-A to meter-C are off-white as panel, and needle color are changed from black to red or blue. Meter-D to meter-F are adopt pale yellow as panel, needle color is changed from black to red or blue.

2.4 Color difference between target and background

The using of colors were selected by the initial setting of the color panel of the animation software (Flash professional mx, Adobe systems) as coloring of illustration image.

Table 2 lists the specification which according to L*a*b* color system in six types of illustrations and hexadecimal color codes of their color images.

Table 2. L*,a*, b* value of meters elements

	Parts	Hexadecimal	Lightness L*	Chromatinecs index a*	b*	Chroma C*
meter-A	Needle	#000000	0	0	0	0
	Panel	#F0F0F0	95	0	0	0
	Scale	#494949	31	0	0	0
meter-B	Needle	#FF0000	53	80	67	104
	Panel	#F0F0F0	95	0	0	0
	Scale	#494949	31	0	0	0
meter-C	Needle	#0000FF	32	79	-108	134
	Panel	#F0F0F0	95	0	0	0
	Scale	#494949	31	0	0	0
meter-D	Needle	#000000	0	0	0	0
	Panel	#FFFFCC	86	18	7	19
	Scale	#494949	31	0	0	0
meter-E	Needle	#FF0000	53	80	67	104
	Panel	#FFFFCC	86	18	7	19
	Scale	#494949	31	0	0	0
meter-F	Needle	#0000FF	32	79	-108	134
	Panel	#FFFFCC	86	18	7	19
	Scale	#494949	31	0	0	0

2.5 Evaluation of analytic hierarchy process(AHP) [5]

For the six types of illustration images which are created in this research, evaluate the visibility etc.. We consider that factors expected for panel design are as follows: Readability, Visibility, Inductivity, and Fatigue.

As the evaluation item, To investigate

the priority order for the following items 1) to 4).
1) Readability:the scale is easy to read
2) Visibility: the needle for easy viewing
3) Inductivity: the eye is easy to move.
4) Fatigue: it does not make the reader tired.

Based on the evaluation items 1) to 4), the meter-A to meter-F are evaluated using AHP method. In this research, we conducted a questionnaire survey for 20 students who took class-room lesson using the engine room simulator, and 7 marine engineer who work in company ship.

In the questionnaire survey, a pair comparison of the evaluation items is carried out firstly. Then it decides the weight for each evaluation items.

Next, for illustration of image in which the color of element is changed, a rating is given by evaluation item in a pair-wise comparison. The rating in the pair-wise comparison are set to 4 levels of "very: 7" "quite: 5" "slightly: 3" "equal: 1" such as below.

e.g.) Which do you think the higher priority?

・The scale for easy to read. ***・The needle for easy viewing.***

very	quite	slightly	equal	slightly	quite	very
7	5	3	1	3	5	7

3. Result and discussion

3.1 Color difference of illustration image

Table 3 shows the color difference between the elements in a illustration images of six. To calculate the color difference of each pairs such as, needle and panel, needle and scale, scale and panel. For example, in the case of a red needle on the black scale, caluculation is "the panel's chroma value substracted with needle's chroma value", this chroma difference obtained as -104.4. It means that the red needle's vividness is bigger than black scale.

In the main engine revolution meter, a black scale is used for the forward (Ahead) revolution and a red scale is means reverse (Astern) revolution. In this study, the color of the scale is always as black at evaluation.

Table 3. Difference of each meters elements

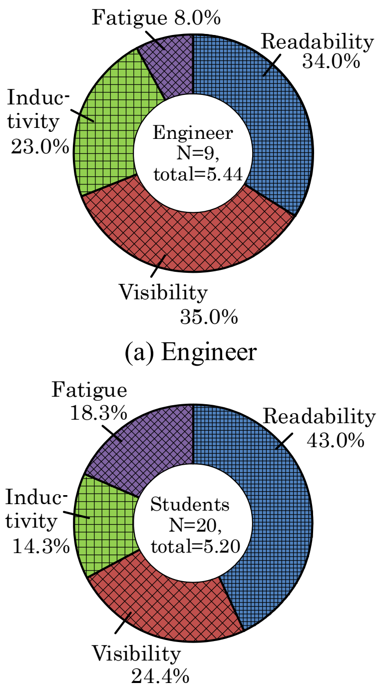
	Parts and Parts	Lightness ⊿L*	Chroma ⊿C*	diff.Color ⊿E*	Hue-diff. ⊿H*
meter-A	Needle and panel	95	0	95	0
	Needle and scale	31	0	31	0
	Scale and panel	64	0	64	0
meter-B	Needle and panel	42.0	-104.4	112.5	1.0
	Needle and scale	-22.0	-104.4	106.7	1.1
	Scale and panel	64.0	0	64.0	0
meter-C	Needle and panel	63.0	-133.8	147.9	0.5
	Needle and scale	-1.0	-133.8	133.8	1.3
	Scale and panel	64.0	0	64.0	0
meter-D	Needle and panel	86.0	19.3	88.2	1.2
	Needle and scale	31.0	0	31.0	0
	Scale and panel	55.0	19.3	58.3	1.0
meter-E	Needle and panel	33.0	-85.0	92.4	14.6
	Needle and scale	-22.0	104.4	106.7	1.1
	Scale and panel	55.0	19.3	58.3	1.0
meter-F	Needle and panel	54.0	-114.5	140.9	62.0
	Needle and scale	-1.0	-133.8	133.8	1.3
	Scale and panel	55.0	19.3	58.3	1.0

As shown in Table 3, the largest value of the lightness difference is 95.0 on the needle and panel of meter-A. The maximum value of chroma difference were - 133.8 on needle and panel at meter-C, as same as needle and scale at meter-F.

3.3 Result of evaluation by AHP method

The questionnaire survey results of 9 marine engineers and 20 students are as follows. Figure 4 shows the priorities for the evaluation items. The full score of the evaluation is 7 points. In the survey, we conducted a pair-wise comparison to determine the priorities for the four evaluation items. Then, the evaluation value of the four items are totaled, and the score ratios of each evaluation item are shown in Figure 4.

At Figure 4(b), the readability rate of the student is much bigger than that of the Engineer 's rate. In addition, Student's evaluation exceeds the result of the engineer's on evaluation of Fatigue.



(a) Engineer

(b) Students

Figure 4. Priority of evaluation item

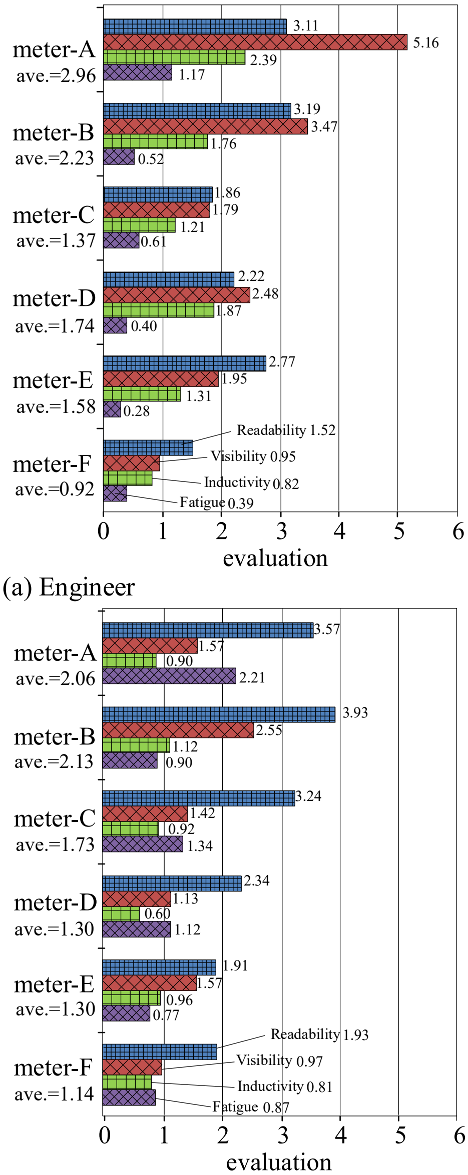
Meanwhile, At Figure 4(a), in the evaluation results of the engineer, Both visibility and inductivity rate make a large proportion.

In real work situation of engine room, an engineer has to take the important information from meters in a short time since a large number of machinary is installed in an engine room. The decisions made by the engineer is based on the experience in such work situations.

Figure 5 shows the evaluation results of from meter-A to meter-F for each participants group. The evaluation on the visibility by the engineer group, At meter-A to meter-C are high. On the other hand, in the student group, evaluation of readability are higher than visibility in meter-A and meter-C.

In evaluation of Inductivity on needle, red needle value is high in students group. In the engineer group, the evaluation of the black needle got higher than red one.

Table 4 shows the correlation between different value of each color element and participant's evaluation.



(a) Engineer

(b) Students

Figure 5. Comparing with eng'r and student by evaluation

In the engineer group, there are correlations at elements, such as lightness difference, saturation difference, color difference, etc., between the needle and the scale. The weak correlation is found between the needle and the panel, also scale and panel too. However, in the student group, there was a correlation only between the needle and scale.

According to reference [4], when the background color is white, red is the most conspicuous color.

Table 4. Coefficient of evaluation average and difference of color

	Parts and Parts	Lightness ⊿L*	Chroma ⊿C*	diff.Color ⊿E*	Hue-diff. ⊿H*
engineer	Needle and panel	0.258	0.227	-0.205	-0.314
	Needle and scale	0.413	-0.413	0.413	-0.413
	Scale and panel	0.178	0.300	-0.305	-0.286
student	Needle and panel	-0.020	-0.077	0.001	-0.291
	Needle and scale	0.478	-0.478	0.478	-0.478
	Scale and panel	-0.119	0.002	-0.012	0.020

In the evaluation results of the student group, the evaluation of the visibility of meter-B, meter-E which are adopting red needle was high. However, if the same coloring on panel, the results of the engineer group showed high evaluations of meter-A and meter-D which adopted a black needle. At evaluation of fatigue, the black needles were high with the engineers as well as with the students.

One of the engineers commented that there was a possibility that lubricating oil could be imagined if the panel was pale yellow, which could lead to a confusion for the user.

It is high possibily that commonsense perceptions may have an affect on the evaluation rather than color features that generally enhance the inductivity.

A knowledge and experience which engineer obtain through the onboard job, may make a priority order and preference which is different with student thinking.

4.Conclusion

The meter panel are expressed by the illustration image, and six images were created with a design that changed the color of the needle and panel.

We conducted a questionnaire survey to evaluate the visibility and inductivity of the these illustration design.

In the engineer group, there was a tendency that the visibility of the needle was required. However, there was a different tendency which readability is required by students group.

In this research, it was suggested that differencis between the colors used on gauges for those with sea-experience and other generally used colors, it may make users feel uncomfortable and cause confusion.

The visibility or inductivity colors may give educational effects to students.

However, students are confused by the color difference when operating the actual machinery near future, and it will be a concern.

When considering the adaptability to real work environments, the engine room simulator manufacturers must pay attention to using the colors that the students will be using in the future rather than the colors of their choice.

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FULL MISSION SIMULATOR COMPLEX APPLICATION IN THE MARINE HIGH VOLTAGE INSTALLATION TRAINING COURSE

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Abstract: In this article it is examined the problem of a knowledge and habits acquisition in the area of Marine High Voltage (HV) Installations for Ship's Engineers and Electro-technical Officersin accordance with Convention STCW 78 with Manila amendments 2010. Respective studying and skilling Course is provided in Odessa Marine Training Center (Full Mission Simulator Complex of the Ship's Automated Electric Power Plant). The Course theoretical part is based on the participants' knowledge of the Marine Electrical, Electronic and Control Engineering (STCW Code Table A-III/1) and has the goal to refine the main features of the HV Installations equipment utilizing: necessity of using, advantages and HV energy managing; risks, hazards and precautions, safety practices and requirements, the components design, operation and protection principles.

The practical part of the Course is provided on the Simulator Complex real HV panels, including: explanation of the training tasks and exercises; drawing up documentation; demonstration of the HV equipment operation and control; disconnection, isolation, short circuiting and earthing procedures execution with safety precautions; diagnosis, alarm handling; monitoring, trouble shooting; preparation of the equipment for operation.

The Course includes: lectures, video presentations, studying of the HV equipment manuals, filling up the documentation samples, practical exercises on the working equipment in accordance with approved program. On the completion of the Course the participants takes the examination, including answers for theoretical and practical questions, which allows to evaluate their competence in subject.

Keywords: Marine High Voltage (HV) Installations Course, Full Mission Simulator Complex of the Ship's Automated Electric Power Plant.

The fleet of vessels powered with High Voltage (HV) is increase in the number, so it became necessary to add a theoretical knowledge and practical training for Ship's Engineering Officers and Electro-technical Officers, operating the HV electrical equipment.

STCW95 convention, with the 2010 Manila Amendments sets new terms for limitation of Officers' license revalidation related to High Voltage Installations. Taking in account mentioned, Odessa Maritime Training Centre provided the training course "Marine High Voltage Installations" (Course), which is aimed to fulfill of requirements for HV on board ships.

Course Program is oriented on utilizing of Electric Power Plant Simulator Complex, which is including: two sets of automated diesel engines with brushless synchronous generators, 14 sections Main Switchboard (MSB) with Power Management System (PMS), one section of Emergency Switchboard (ESB), Schneider Electric High Voltage MC set 7,2 kV and MOTORPAC RVSS Motor Soft Starter Module with PLC.

The Course includes theoretical part and practical hands-on exercises on the actual High Voltage Panels, comprising of Schneider Electric EVOLIS Vacuum type Circuit Breaker VCB), Main Earthing Switch (ES) along with the associated interlocks and Programming Electronic Protection and Control relays SEPAM [1].

Course theoretical part is based on the participants' knowledge of the Marine Electrical, Electronic and Control Engineering (STCW Code Table A-III/1), and have given a brief understanding about the important considerations in marine electrical installations, preferences of power generating and distributing at HV, dangers of electricity and HV effects on human body, characteristics of HV equipment components on-board. As results of explanation and video presentations it should be clear that the principal parts of a ship electrical system operated at HV would be the main alternators, HV MSB, cables, transformers and electric motors. Large consumers such as bow thrusters, some of big pumps electric motors, step-down transformers or reefer's transformers are fed directly from the HV MSB. HV system from economical and technical points of view must be simple to operate, reasonably priced, require a minimum of maintenance over the ship's life.

The ideology of onboard power distribution is presented by star net type, where metal-clad MSB contains the switchgear and protective devices. Components in MSB are arranged in separate compartments with metal partitions intended to be earthed. Each section of the metal-clad MSB consists of four compartments: circuit breaker (air type – ACB, gas SF6 filled type or vacuum type – VCB), main bus bar, cable terminations, low voltage (LV) equipment. To withstand internal electrical arc faults in case of short circuits, separation between compartments is achieved by the use of metal partitions (four sides protection). According to the section's destinations MSB comprises: generator panel, HV main consumers (propulsion motor drive transformers, main pumps) panel, bus-tie panel, reefer transformer panel, main step-down transformer panel, bow and stern thrusters panel, pre-magnetizing transformers and grounding protection (gpt) panels. Function of gpt is to monitor the insulation values on the HV bus bars and that panels incorporated with earthing trucks.

In the MSB LV compartment is installed Electronic (microprocessor) Protection Relay for power data measuring and transmitting, VCB remote control and electrical protection of connected equipment. Protection Relay functions depends of which electrical consumer or source (generator, motor, transformer, bus tie, feeder, etc) is connected to the MSB section. Important functions of Relay are: overload protection (IDMTL adjustable curve); monitoring of electrical power parameters; accuracy of measuring units and VCB; self checking; remote or local configurability and adjustment; alarm panel, visual indicator and electrical interlocks control.

MSB panels shall be equipped with visual voltage (HV presence) and components status (ON / OFF) indicators such as LV signal lamps or LED or mechanical type flickers.

All HV compartments access doors and component control units are equipped with mechanically or electrically locking devices against incorrect operations and preventing restricted access, such as: force locks, prevention locks, electromechanical locks, safety locks (padlocks/keys).

Using the references on the maker manuals and Classification society requirements it is demonstrated the construction features and differences between HV and LV power equipment, protection methods and units, maintenance and testing.

In order to ensure the safe operation of the switchgear into the panels there are dedicated Accessory Tools: main earthing switch (ES) operating handle, VCB drawing or inserting crank handle, VCB trolley lifter. Safety using of these tools during HV apparatus maintenance and testing is possible only by skilled personal fully appreciated function of Safety Interlocks and Protecting Devices. Among these interlocks are such equipment:

Mechanical safety interlock for VCB compartment door;

ES interlock key: can be released only in ES CLOSED position; must be inserted and in unlocked position to enable opening of the ES; this interlock key enables access to the cable compartment from rear side of the panel;

ES crank position mechanical interlock;

VCB position switches;

mechanical interlock for VCB racking;

VCB opened position / ES closed position;

electrical interlock of the panel door interlock device.

For HV MSB equipment maintenance tasks the such works in particular are concerned:

VCB visual inspection (the purpose of visual inspection is to check the exterior of the breaker in usual

operation. Once a year, a general

visual inspection is should be carried out. And the outer insulation parts should be wiped with a rag more frequently if the breakers are exposed to a dust area);

checking the VCB after 10 trips due to short circuit;

one year regular maintenance of the VCB as per maker manual;

checking the insulating resistance of VCB;

checking the VCB main contacts wear;

outgoing HV cables connecting point check.

For these works carrying out it is necessary to provide explain and demonstrate operation sequence (for example): prepare the job, set up the working area, prepare the tools, use the safety equipment, extract the VCB, check ON/OFF indicator is normal, check for the presence of dust and moisture, check for unusual smell or discoloration, check main circuit terminals for discoloration or traces of overheating, check the operating voltage and control voltage with the voltmeter, insert the VCB, connect and clear the working area.

During maintenance work the follows special and personal Protective Equipment should be used:

Low voltage insulating gloves Class 00 (500V); Insulating Gloves High Voltage Class 01 (10000V); Protective leather gloves; Insulating sheet; Insulating platforms 24kV; Insulated pole 45kV with handguard; High voltage detector: 700V up to 7kV (60Hz), 40 mm multi-purpose probe (M8), APV type adapter; Telescopic stick for detecting the absence of current before earthing a line or transformer (stick supplied with APV end fitting); Low voltage detector (range: 12V - 690V 60 Hz) with carrying case; Set of 2 probe extensions (90cm x 0.4mm IP2x); Megger insulation tester with testing voltage range not less of HV system working voltage; Portable Earthing Cable set; Electrician's isolated tools set; Mask anti flash; Plackards: Electrical warning flags: Electrocuted man or Electrical danger warning signals (Plastic triangle): Electrocuted man + Lightning; Padlock of deposit; Adhesive tape "black and yellow"; Pneumatic tester for insulated electricians' gloves; Insulated material box for electricians' gloves.

Each Voltage detector have to be used only for specific voltage range.

To cover all voltage ranges, 2 detector set are required. HV voltage detector mast have detector accuracy testing device.

Insulating HV Gloves have a test date recommended by the manufacturer, which does not have statutory value. After this date, a test of strength must be done in order to determine whether they can still be used. Two cases are to be considered: infrequent use - gloves have to be checked every 6 months; frequent use: gloves have to be checked every 3 months. To protect the insulating gloves from eventual tears, leather over-gloves will be provided. Those will also protect from thermal burns in case of short-circuit arc.

Personal Protective Equipment (PPE) must comply with safety and health provisions of European Directive 89/686/EEC and be subject to the CE compliance marking.

Working with an electrical equipment has to be wearing in working suit without metallic parts, with adapted safety shoes and without watches and jewelry. Working suits, safety shoes and Eyes protection goggles meet the electrical safety criteria.

For an efficient follow-up of the electrical safety equipment, a record binder must be opened. In this binder, the following minimum items must be provided: a periodic working test (must be done in accordance of maker's instruction), inventory list with minimum equipment to be on board.

Important part of explanation is Safety measures in case of fire on HV installations. Intervention on power plant under HV has a low probability, therefore recommendation given by firemen and Schneider Electric is: "switch off the high voltage and put the switchboard to the ground before intervention». It is the best protective measure. For firefighting it is recommended to use of fog stream (distilled water). In theory, it is acceptable; however the fog stream must be perfect, the least defect can allow the power to go through. For that reason, if it is not possible to switch off the power plant, and if the fire is growing in size, it is recommended to evacuate personal from engine room and use the fixed CO_2 extinguishing system. Rules describe the high-voltage safety equipment to be used in case of fire directs: CO_2, Dry-chemical fire extinguisher, Fog (if spread jet is perfect). Generally, limitation specified by the extinguisher manufacturer must be adhered to.

Next important part of Course is the HV Safety for carrying-out equipment handling and maintenance operations on-board. HV installations Safety is related to various international standards and guidelines systems, defining important considerations in organizing the works.

Base of Safety on board is Work Permit system. In the Work Permit should be pointed out: work area or equipment, details of the work to be done, details of all the controls / precautions required, emergency procedures, any limits on the work. Permit should specify: written acceptance by the person who will do the work, written signed confirmation that the work has been completed and the area restored to safety, any permitted time extension to the work, how the permit is to be cancelled.

At least every six months the Manager or Autorized Person should lead a review of how the permit to work procedure has performed. Content of HV Electrical Work Permit depends of Company policy, but must contain follows: equipment or work area location, limitations, purpose or scope of work, materials and tools used, sequence of operations including all necessary safety measures, release, temporary removal, contractors, group works. Before work beginning the Work Permit must be signed by Autorized Person and Competent Person, taking responsibility for safe work carrying out. Work group members and contractors must be informed by Competent Person accordingly. In common case it is recommended some compulsory rules, which ensure safety of works: identification of the work location, equipment disconnection and securing against reconnection, protection against any other live parts, proving the installation is dead, carrying out earthing and short-circuiting. In this list of safety rules the “securing against reconnection” means to provide “Tag Out – Lock Out” measures, depending of specific work and including procedure as follows: preparation for equipment shutdown, shutdown and verification, equipment isolation, lock out or tag out devices application, stored or residual energy relived, verification of isolation. All listed operations are carrying out only by competent persons after permission of Autorized Person in accordance with procedures, pointed out in the signed Work Permit. Before any work begins on machines or equipment that have been locked out or tagged out, an Authorized and Competent Persons must verify that the machine or equipment has been properly isolated and de-energized.

On work completion the HV equipment components must be installed in place, doors and covers put in closed position, ES disconnected, interlocks restored. Work group must leave working place and have been informed about Work Permit is cancelled.

All above mentioned is explained and demonstrated for Course participants as oral lecture information, presentations and short video. Then received knowledge is consolidated and improved by practical exercise on the real HV MSB simulator panels. Course practical part include: preparation and filling of Electrical Work Permit; Risk Assessment; familiarizing with manuals, drawings, components characteristics; working equipment parameters observation; carrying out disconnection, isolation, lock out and tag out operation, Safety Rules sequence, using accessory tools and PPE; opening HV compartments doors; inspection: interior apparatus, VCB, HV Soft starter power and LV circuits; familiarizing with Protection Relay SEPAM and Soft starter PLC functions; familiarizing with some of maintenance, testing, trouble shooting operations. On the completion of the Course the participants takes the examination, including answers for theoretical and practical questions, which allows to evaluate their competence in subject.

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SCENARIO BASED ASSESSMENT METHOD FOR ENGINE ROOM SIMULATOR COURSES

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Abstract: Education of engine crews is important, due to reduced number of persons on the ship. Especially, importance of education shows up at the engine room emergencies. Engine room simulator is an effective tool for the education of engine room officers, which provides close to real engine room atmosphere with real failures in the engine room. In addition to the education, engine room simulators can be an effective evaluation tool. Students can be evaluated while doing scenario, and their strong and weak sides can be determined. In this study, scenario based assessment method was formed, and used for the evaluation of the students at the engine room simulator course. Behavior, leadership, communication skill, and operational capability criteria with their sub-criteria were evaluated at the cold ship scenario. Assessment method showed strong and weak sides of the students. This study confirms that scenario based assessment method can be a good tool to evaluate the students at various scenarios.

Keywords: assessment method, human behavior, teamwork, communication, operation.

Nowadays engine crew number on ships is reduced, due to modernization of ships from mechanical based engine rooms to automation engine rooms. Reduction of engine crew imposes more workload to each engine crew. This workload increases at emergency situations in short time with limited crew number. Previous analyses show that 90% of engine room breakdowns are the reason of human factor [1]. It is important that, adapting to the operations in engine room, students of engine department have to get adequate education before they start to work on ships.

Engine room simulator is an essential part of adequate education of the students. Engine room simulator provides students to gain practical experience, to face with real failures and situations which engine crew face with on ship.

Evaluation of human character in routine and emergency situations, and evaluation of student knowledge with engine room simulator is another essential part of adequate education. By the evaluation results, students can see their strong and weak sides in routine and emergency situations. Lecturers can give advice to the students to go towards to their weak sides, and this provides more complete learning, and self-improvement.

There are many studies in the literature by using engine room simulator as education tool, assessment tool, or education evaluation. Deniz et al. [2], did study about the application of computer based training for seagoing engineers. They used Norcontrol PPT 2000 full mission engine room simulator for their study. Heavy fuel oil system at engine room simulator was used for to see the teaching and learning process on engine room simulators. Tsoukalas et al. [3], did another study about the pedagogical evaluation of the educational system for an engine room simulator. They also used Norcontrol PPT 2000 full mission engine room simulator, and they found that engine room simulator is an important tool for the practical exercise of trainers. Zincir and Dere [4], have study about training of engine officers for liquefied natural gas (LNG) fuelled ships. They formed simulator training program, and indicated what kind of additions should be made to a full mission engine room simulator for effective training of engine officers at engine room simulator classes before they do voyage on LNG fuelled ships. Laskowski et al. [1], have a study about using a full mission engine room simulator as a tool for environmental education of marine engineers. They wanted to show effects of fuel – water emulsion, which is a NO_X reduction method, to students on Kongsberg Neptune MC90-IV engine room simulator. Kandemir et al. [5], did a study about investigation of competency of engine room simulators to analyze human reliability. As a result of their study, they found that engine room simulators are effective tool to conduct human reliability analysis.

It can be understand from the previous studies that engine room simulator is an effective education and evaluation tool. In this study, scenario based assessment method was formed and used to evaluate students. Basic engine room simulator scenario was formed, and assessment of students with various criterions was made at the certain points of the scenario.

SIMULATOR SPECIFICATIONS AND SCENARIO

Evaluation of students with scenario based assessment method was done at Norcontrol PPT 2000 full mission engine room simulator. Mimic panel and engine control room of the simulator was used at the study. Table 1 shows specifications of engine room simulator, and Figure 1 and 2 shows engine control room and mimic panel of the engine room simulator respectively.

For this study, basic simulator scenario is formed to evaluate students. Basic simulator scenario assesses basic knowledge of students about engine room systems, and their behavior and communication skills while preparing these systems to work. At this scenario, ship is at cold ship position which is the state that all engine room systems are not working. According to the scenario, ship is a new building ship is delivered by shipyard, and engine crews prepare the ship for departure from shipyard. They are going to start emergency generator for deliver electricity to necessary areas and equipments. After that they are going to start sea water system, fresh water system, and compressed air system. Lastly, they are going to start diesel generator and give electricity to ship completely.

Table 1. Specifications of engine room simulator[6]

Ship Particulars	
Length overall	295.00 m
Breadth moulded	32.00 m
Draught	12.60 m
Deadweight	55,000 tons
Twenty foot equivalent unit (TEU)	4200
Speed	25 knots
Main Engine Data	
Type	Sulzer RTA84C
Cylinder bore	840 mm
Piston stroke	2400 mm
Number of cylinders	12
Number of turbochargers	3
Continuous service rating of main engine	48,600 kW
Corresponding engine speed	102 RPM
Mean indicated pressure	17.9
Scavenge air pressure	2.4
Turbine speed	9500 RPM
Propeller type	Fixed
Number of propeller blade	5
Propeller pitch	0.9 P/D
Specific fuel oil consumption	171 g/kWh
Fuel type	730 cSt (50ºC)

Figure 1. Engine control room of full mission engine room simulator

Figure 2. Mimic panel of full mission engine room simulator

According to this scenario exercise, there are five scenario objectives. These are starting of emergency generator, line up sea water system, line up fresh water system, line up compressed air system, and start up and connect diesel generator.

Scenario exercise is executed by three engine crews, chief engineer, first engineer, and second engineer. For this scenario, chief engineer is selected as experienced student who gets engine room simulator classes before, did exercise at mimic panel, and has not done his long term sea training yet. First engineer is selected as lesser experienced student who gets engine room simulator class before, did lesser exercise at mimic panel, and has not done his long term sea training. Second engineer is selected as experienced at workstation computers, but did not done exercise at mimic panel, and has not done his long term sea training yet.

SCENARIO BASED ASSESSMENT METHOD

In this study, there are four main criteria, and their sub-criteria. Main criteria are behavior, leadership, communication skill, and operational capability. Main criteria with their sub-criteria are shown at Table 2. These sub-criteria are evaluated at each scenario objectives which were mentioned at previous section.

Table 2. Assessment criteria and sub-criteria

Behavior
(A1) Judgment
(A2) Self-confidence
(A3) Decision making
(A4) Automation
(A5) Concentration
(A6) Stress
Leadership
(B1) Management
(B2) Encouragement
(B3) Cooperation
(B4) Coordination
Communication Skill
(C1) Attitude while communication
(C2) Clear and effective communication
(C3) Using marine & engineering phrases
(C4) Communication at engine room emergencies
Operational Capability
(D1) Electric generation system knowledge
(D2) Electric power plant knowledge
(D3) Sea water system knowledge
(D4) Fresh water system knowledge
(D5) Compressed air system knowledge
(D6) Diesel oil system knowledge

Judgment means correct thinking and action while preparing systems. Self-confidence is does student make action hesitantly or certainly. Decision making assesses does the student give correct decisions or does not. Automation means does the student decisions be as their reflex or does not. Concentration evaluates the focus of the students while executing simulator scenario. Stress evaluates the level of pressure on the student. Management is how the student controls the situation. Encouragement judges students level of encouragement to other students. Cooperation means does the student cooperate with other students or do works on his/her own. Coordination is the level of coordination while doing scenario. Management, encouragement, cooperation, and coordination are the criteria for chief engineers. Attitude while communication evaluates attitude between the students while doing communication with communication equipment or face to face. Clear and effective communication evaluates simplicity and effectiveness of the communication. Using marine & engineering phrases is important while communicating in the engine room. Communication at engine room emergencies evaluates the communication quality at emergency situations. Electric generation system knowledge, electric power plant knowledge, sea water system knowledge, fresh water system knowledge, compressed air system knowledge, and diesel oil system knowledge criteria evaluate level of knowledge of the students about these systems.

Evaluation points are given to students for each sub-criterion at scenario objectives. These points are given from 1 to 5. 1 refers for very bad, 2 is bad, 3 is average, 4 is good, and 5 is excellent.

After the evaluation of sub-criteria at certain scenario objectives, all points for these sub-criteria are summed, and normalized. This value shows us the final assessment point of the sub-criteria. To calculate criteria assessment point, arithmetic mean of sub-criteria points related with criteria is calculated, and assessment points of main criteria are found. It is assumed for this scenario that below 0.6 is unsuccessful.

SIMULATOR EXCERCISE AND ASSESSMENT RESULTS

Before starting to the scenario, information about the simulator scenario was given. Information was what the scenario is about, what is their task, what is the initial condition of the scenario, scenario duration. Table 3 shows the information about the scenario.

Table 3. Scenario information

Name of The Scenario
Starting engine room systems from cold ship position
Objective
Safe operation of auxiliary machinery
Scenario
New vessel is delivered from the shipyard. Systems have to be started from cold ship position. Firstly electric should be given to the ship by starting diesel generator and connect to the main bus bar
Initial Condition
Cold ship
Duration
One hour
Scenario Tasks
Starting of emergency generator Line up sea water system Line up fresh water system Line up compressed air system Start up and connect diesel generator to main bus bar

After giving briefing to the students about the simulator scenario, roles for the scenario were given to the students, and it was allowed them to take a round of the engine room space.

At the beginning of the scenario, the student who is in role as chief engineer was at engine control room. It was said that his duty is to watch other engine crews, warn them or assist them if they need. Mostly he has to stay at engine control room, and use communication equipment to give orders or assist them. But if engine crews need additional help, he can enter to the engine room, and assist them. He can check the engine room parameters and ongoing scenario from the computer, but cannot intervene to the scenario from the computer. One observer was at the engine control room to observe chief engineer while the scenario.

Other students were in the roles as the

first engineer and second engineer. They had to be in the engine room. They did the operation on the mimic panel. They did not allow entering into the engine control room except starting emergency generator, and connecting diesel generator to the main bus bar. They had to communicate with chief engineer from communication equipment. Another observer was in the engine room, and he observed both the first engineer and second engineer.

Students begun with try starting emergency generator which was their first scenario task. After short conversation they started emergency generator and connected to the emergency bus bar. At their second scenario task, they started sea water system without any hesitation. While their third scenario task of line up fresh water system, first and second engineers could not find place of some valves, as a consequence chief engineer entered into engine room to help them. At their forth scenario task of line up compressed air system, first and second engineers line up the system, but opened some unnecessary valves for this scenario. Chief engineer warned them via communication equipment, and they corrected their error. At their final scenario task of start up and connect diesel generator to main bus bar, first and second engineers lined up fresh water, sea water and lube oil of diesel generator no.1, but while they lined up diesel oil system for diesel generator, they forgot that fuel pump is coupled with diesel generator. Chief engineer also did not notice that. For this reason observer intervene to the scenario, and scenario was continued. After that while students wanted to connect diesel generator to the main bus bar, they could not connect it at the first time, but they did at their second.

Evaluation points were given by the observers while scenario was ongoing. Table 4 to 6 shows evaluation points of chief engineer, first engineer, and second engineer, respectively. O1 to O5 are objectives of the scenario, TP is total point, and NP is normalized points.

Chief engineer was generally good, and got high points especially at decision making, concentration, stress, sea water knowledge, and fresh water knowledge. Most of his points were above average. On the other hand, he had low points at using marine and engineering communication phrases, and communication at engine room emergencies.

Table 4. Chief engineer assessment points

	O1	O2	O3	O4	O5	TP	NP
A1	3	5	4	5	4	21/25	0.84
A2	4	5	4	4	4	21/25	0.84
A3	3	5	5	5	4	22/25	0.88
A4	2	4	4	4	3	17/25	0.68
A5	4	5	5	5	5	24/25	0.96
A6	5	5	4	5	4	23/25	0.92
B1	4	4	5	4	4	21/25	0.84
B2	4	4	5	4	4	21/25	0.84
B3	4	4	3	4	4	19/25	0.76
B4	5	5	3	5	3	21/25	0.84
C1	3	3	3	3	3	15/25	0.60
C2	4	4	4	4	4	20/25	0.80
C3	2	2	2	2	2	10/25	0.40
C4	-	-	-	-	2	2/5	0.40
D1	4	-	-	-	3	7/10	0.70
D2	3	-	-	-	3	6/10	0.60
D3	-	5	-	-	-	5/5	1.00
D4	-	-	5	-	-	5/5	1.00
D5	-	-	-	4	-	4/5	0.80
D6	-	-	-	-	3	3/5	0.60

First engineer mostly had average points during the scenario. His best points were at concentration, clear and effective communication, and sea water system knowledge. On the other hand, he got the worst points from automation, using marine and engineering communication phrases and communication at engine room emergencies.

Second engineer mostly had average and below average points. Concentration and clear and effective communication was given as highest points which were above good. In contrary, he had the lowest points at automation, using marine and engineering communication phrases, communication at engine room emergencies, and fresh water system knowledge.

Table 5. First engineer assessment points

	O1	O2	O3	O4	O5	TP	NP
A1	4	5	2	3	3	17/25	0.68
A2	4	5	3	3	3	18/25	0.72
A3	3	5	3	3	3	17/25	0.68
A4	2	4	1	3	3	13/25	0.52
A5	4	5	4	4	3	20/25	0.80
A6	3	4	2	3	3	15/25	0.60
B1	-	-	-	-	-	-	-
B2	-	-	-	-	-	-	-
B3	-	-	-	-	-	-	-
B4	-	-	-	-	-	-	-
C1	3	3	2	3	3	14/25	0.56
C2	4	4	3	4	4	19/25	0.76
C3	2	2	2	2	2	10/25	0.40
C4	-	-	-	-	2	2/5	0.40
D1	4	-	-	-	3	7/10	0.70
D2	4	-	-	-	3	7/10	0.70
D3	-	5	-	-	-	5/5	1.00
D4	-	-	3	-	-	3/5	0.60
D5	-	-	-	3	-	3/5	0.60
D6	-	-	-	-	3	3/5	0.60

Table 6. Second engineer assessment points

	O1	O2	O3	O4	O5	TP	NP
A1	3	4	2	3	3	15/25	0.60
A2	4	4	2	3	3	16/25	0.64
A3	3	4	3	3	3	16/25	0.64
A4	1	3	1	2	2	9/25	0.36
A5	4	4	3	3	4	18/25	0.72
A6	3	3	2	3	3	14/25	0.56
B1	-	-	-	-	-	-	-
B2	-	-	-	-	-	-	-
B3	-	-	-	-	-	-	-
B4	-	-	-	-	-	-	-
C1	3	4	3	3	4	17/25	0.68
C2	4	4	4	4	4	20/25	0.80
C3	2	2	2	2	2	10/25	0.40
C4	-	-	-	-	2	2/5	0.40
D1	3	-	-	-	3	6/10	0.60
D2	3	-	-	-	2	5/10	0.50
D3	-	3	-	-	-	3/5	0.60
D4	-	-	2	-	-	2/5	0.40
D5	-	-	-	3	-	3/5	0.60
D6	-	-	-	-	3	3/5	0.60

Main criteria of behavior, leadership, communication skill, and operational capability were calculated, according to sub-criteria points of the students. Figure 3 shows the comparison graphs of the students. As before mentioned, below 0.6 was assumed as unsuccessful.

It can be seen from the graph that the students who were the role in the chief engineer and first engineer were successful at behavior criteria with the points of 0.853 and 0.667, respectively. On the other hand, second engineer was unsuccessful with 0.587. The reason can be his unfamiliarity and inexperience with mimic panel, and how to do operation on the panel. This reflected his behavior skills during the simulator scenario.

It can be seen from the graph that there is only one column for leadership criteria. This is because, leadership criteria was only evaluated for chief engineer. Chief engineer was successful at leadership skill with the point of 0.820.

Communication skills of the students were 0.550, 0.530, and 0.570 for chief engineer, first engineer, and second engineer, respectively. All students were assumed as unsuccessful at this criterion. The reason can be their lack of long term sea training. They have not been on a ship before, and they do not know how is a proper communication can be done.

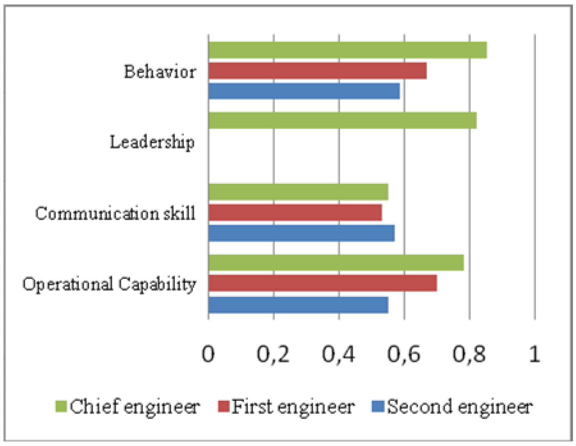

Figure 3. Criteria points of the students

Operational capabilities of the students were 0.783, 0.700, and 0.550 for chief engineer, first engineer, and second engineer, respectively. Second engineer was assumed to be unsuccessful at this criterion. This student has experience with workstation simulator, but has not worked at mimic panel before. This situation can be effected his performance to find the places of the valves, pumps, and other equipments, and caused him getting low evaluation point.

CONCLUSION

This study is about scenario based assessment method for engine room simulator courses. Norcontrol PPT 2000 full mission engine room simulator was used at the study. For assessment method, behavior, leadership, communication skill, and operational capability criteria were determined with their sub-criteria. A basic scenario was formed which started with the cold ship position of the ship. Students had to start the emergency generator, line up sea water system, fresh water system, compressed air system, and diesel generator during the simulator scenario. Three students executed the scenario. One of them was in chief engineer role, and the others were first engineer, and second engineer. Two observers observed and evaluated these students at the mentioned sub-criteria. Results of the evaluation showed that students have strong and weak sides. Weak sides can be the results of lack of sea experience, lack of practice with mimic panel, and lack of familiarity with the systems.

Assessment method was applied on one basic scenario in this study. This assessment method can be applied more complicated scenarios with different engine room emergencies. Criteria and sub-criteria can be changed and various criteria or sub-criteria can be added which are related with the scenario. This study shows that scenario based assessment method can be an effective tool for the evaluation of the students at the engine room simulator courses. More detailed study can be done in the future, for more detailed evaluation.

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COMPUTER SYSTEM FOR DETECTING THE COANDĂ EFFECT WHEN USING ELECTRIC PODDED AZIMUTH THRUSTERS

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Abstract: During position retention of semi-submersible drilling rigs, slow speeding of pipe- cable-laying ships and research vessels, ships with electric podded azimuth thrusters maneuvering in restrained areas a Coandă effect occurs. This effect is characterized by the loss of propeller thrust.

We developed a computer system, which is based on using of piezoelectric sensors that can detect the Coandă effect. The benefits of this system over existing mechanical systems are greater efficiency of propulsive complex due to lower complexity system and lower malfunction probability.

This Coandă effect detection system was installed to experimental multifunctional platform with six electric podded azimuth thrusters. Based on Phoenix Contact equipment we develoed a three level hierarchical software and hardware complex. We designed an algorithm and developed a program in "AUTOMATIONWORX Software Suite" using experimental stands that were developed by a association of universities within TEMPUS 544010-TEMPUS-1-2013-1-DE-TEMPUS-JPHES – "Trainings in Automation Technologies for Ukraine" (TATU) project. Experimental data was received from each electric podded azimuth thruster, when it's boom was bending.

Keywords: safety of navigation, The Coandă effect, an electric podded azimuth thrusters, propulsion complex, piezo transducers.

Nowadays, due to development of shipbuilding technology, electric podded azimuth thrusters (AziPods) are used more often for increasing vessels maneuverability. The major part of operational time of specialized vessels, such as semi-submersible drilling rigs, pipe-cable-laying ships and research vessels consists of position retention or slow speeding on a fixed course. Such vessels equipped with several AziPods that are a part of Dynamic Position System (DP). During position retention of such vessels, DP System is trying to keep the vessel in fixed position despite external factors that are trying to move the vessel from a given course. To achieve this AziPods are turned in opposite directions. In this case, the water flow can be directed under vessel's bottom, that causes the Coandă effect (water stream adhesion to the vessel's hull). In that situation the propeller is trying to bend AziPod's support, causing dislocation of the propeller shaft and uneven wearing of stern tube and thrust bearings. The thrust of the propeller is decreasing as well.

Based on researches [1], there are only mechanical methods that are used to counteract the Coandă effect. ABB Group Company implements tilt angle of AziPod supports of around 4 ^{o} [2]. Another mechanical method is the use of propeller nozzles. In both cases, the water flow deviates from vessel's hull, causing efficiency decrease of all propulsion system.

We developed a computer system that is based on piezoelectric sensors usage that can detect the Coandă effect. The benefit of this system over existing mechanical systems is lower complexity that helps decrease efficiency of the propulsion system and ensures trouble-free operation [3, 4].

Piezoelectric elements (PE) were chosen as sensors. Functional modeling and electric circuit simulation were used to determine optimal parameters of PE sensors. We developed functional models, which help us to find out Amplitude-Frequency Characteristics and Phase-Frequency Characteristics (Fig. 1).

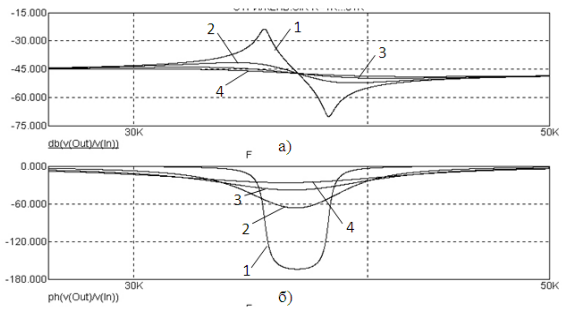

Figure 1. Amplitude-Frequency and Phase-Frequency Characteristics of PE

We conducted system stability analysis with a help of Nyquist criterion. As seen at Figure number 2 piezoelectric sensors are stable systems since Nyquist Hodograph is not crossing negative part of *Re* axis and is located between number 3 and 4 quadrants.

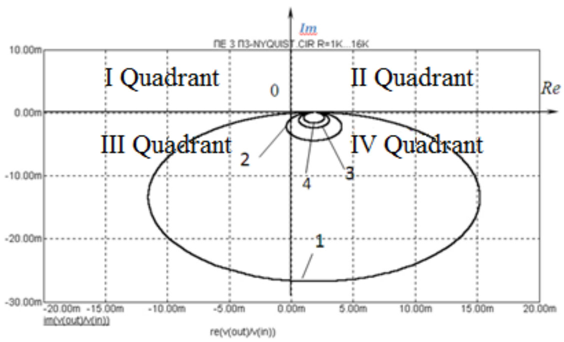

Figure 2. Nyquist Hodograph

Figure number 3 demostrates electric circuit simulation of PE sensors. This model helps to choose optimal shape and dimensions of PE sensors and analyse PE reaction to different forms of physical impacts.

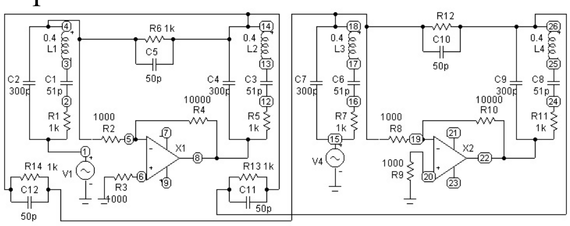

Figure 3. Electric circuit simulation of PE sensors

We developed the structural diagram that consists of three level hierarchical software and hardware system (Fig. 4).

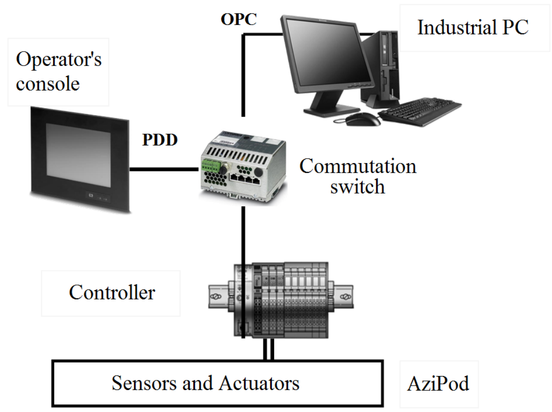

Figure 4. Three level hierarchical structural diagram

PE sensors were integrated into AziPod control system (Fig. 5) that was installed at experimental multifunctional platform with six AziPods [5].

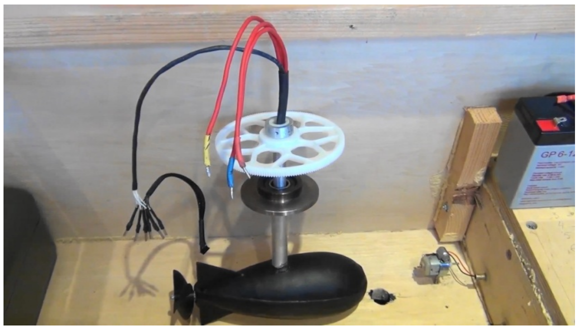

Figure 5. AziPods used at experimental platform

Experimental stand is based on Phoenix Contact laboratory equipment (Fig. 6). We designed an algorithm and developed a program in “AUTOMATIONWORX Software Suite” using experimental stands that were developed by the association of universities within TEMPUS 544010-TEMPUS-1-2013-1-DE-TEMPUS-JPHES – "Trainings in Automation Technologies for Ukraine" (TATU) project [7]. Experimental data was received from each electric podded azimuth thruster when its boom was bending.

Figure 6. Experimental stand based on TEMPUS–TATU equipment

As a result of this research we achieved the following:

1. Based on analysis of AziPods design we found out that AziPod's booms and supports are experiencing similar excessive stress as propeller bearings. This helps us determine the number and location of the sensors.
2. Calculation method developed by us, helps to plot the 3D load graph.
3. There was a computer system developed that detects the Coandă effect and will help Deck Officers and Engineering Officers to react propeller thrust force decrease that can reach up to 15 %.
4. There were models developed and computer system components (transducers) design determined.
5. Experimental stand developed by our team helped us to confirm that our research is correct. It will also help us to integrate computer system for detecting the Coandă effect into the field model of multifunctional platform.

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REAL-TIME PROPULSION PLANT SIMULATION AND HARDWARE IN THE LOOP (HIL) IMPLEMENTATION OF MICROPROCESSOR ENGINE GOVERNOR

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Abstract: For over several decades the propulsion plant control system design has evolved significantly with the introduction of microprocessor-based controllers. Application of information technologies to propulsion plant has brought wide possibilities to control, monitoring and tuning aspects of marine engines. At the same time, marine engineers should demonstrate knowledge and competency in understanding the fundamentals of the electronic control of marine engine processes.

This paper presents a software-hardware tool for evaluation and design of control systems. The tool consists of the real-time simulator of ship propulsion plant and an engine speed governor implemented on a microprocessor controller. One of the main advantages of the developed tool is that it enables to acquire the feel of physical sense in the interaction of propulsion engine and microprocessor control in the real-like conditions of the actual sea which is essential for the training of marine engineers. Furthermore, the proposed simulator gives a possibility to investigate the influence of the governor parameters on engine responses, as well as alternative control algorithms can be developed and evaluated.

Keywords: simulation tasks, propulsion plant, microprocessor control.

1. INTRODUCTION

The contemporary stage of ship propulsion plant automation is characterised by the intensive introduction of microprocessor-based controllers to control the propulsion engines and auxiliary systems. Since introduction in the year 2000 of the first electronically controlled low-speed Diesel engine, the electronic control systems have brought wide possibilities to the control system design. At the same time, the introduction of information technologies to marine engines has raised a number of new problems – the marine engineers can expect not only basic operations such as maintenance, engine manoeuvring, etc. but also should possess extensive knowledge in the fields of computer technologies and electronic means of control. Furthermore, most of the implemented microcontrollers utilise the proprietary software with the algorithms concealed from a user, and this complicates understanding of the control system behaviour by the marine engineers. Thus, the only way to increase marine engineer's awareness of modern means of control is to use the appropriate simulator training.

The simulator is a technical means, designed for the special professional training of operators, complying with the training purposes and tasks and ensuring the increase of efficiency and reduction of the training time. Simulators have been developed for a long time. The latest scientific and technical achievements in the area of technological processes modelling have been used at every stage in order to ensure adequacy of a simulation model to the real object. A great variety of simulating and training means, which uses the sophisticated simulation models and relates to the propulsion plant operation, can be divided into three main types [1]:

- Full Mission (Task) Simulators
- Part Task Simulators
- Computer Based Training System.

The part task simulators combine the software and hardware tools to represent the operation of separate units of the ship propulsion plant. The simulator consists of computer, modelling the functioning of a unit – virtual plant, and real hardware representing the control element. Such the approach is often referred to as hardware in the loop (HIL) simulation.

The HIL test bench has been designed to facilitate understanding the fundamentals of the electronic control of the propulsion plant as well as to bring possibilities in development and optimisation of the control algorithms at the system level. The virtual propulsion plant has been implemented on a system controlled by the real-time operating system (RTOS) using open-source software ScicosLab/RTAI-Lab [2]. The virtual plant simulator is modular and consists of a propeller model, two-stroke low-speed Diesel engine model, and disturbance model representing actual sea behaviour. The simulator communicates with the real world by means of an analog-to-digital converter from National Instruments.

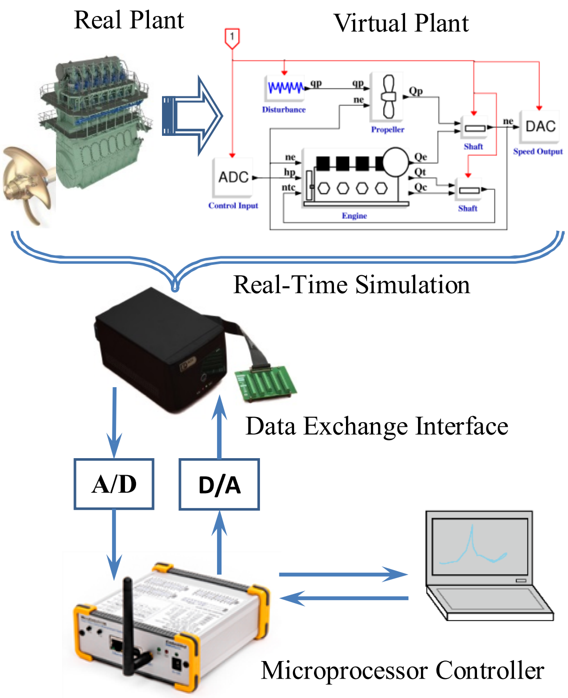


Figure 1. Outline of propulsion plant HIL simulator

The microprocessor controller, based on a MicroDAQ platform [3], is interfaced with the virtual plant realising a control algorithm. The framework of the HIL simulator is shown in Fig.1. The subsequent chapters give the detailed description of the simulator components.

2. PROPULSION PLANT MODEL

The development of propulsion plant simulator is based on the representation of a system as a set of mutually related subsystems. Following the methodology, each element of a complex system is described separately, and then, based on interconnections, the elements are integrated into the total system, suitable for simulation. Thus the considered propulsion plant consists of two main elements – propeller and engine connected through the propeller shaft rotational dynamics:

$$2\pi I_e \frac{dn_e}{dt} = Q_e(x_1, x_2, \ldots, t) - Q_p(x_1, x_2, \ldots, t) \quad (1)$$

where I_e is the joint moment of inertia of rotating parts, reduced to the propeller shaft; Q_e, Q_p are the engine and propeller torques respectively; n_e is the shaft rotational speed.

The dynamic response of propulsion plant depends upon the representation of nonlinear functions that comprise the above equation. In pursuance of obtaining the compact and practical models for torque functions, the objects – engine and propeller have to be processed further by the system analysis to isolate constituent elements and mutual relationships between them.

2.1 Engine Model

The main purpose of the engine model is to capture the major dynamics intrinsic to the real engine at the same time providing that the real-time constraint is preserved. Marine Diesel engine is a complex thermodynamical and mechanical system, composed of the three main units – compressor, cylinder and turbine. Change of operation regime in one of these units causes a change of operation regime of the whole engine. Thus the engine model should be considered as a set of coupled processes taking place in the compressor, cylinder and turbine. Cycle mean-value (CMV) engine modelling approach provides capturing most of the physic phenomena in the engine system components, except for the combustion cycle which is simplified such as to produce average torque and mass/energy flow of combustion gas. The main principle used in the CMV model is the flow similarity of air and exhaust gas through the two throttles: the first one is the cylinder unit; the second is the turbocharger (TCH) turbine. The equations of flow through the throttles together with the equation of fuel mass flow constitute the core part of the model. The general equation of compressible flow through a nozzle orifice can be expressed as follows:

$$G = \mu\widetilde{A}\frac{p_{in}}{\sqrt{RT_{in}}}\Psi\left(\frac{p_{out}}{p_{in}}\right),$$
$$\therefore \Psi\left(\frac{p_{out}}{p_{in}}\right)=\sqrt{\frac{2\gamma}{\gamma+1}\left[\left(\frac{p_{out}}{p_{in}}\right)^{\frac{2}{\gamma}}-\left(\frac{p_{out}}{p_{in}}\right)^{\frac{\gamma+1}{\gamma}}\right]} \quad (2)$$

where $\mu\widetilde{A}$ is the effective area of the corresponding orifice; p_{in}, p_{out} are the pressures across the orifice; T_{in} is the temperature before orifice; γ is the specific heat ratio of corresponding gas.

The fuel mass flow G_f is considered proportional to a fuel pump index h_p as follows:

$$G_f = g_{f0} h_p n_e \quad (3)$$

where g_{f0} is the injection fuel mass per cycle (hereinafter the subscript “0” denotes a Maximum Continuous Rating (MCR) running mode of the engine).

The engine torque, which is necessary to evaluate the propulsion plant dynamics, is produced by indicating mean effective pressure (IMEP) developed in the engine cylinder as the result of fuel combustion, less the pressure due to friction forces:

$$Q_e = \frac{z_c V_s}{2\pi}\left(P_i - P_f\right) \quad (4)$$

The pressure of friction forces P_f is simply an empirical function of engine speed; the coefficients can be found from the engine operation data.

The IMEP can be considered proportional to the fuel pump index:

$$P_i = h_p \eta_c P_{i0} \quad (5)$$

However, the proportionality between IMEP and fuel pump index ceases to hold if air-to-fuel ratio drops below the certain limit. Such the situation may often occur during fast and large transients due to so-called turbo-lag. Concerning this nonlinear effect, combustion efficiency η_c is introduced to the model:

$$\eta_c = 1 - 1.1\, e^{-(1.2\alpha)^2}, \quad \therefore \alpha = \frac{G_a}{L_0 G_f} \quad (6)$$

where L_0 is the stoichiometric air-to-fuel ratio; G_a is the air mass consumption of the engine.

The air necessary for combustion is supplied from the compressor which is driven by the turbine transforming the energy of exhaust gas to mechanical energy. Thus the engine simulation loop is closed through the simulation of a turbocharger unit.

The torque delivered by the turbine is defined as:

$$Q_T = \frac{\eta_{iT} C_{pe} T_e G_e}{n_{tc}}\left(1-\left(\frac{p_0}{p_e}\right)^{\frac{\gamma_e - 1}{\gamma_e}}\right) \quad (7)$$

The torque absorbed by the compressor is defined as:

$$Q_C = \frac{C_{pa} T_s G_c}{\eta_{iC} n_{tc}}\left(1-\left(\frac{p_s}{p_a}\right)^{\frac{\gamma_a - 1}{\gamma_a}}\right) \quad (8)$$

In a marine application where the engine is loaded according to the propeller law, the compressor operating points lay on a single curve, and thus the compressor efficiency η_{iC} can also be assumed constant. On the contrary, the turbine efficiency η_{iT} is taken as a function of the ratio of blade tip velocity to theoretical gas velocity [4].

As the result of compression the temperature of air increases, and using the definition of compressor efficiency [5], the following equation for temperature has been derived:

$$T_c = T_a\left[\frac{1}{\eta_{iC}}\left\{\left(\frac{p_c}{p_a}\right)^{\frac{\gamma_a - 1}{\gamma_a}} - 1\right\} + 1\right] \tag{9}$$

In order to keep the density of scavenging air as high as possible, an air cooler is installed between compressor output and air receiver, which is modelled as follows:

$$T_s = T_{cw} + k_{ac}(T_c - T_{cw})\left(\frac{G_c}{G_{c0}}\right)^{\frac{1}{3}} \tag{10}$$

where T_{cw} is the cooling water temperature, p_a, T_a are the ambient air parameters, k_{ac} is the air cooler constant.

The TCH rotational speed n_{tc} is calculated from the equation of shaft dynamics:

$$2\pi I_{tc}\frac{dn_{tc}}{dt} = Q_T - Q_C \tag{11}$$

where I_{tc} is the joint moment of inertia of the turbine and compressor.

Last but not least components of the engine model are scavenging and exhaust gas flow receivers which interface the flow elements: compressor, cylinder unit and turbine. Applying mass and energy balances on flow receiver element and assuming ideal gas law, the following model of exhaust gas receiver is obtained:

$$\begin{aligned}
\frac{dm_{er}}{dt} &= G_a + G_f - G_e \\
\frac{dT_e}{dt} &= \frac{\gamma_e}{m_{er}C_{pe}}\left(G_a C_{pa} T_s + G_f H_u \xi_a\right) \\
&\quad - \frac{T_e}{m_{er}}\left(\gamma_e G_e + \frac{dm_{er}}{dt}\right) \\
p_e &= \frac{m_{er} R_e T_e}{V_{er}}
\end{aligned} \tag{12}$$

where C_p is the specific heat capacity of corresponding gas, R_e is the exhaust gas constant, V_{er} is the volume of receiver.

The important point to be considered in the above equation is the proportion of fuel energy remained in the exhaust gas, denoted by ξ_a, and expressed as a linear function of IMEP in the following form [6]:

$$\xi_a = k_1 P_i 10^{-5} + k_2 \tag{13}$$

For the scavenging air receiver, it is more convenient to write equations with respect to pressure, assuming that the temperature T_s is constant as the intercooler governs it:

$$\frac{dp_s}{dt} = \frac{\gamma_a R_a T_s}{V_{sr}}(G_c - G_a) \tag{14}$$

However, this approach requires an evaluation of mass flow G_c from the compressor performance map, which is often unavailable. In the direction of overcoming this difficulty, it is proposed to use dummy dynamic of the scavenging air receiver expressed by a first order lag system:

$$\frac{dp_s}{dt} = \frac{1}{T_{sr}}(p_c - p_s), \quad \therefore T_{sr} = \frac{V_{sr}}{\gamma_a R_a T_s} \tag{15}$$

where T_{sr} is the time constant of the air receiver, R_a is the air gas constant, V_{sr} is the volume of receiver; p_c is the pressure developed by the compressor and it is assumed to be fully determined by the compressor rotational speed [7]:

$$\frac{p_c}{p_a} = \left[\left\{\left(\frac{p_c}{p_a}\right)_0^{\frac{\gamma_a - 1}{\gamma_a}} - 1\right\}\left(\frac{n_{tc}}{n_{tc0}}\right)^2 + 1\right]^{\frac{\gamma_a}{\gamma_a - 1}} \tag{16}$$

2.2 Propeller and Disturbance Models

For a ship propeller, of the fixed pitch type, the torque is calculated using the standard open-water coefficients, as follows:

$$Q_p = K_Q \rho_w n_e^2 D_p^5 \tag{17}$$

The torque coefficient K_Q is usually represented as a set of curves measured for a range of propeller advance ratio J_p. Thus, approximating the K_Q – curve by a second order polynomial, the torque can be written explicitly as a function of inflow velocity U_p and shaft rotational speed n_e as follows:

$$K_Q = c_{q1} + c_{q2} J_p + c_{q3} J_p^2, \quad \therefore J_p = \frac{U_p}{n_e D_p}$$

$$\begin{aligned} Q_p = &\left(c_{q1} \rho_w D_p^5\right) n_e^2 \\ &+ \left(c_{q2} \rho_w D_p^4\right) n_e U_p \\ &+ \left(c_{q3} \rho_w D_p^3\right) U_p^2 \end{aligned} \tag{18}$$

The inflow velocity relates to the propeller speed of advance, i.e. ship speed. However, in the development of HIL simulation of propulsion plant, the dynamics of the ship hull was neglected, and attention was focused on the propeller-engine interaction disturbed by waves. Thus, following the method of perturbation analysis, the value of U_p is decomposed to a steady-state and fluctuating parts as follows:

$$U_p = U_{p0} + u_p(t) \tag{19}$$

The steady-state value U_{p0} can be obtained from the equilibrium condition of engine and propeller torques, selecting the shaft rotation speed arbitrary according to the engine characteristics. The time-varying component $u_p(t)$ of inflow velocity is the result of the disturbed velocity field due to waves and ship motions, and since the dynamics of hull is neglected, only wave component is considered:

$$u_p(t) = u_w(t) \tag{20}$$

Here, $u_w(t)$ denotes component due to the orbital motion of waves, and this can be computed from the velocity potential of waves in the following form for the head sea condition [8]:

$$\begin{aligned} u_w(t) &= -C_w \zeta_a \omega e^{-k z_p} e^{i k x_p} e^{i \omega_e t} \\ C_w &= 1 - 0.754 \left| \cos \chi \right| e^{-0.634 \frac{\lambda}{L}}, \quad \therefore \chi = 180^\circ \end{aligned} \tag{21}$$

where ζ_a is the incident wave amplitude, with the reduction coefficient C_w applied at the stern, x_p, z_p are the coordinates of the position of the propeller with respect to the centre of gravity, k is the wave number, λ/L is the ratio wavelength to ship length.

Now, making use of eqs (18), (19) and (21) the propeller torque fluctuation due to waves can be computed for a particular wave frequency ω. Ocean waves are an essentially stochastic phenomenon, however. Thus, it is of practical interest to obtain a deterministic record of the random propeller torque fluctuation due to actual waves. This can be done by summing up a large number of elementary wave components according to:

$$u_p(t) = \sum_{n=1}^{N} u_{pn} \cos(\omega_n t + \varepsilon_n) \tag{22}$$

The amplitudes u_{pn} can be determined, knowing that the area under the associated segment of the energy spectrum $S_{u_p}(\omega)\Delta\omega$ is equal to the variance of the concerned variable, so that:

$$u_{pn} = \sqrt{2 S_{u_p}(\omega) \Delta\omega} \tag{23}$$

The phase angle ε_n is the uniformly distributed random variable in the range $(0, 2\pi)$. The N-2 randomly chosen frequencies is generated using the random frequency interval $\Delta\omega$ [9]:

$$\omega_k = \omega_1 + g_{rnd}(\omega_N - \omega_1), [k = 2, N-2] \tag{24}$$

where g_{rnd} is the random number in the range $(0, 1)$.

The energy spectrum of inflow velocity S_{u_p} can be obtained as a response of the linear time-invariant system to a random input in the frequency domain as follows:

$$S_{u_p}(\omega) = \left| H_{u_p}(\omega) \right|^2 S_{\zeta_a}(\omega) \tag{25}$$

where the response amplitude function of inflow velocity is simply the time-invariant part of eq. (21), defined as follows:

$$H_{u_p}(\omega) = \frac{u_w}{\zeta_a} = -C_w \omega e^{-k z_p} e^{i k x_p} \tag{26}$$

For the wave spectrum $S_{\zeta a}(\omega)$, the standard ITTC type spectrum can be used.

In this way, real-like time histories of propeller torque fluctuation in the actual sea can be obtained. The time histories preserve the statistical characteristic of the wave spectrum.

2.3 Control System Model

The speed governor is an integral part of the engine and propulsion plant. Apart from the primary function of maintaining the pre-set propeller rotation speed it also ensures the safe operation of propulsion plant. The governor is intended to prevent engine overload in case of heavy operating conditions which usually occur in rough sea conditions. In the developed HIL simulator it is possible to implement any controller if the algorithm can be described in input-output relationships. However, for the purpose of present development, the model of a well-known and classical mechatronic governor of Woodward PG type has been implemented. The functional block diagram is shown in Fig. 2. The linear part of the governor's dynamic can be represented in state-space form as demonstrated by Eq. (26).

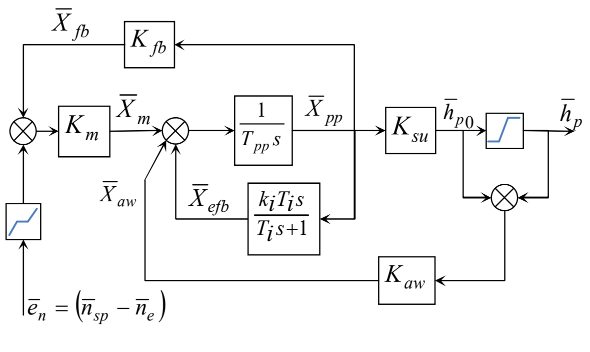


Figure 2. Governor functional block diagram

$$[\dot{\mathbf{x}}] = \mathbf{Ax} + \mathbf{Bu},\ \mathbf{x}^{\mathrm{T}} = [\bar{X}_{pp}, \bar{X}_{efb}],\ \mathbf{u}^{\mathrm{T}} = [\bar{e}_n, \bar{X}_{aw}]$$
$$[\mathbf{y}] = \mathbf{x} \tag{26}$$
$$\mathbf{A} = \begin{bmatrix} -\frac{K_{fb}K_s}{T_s} & -\frac{1}{T_s} \\ -\frac{K_i K_{fb} K_s}{T_s} & -\frac{K_i T_i + T_s}{T_s T_i} \end{bmatrix},\ \mathbf{B} = \begin{bmatrix} \frac{K_s}{T_s} & \frac{K_{aw}}{T_s} \\ \frac{K_i K_s}{T_s} & \frac{K_i K_{aw}}{T_s} \end{bmatrix}.$$

Besides the governor includes nonlinear elements such as a speed sensor dead-band and an output limit. The limit is governed by a torque limiter function (TLF). The TLF aimed at preventing the engine from thermal and mechanical overloads setting the maximum fuel injection amount as a function of present engine rotational speed. The characteristic of TLF, implemented in HIL simulator, is shown in Fig. 3.

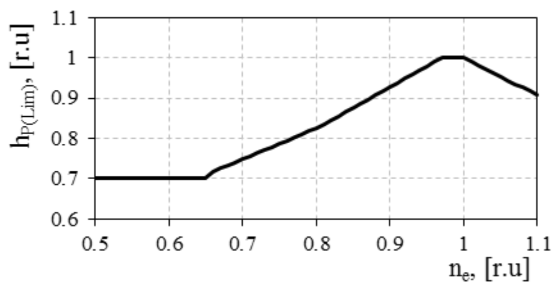


Figure 3. Fuel pump rack limit as a function of normalised engine rotational speed

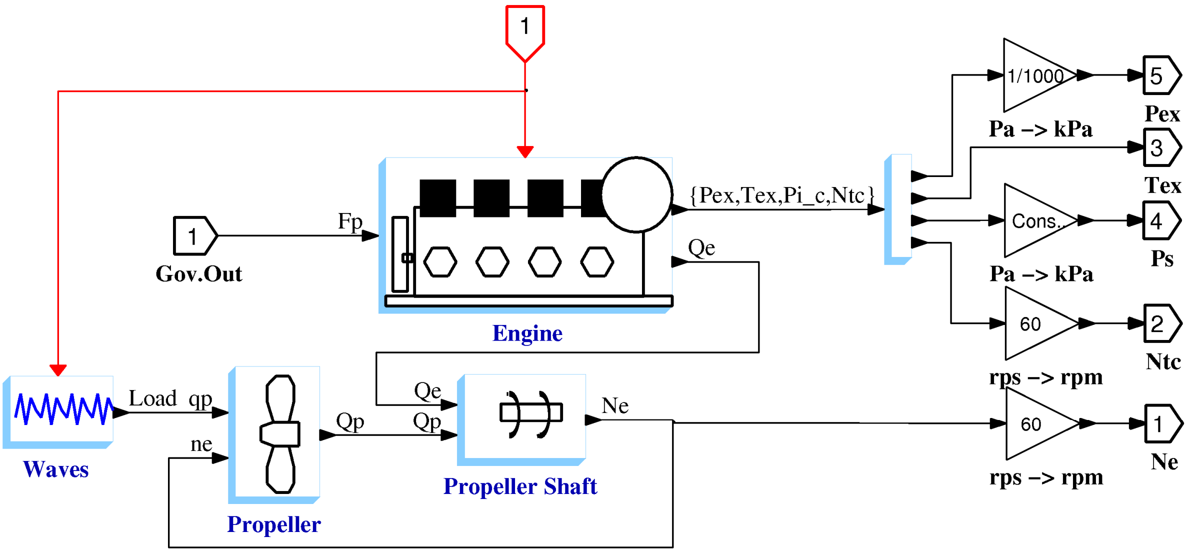
3. HARDWARE IMPLEMENTATION

3.1 Real-time virtual plant

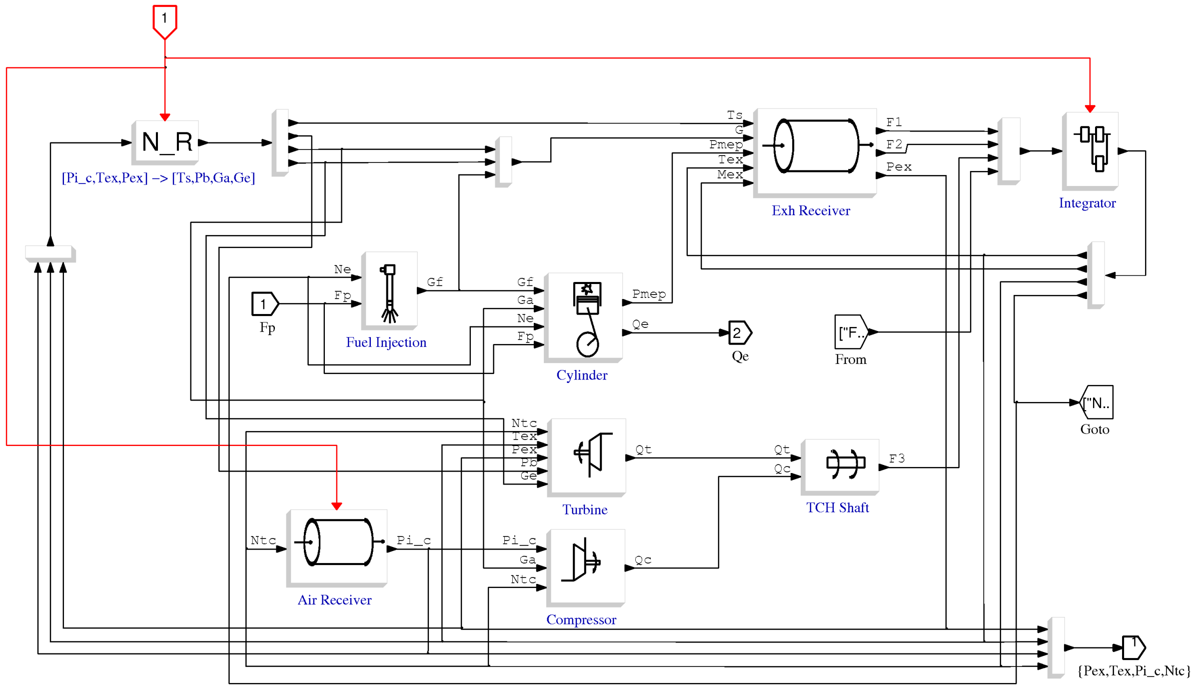
As was mentioned earlier, the open source real-time platform RTAI-Linux is used to simulate the developed model of propulsion plant. An integrated development environment (IDE) ScicosLab is used to realise the mathematical model. Figure 4a shows the top level of the virtual plant, the details of engine block is shown in Fig. 4b. The IDE is aimed at simulation of the virtual plant as well as the executable code for RTOS target can be generated and compiled straight from the graphical environment. The resulted executable code is able to provide correct engine states in strict time requirements – the states are updated every 0.005 seconds (200 Hz). Furthermore, the virtual plant is in charge of reading/writing analogue signals at the terminals of the acquisition card.

3.2 Microprocessor controller

Nowadays dozens of small single-board computers with an embedded microcontroller are available on the market. The well-known and the most popular platforms are the Raspberry Pi and Arduino.



a) Propulsion plant top level



b) Engine model block

Figure 4. Propulsion plant realised in the IDE ScicosLab

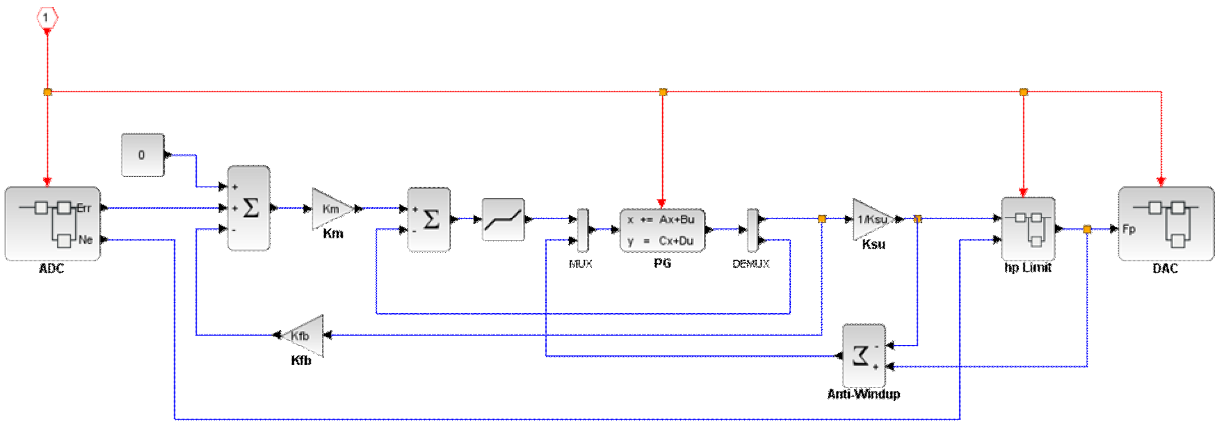


Figure 5. Governor model realised in the IDE SciLab/Xcos

For the purpose of controller development and virtual plant interface, however, the less popular MicroDAQ platform has been selected, mainly due to the full integration with the open-source Scilab/Xcos IDE. The MicroDAQ device combines Texas Instrument digital signal processor (TI DSP) for floating/fixed point operations, numerous analogue/digital input/output channels and ARM processor core for communication and system control. As in the case of the virtual plant, the controller model is constructed in the graphical environment using standard blocks, and then it can be directly simulated, or real-time executable code can be generated and executed on the TI DSP under the control of RTOS. Figure 5 shows the governor model realised in the IDE.

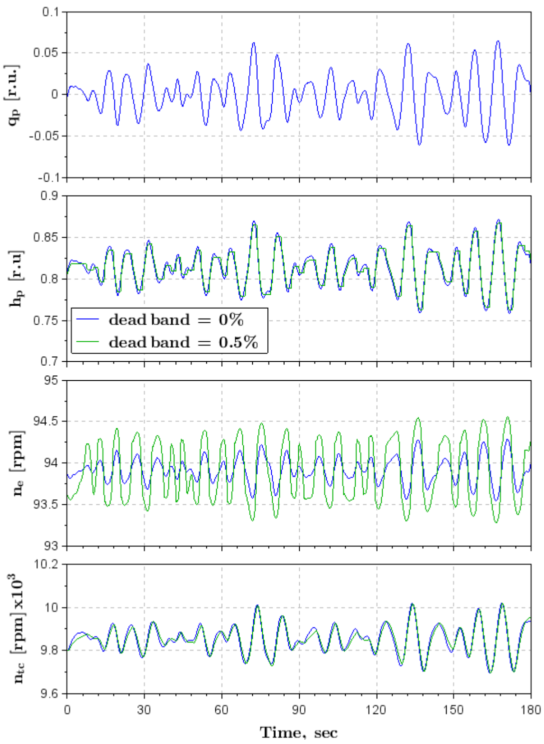


Figure 6. Propulsion plant responses in actual sea with different dead-band settings

4. CONCLUSION

The HIL test bench of propulsion plant has been developed and realised in this work. The fundamental part of the setup is the utilisation of open-source RTOS and IDE software providing the effective framework for studying and testing the propulsion plant behaviour in actual sea conditions with different control algorithms without costly investments. Figure 6 shows an example of propulsion simulator utilisation, where the effect of dead-band width on the engine and control system responses are compared. Furthermore, the various parameters of the virtual plant and controller can be modified online with the effect become visible immediately.

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PLC-BASED SHIP'S ELECTROMECHANICAL SYSTEMS LABORATORY

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Abstract: This article discusses practical preparation of marine engineers on the PLC-based ship's electromechanical system laboratory, which is the part of the full mission simulator complex of the Ship's Automated Electrical Power Plant.

Modern tendencies in automation of ship power and electromechanical systems require a high level of cadet training to ensure the successful solution of complex tasks of control and automation systems operation and maintenance. The article focuses on the possibilities and methods of laboratory equipment usage, based on Mitsubishi Electric modern programmable logic controllers FX 3U and Alpha 2, inverters FR-E700 and graphic operation terminals GOT 1000, in the National University "Odessa maritime academy" educational process for order to improve the quality of marine electro-technical officers and marine engineers and to meet the growing demands of employers.

Keywords: programmable logic controller, inverter, graphic operation terminal, networks, process modelling, electromechanical systems, training.

Electrical equipment and automation facilities of a modern vessel are characterized by high energy saturation and a high level of automation based on modern computer control technologies. Modern tendencies in automation of ship power and electromechanical systems require a high level of cadet training to ensure the successful solution of complex tasks of control and automation systems operation and maintenance. The National University "Odessa maritime academy" educational process for order to improve the quality of marine electro-technical officers and marine engineers and to meet the growing demands of employers was created the authorized teaching center Mitsubishi Electric and the laboratory complex of six automated Electromechanical systems (see Fig. 1) based on programmable logic controllers and frequency converters.

PLC-based electromechanical system laboratory (see Fig. 5) is the part of the innovative simulator complex, equipped with the most advanced means of shipboard and industrial automation such as programmable logic controllers (PLC), variable frequency drives (VFD), operator panels(human machine interface, HMI) and network communication equipment (Fig. 1).

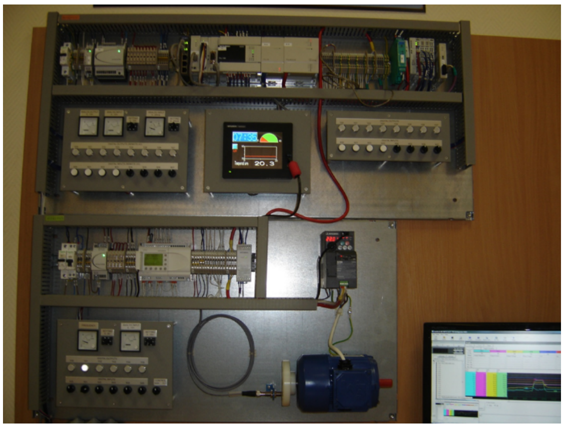

Figure 1. One of six laboratory stand

Connection diagram of the laboratory stand is presented on Fig. 2.

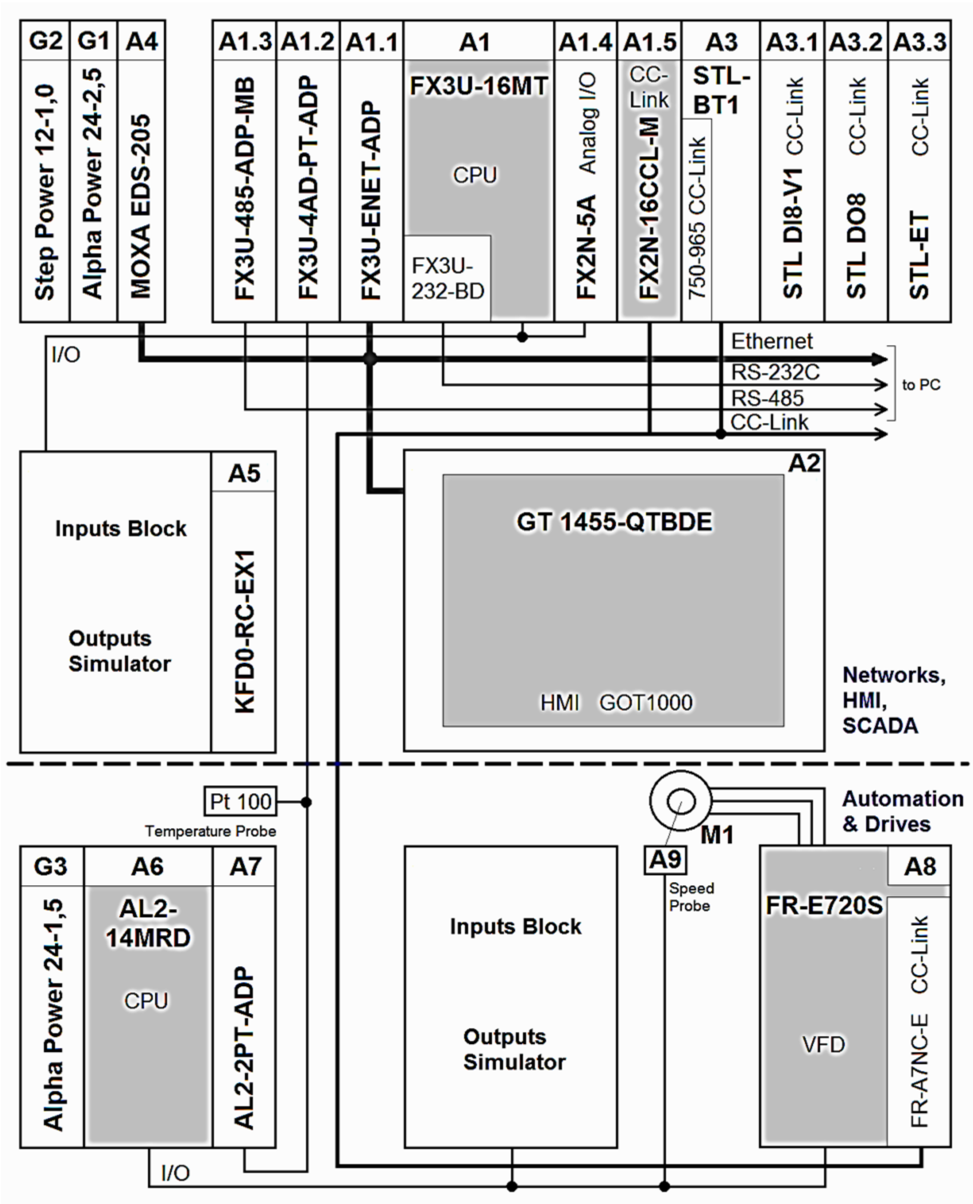

Figure 2. Connection diagram of the laboratory stand

Now we will plane to supplemente each laboratory stand by PLC-adjustable load for asynchronous motors, which to modelling on the motor shaft the load of different ship's mechanisms, Fig.4. To this end, we will use the following MEROBEL torque control products (see Fig. 3):

1. EMP (Electro-Magnetic Particle) Through Bore Brake, model FAT 50;
2. Torque sensor TRS 05;
3. WEB Tension Controller DGT 300+;
4. Power Supply, model PowerBlock2.

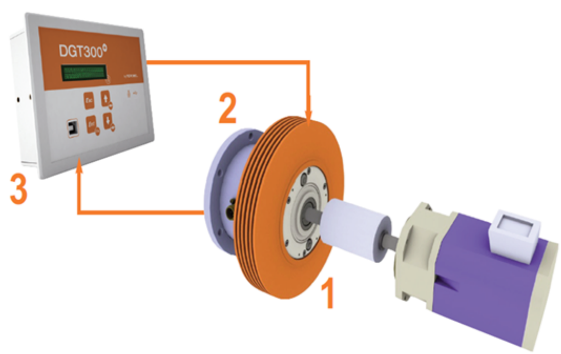

Figure 3. Resistant torque control principal

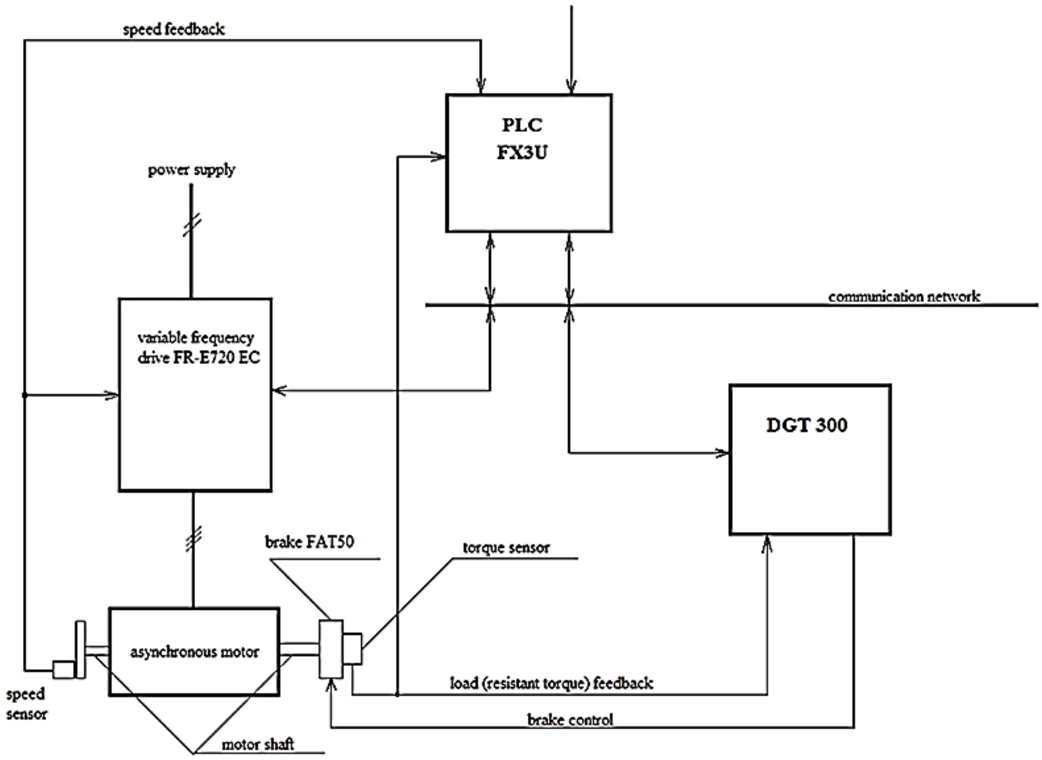

Figure 4. Functional diagram of the motor shaft load simulator (resistant torque)

Figure 5. Electromechanical systems laboratory

Main idea and tendency during design and realizing of this project was: only actual ship equipment and control systems with maximal approach to nowadays configuration should be used for practical education of marine engineers and ETO.

Electromechanical systems laboratory - actually functioning, and as close as possible to the modern configuration of shipboards control equipment and means of automation meets the requirements of standards that define the use of simulators (Section A-I/12, Part 1 - performance requirements), STCW 78 with Manila Amendments.

The laboratory fully provides training for shipboard electro-technical officers (ETO) and marine engineers in terms of practical skills in the operation of modern electrical equipment and automation equipment in accordance with the International Convention STCW 78 with Manila

Amendments.

Educational-laboratory stands on the composition, functional capabilities, educational-laboratory tasks can be divided into two, to a certain extent, autonomous parts with the conventional names "Automation and drive" and "Networks, HMI, SCADA" (Fig. 2):

- a simple PLC Mitsubishi Alpha 2 and variable frequency drive, which includes a Mitsubishi inverter E700 series and induction motor;
- compact modular PLC Mitsubishi FX3U with network modules Ethernet and CC-Link, temperature sensors processing module, combined analog input / output module and graphical operator panel GOT 1000.

To build a hierarchical structure, both parts are connected together via an Ethernet network. In addition, the FX3U and VFD are directly connected via the CC-Link network.

The part of the laboratory stand "Automation and drive" includes:

- PLC Mitsubishi AL2-14-MRD, containing eight discrete-analog inputs and six contacts type discrete outputs;
- Power supply unit Mitsubishi Alpha Power-24-0,75;
- Mitsubishi inverter FR-E720S-030SC-EC;
- Induction motor AIRM 63IVU2;
- The input-output signals panel.

The second part of the laboratory stand "Networks, HMI, SCADA" includes:

- Mitsubishi FX3U-16MT / DSS programmable logic controller with FX3U-232-BD interface card and sixteen discrete I/O channels;
- Four inputs and one output combined analog I/O module with Mitsubishi FX2N-5A;
- Ethernet adapter Mitsubishi FX3U-ENET-ADP;
- Communication adapter for RS485 and Modbus RTU/ASCII protocols Mitsubishi FX3U-485ADP-MB;
- CC-Link network communication module Mitsubishi FX2N-16CCL-M;
- object communication module Mitsubishi STL-BT1 with expansion modules for inputs and outputs;
- operator panel Mitsubishi GT1455-QTBDE;
- Mitsubishi temperature measuring module FX3U-4ADP-PT-ADD with temperature sensor Pt 100;
- the potentiometer position transmitter to the current loop signal Pepperl + Fuchs KFD0-RC-EX1;
- Ethernet module MOXA EDS-205;
- Power supplies Mitsubishi Alpha Power-24-2,5 and Phoenix Contact Step Power-12-1,0;
- Input-output signals panels.

The composition of training and laboratory stands determines the basic directions of laboratory and practical exercises, which can be carried out using the equipment listed:

- Typical technological tasks automation;
- Variable frequency drive control;
- Industrial data exchange networks organization and operation;
- Interaction of the control system and the operator through the human-machine interface (HMI);
- Monitoring, Control And Data Acquisition (SCADA) learning.

Separate attention deserves modern software, which is equipped with training and laboratory stands. This is a powerful program complex Mitsubishi MELSOFT iQ Works, which forms a single environment for the development of automation solutions, covering PLC, motion control and HMI.

The MELSOFT Navigator package is the central part of iQ Works. It allows you to easily design complete top-level systems and seamlessly integrate other MELSOFT programs included in iQ Works. The package has such functions as system configuration design, file batch settings, system labels and batch reading. Several projects including different levels programmable controllers, positioning controllers and operator panels can be managed from the working area of MELSOFT Navigator in real time. Functions such as program editing, parameter setting and batch reading are performed intuitively and easily through a graphical interface. MELSOFT GX Works2 is an environment for programming and maintenance of the PLC itself, developed on the basis of well-proven packages for programming and documentation of GX Developer and GX IEC Developer.

The modern environment GX IEC DEVELOPER is developed in accordance with the international standard IEC 61131-3 for PLC programming languages. The most significant features of the GX IEC DEVELOPER environment are:

- descending architecture;
- structured programming;
- an overview of the project of the programmable controller and resources;
- the possibility of developing large and complex projects;
- a unified programming environment for modular and compact controllers;
- high-level technology in accordance with the standard IEC 61131-3;
- simultaneous support of various programming languages, allowing parallel development of various software modules using ladder-step diagrams (LD), functional block diagrams (FBD), structured text (ST), instruction list (IL) and sequential function chart (SFC);
- powerful autonomous modeling;
- function libraries using;
- on-line debugging programs.

Development and debugging of application programs for Mitsubishi PLC series Alpha is carried out in the software package AL-PCS / WIN-EU. This package is indispensable at the initial stage of acquaintance with the PLC. The package allows you to quickly master the techniques of application programming in the language of functional block diagrams (FBD).

FR Configurator software is designed to configure and debug VFD and to change the drive settings, control the electric drive in various modes directly through the computer, monitor the change in the main parameters of the drive and obtain the time characteristics of the investigated quantities in real time. Typical FR Configurator advantages:

- FR Configurator allows the operation of up to 32 inverters at the same time;
- the configuration of various parameters is facilitated with the help of full and group overview functions;
- convenient display functions that provide the output of digital and analog data, fault messages and oscillograms;
- the developed system of diagnostics allows to develop and fix skills of fast and effective definition and elimination of malfunctions;
- the test mode allows simulating the operation of the frequency converter;
- the automatic tuning function allows you to more precisely control the various motors;
- settings can be saved in a special file, printed and moved as settings to other electric drives.

FR Configurator is software that offers an easy operating environment. Can be utilized effectively from inverter setting up to maintenance.

Parameter setting, monitoring, etc. can be performed on a display of Windows personal computer.

RS-485 communication is available to connect a personal computer to an inverter using a PU connector.

At present, the curriculum teachers have developed training programs in several areas of training, a summary of which is given in the table below.

At present, the curriculum teachers have developed training programs in several areas of training, a summary of which is given in the table below. An obligatory result of all courses is the fulfilment of an independent task by the trainee, according to which the degree of mastering the material and its competence are assessed.

An example of the execution of a term assignment to the trainee is shown in Fig. 6.

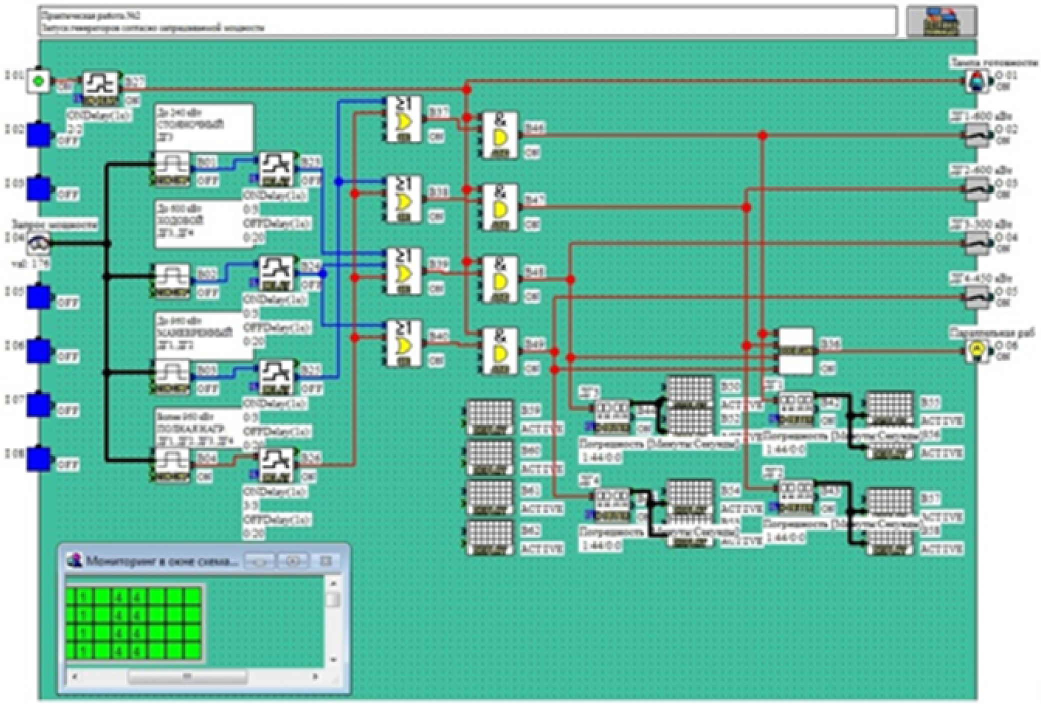

Figure 6. PLC programming example: process of starting generators according to the required power

Engineering Courses List on
Full Mission Simulator Complex of Ship's Automated Electric Power Plant

Course description	Course duration	Entry Criteria	Course price (USD)
Programmable Logic Controller (Basic, and advanced) The basic course is designed to give an overall understanding of the functions and capabilities of the PLC and important safety aspects of its operation. Course contents: - General data of CPU and I/O modules; - Input and Output of PLC and principle of its connection and operation; - Understanding the configuration of PLCs; - Basic ladder program instructions and simulator exercises; - Application of PLC on shipboard (advanced); - Programming PLC, uploading and downloading data (advanced); - Care and maintenance on PLC	2 Days (3 Days)	C/E, 2E, 3E, 4E, ETO	260 (390)
Ship electrical energy generating and distribution This course mainly focuses on improving practical skills, fault finding and troubleshooting on real MSWB. Teaching objectives: - To study the hardware of a main LV and HV switchboards; - To control distribution; - To manage an electrical energy; - To study the ship generators and generator excitation systems; - Training on live main LV and HV switch board and emergency switch board	3 days	C/E, 2E, 3E, 4E, ETO	390
Ship power management system - To learn the generator automation and power management system (PMS) structure and operating principle; - To learn PMS algorithms and modes; - The live PMS equipped with FlexGen controller C6200 and C6250 UI module; - Training on live main switch board and emergency switch board	3 days	C/E, 2E, 3E, 4E, ETO	390

Marine high voltage course: electrical safety, maintenance, adjusting. The course is designed to increase the troubleshooting skills and fault diagnostics procedures for marine electrical and mechanical engineers employed on various ships and offshore High Voltage Electrical Equipment and Systems. This course will give knowledge and understanding of maritime HV installations and safety working, maintenance and adjusting procedures. The course will emphasize the safety aspect of electrical engineering work, recommendation on good safe practices, procedures and precautions be taken to maximize the safety of personnel. The course will provide both theoretical and practical instructions in safe training environment. Duration of the course: 5 days	5 days	C/E, 2E, 3E, 4E, ETO	650
Diesel engine monitoring and control *Teaching objectives:* - To study the control and monitoring principle of marine auxiliary engines with PLC; - Care and maintenance on diesel engine PLC; - Training on live diesel engine PLC M2500	2 days	C/E, 2E, 3E, 4E, ETO	260
Automated electric drive technology *Teaching objectives:* - To study and implement the power control of an electric motor - To study and create the various motor starter diagrams - To control asynchronous motors; - To learn the speed controller operating principle; - To learn the main speed controller settings and programming; - To learn the electromechanical and electronic control of motor starters.	5 days	C/E, 2E, 3E, 4E, ETO	500
Advanced Instrumentation and Process Control This course is designed to cover basic instrumentation and automation on shipboard, dealing with various aspects of main engine automation, boiler automation controls, PID controllers and various latest instrumentation, which used on ship. Training on live M3000 alarm and monitoring system.	3 days	C/E, 2E, 3E, 4E, ETO	390
Energy efficiency systems *Teaching objectives:* - To learn the concepts of energy efficiency; - saving means of automated electric drive; - power factor correction system on shipboard	2 days	C/E, 2E, 3E, 4E, ETO	230
Control communication and information network This course is designed to cover basic control communication and information network on shipboard. Teaching objectives: - To learn the operating of computers and computer networks on ships; - To learn the basic communications protocols used on ships, such as Modbus, Fieldbus, CANopen, Ethernet, and also with remote control and data transfer; - Training on live simulator complex.	2 days	C/E, 2E, 3E, 4E, ETO	250

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REVIEW OF THE ENGINE ROOM SIMULATOR DESIGN AND TRAINING PRINCIPLES UNDER THE LIGTH OF ENGINE CONTROL ROOM WATCHSTANDING BASICS

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Abstract: The aim of this study is to review the application of Engine Room Simulator trainings in the light of the lessons learned from the ship accident reports, practices, and needs for different type of ships to cover the STCW2010 requirements.

Although being one of the most important tool for seafarer training, Engine Room Simulator can only be effective when applied correctly. From this point of view, Marine Engineers who manage the ship's systems and machines should have furnished with basic knowledge of command and control instruments, signals, correlated communications and their functions.

It is true that a commercial ship, having automated class, aims to increase its income while decreasing the expenses. This can be achieved only if the ship is operated continuously in economic, efficient, safe and environment protection conditions according to the international norms. From this point of view teacher and simulator factors are very important in ERS training. Because a teacher equipped with automation and process concepts can only add value to training with a well-designed ERS. If used by well-trained and experienced trainers, a well-designed ERS may help the student to monitor, analyze and define the operating parameters relevant to the ships systems and devices and, make decisions for corrective actions if necessary.

There are several type of ERS still in service on board ships. The difference is in the arrangement of modules, files and folders. Number of screens, software used for programing or visual effects, etc. may be different. For marine engineers it is inevitable to work in different engine control rooms which are developing every day. Since it is not possible to supply and install a wide variety of simulators in training locations, the philosophy of using it in the most effective manner is gaining importance.

Keywords: ERS design, Automation, Process, Instructor, Marine Engineer, Decision making.

Introduction

Very successful trainings can be realized via the Engine Room Simulator (ERS). For this, the basic needs of ERS training must be defined and applied without sacrificing quality and standards. Requirements should be initially provided satisfactorily to establish a multi-purpose ERS training system.

Dominant factors and nodes that affect thedecision makers to invest for an effective ERS training system, is shown in Tab.1

Factors dependency assessment analysis is the most important issue that must be completed during the investment phase of the ERS training project. Qualitative and descriptive analysis of the dependency statistics of the factors will help to determine the most accurate project in order to invest for a quality ERS training. Educational institutions that want to make an effective ERS training investment using the factors mentioned in the Tab.1 must analyze a lot of combinations including all of these factors the most accurate project in order to invest for a quality ERS training.

Tab.1 Cluster of dominant factors and nodes affecting the ERS training systems investments

1. Applied groups	6. Software features
1.1 Classroom	6.1 Command and control monitors
1.2 Team	6.2 Command and control elements
1.3 Individual	6.3 System diagrams monitors
1.4 Full ship	6.4 System diagrams elements
2. Modelled ships	6.5 Alarm monitors
2.1 General Cargo	6.6 Alarm monitors elements
2.2 Container	6.7 Data analysis and definitions
2.3 LNG/LPG	6.8 Graphical analyses and Histograms
2.4 Tanker	6.9 Predictive decisions and suggested actions
2.5 Chemical	6.10 Maritime Laws and regulations
2.6 CPP	6.11 International standards and limitations
2.7 Azipod	6.12 Data and bridge switching matrix
3. Operational conditions	6.13 Application combinations
3.1 At sea-no fault	7. Assessment methodology
3.2 At sea-with fault	7.1 Course catalogue forms
3.3 At sea-with emergency	7.2 Course syllabuses
3.4 At port-no fault	7.3 Course plans and programs
3.5 At port-with fault	7.4 Trainee personal records
3.6 At port-with emergency	7.5 Trainee evaluation records
4. Site features	7.6 Trainers qualification records
4.1 Location architecture	8. Simulators and trainees
4.2 Interior design	8.1 Classroom-Multi-trainee
4.3 Multi-media	8.2 Engine control room-Team
4.4 Data cabling	8.3 Watch officer-Individuals
4.5 Power cabling	8.4 High voltage-Individuals
4.6 Lighting	8.5 Main Propulsion Power plant-Team
4.7 Air Conditioning	8.6 Auxiliary systems-Team
4.8 Touch-panel board	8.7 Electric power Plant-Team
4.9 Manual applications pad	8.8 Electric distribution system-Team
5. Hardware features	9. Mandatory requirements
5.1 Data matrix and network	9.1 Pre-completed courses - Operational ERS
5.2 Data transfer	9.2 Pre-gained experiences - Managerial ERS
5.3 Server capacity	9.3 Well-designed course plan and timing
5.4 Pc monitors	
5.5 Printer units	
5.6 Touch Panel units	
5.7 Desk-top units	
5.8 Modules' combinations	

(*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017)*

Literature

The rapid development of electronics, digital systems and automation technology has also affected robot system designs. In addition to reducing ship and system accidents resulting from human error as well as saving man power has also affected ship-owners and therefore automatic system designers. The feedback control systems, which operate more quickly, precisely, accurately and with feedback, have developed so much that it is no longer a dream to carry out an unmanned ship or use an airplane. Nevertheless, the responsibility for designing, using and monitoring these systems, called automation or automatic control, will always belong to human beings.

No matter how much it evolves, no automatic control system that exists today has the ability to observe, analyze, interpret, judge and apply it as a human being. The advantages of automation systems are that they can perform many observations, operations, analysis, interpretation, decision making and application at a very high speed. However, every action they can make can only be done at a level determined by the human. The automation system can only be useful if it is very well maintained, calibrated and adjusted. Otherwise, it causes the user to make wrong decisions and take wrong actions. No matter how developed, automation systems can never be as complex, emotional and intuitive as a human brain. Human beings can win this battle with the automation systems, but it seems possible by doing business with them. The users have a preliminary sense, a preliminary vision, amazing sudden reactions, incidents and many other features.

On the other hand, well-tuned and calibrated automation systems have superior features, such as limited but very fast running, monitoring, analysis, interpretation, calculation and recommendations for immediate counter measures. There is no doubt that excellent results can be obtained with the cooperation of both sides. This can only be achieved if the user and the automation system know each other very well. For this reason, the well-designed automation system is essential to establish an efficient ERS training system where the user is well aware of this design and has the ability to fill the weak points of the system.

The Goal

The main goal of the ERS training is to educate the trainees to be excellent decision maker marine engineers to operate the ships systems and machineries continuously and efficiently in economic, safe, secure and environmental conditions. Therefore, ERS training system designs must fit properly to this goal and satisfy all type of requirements specified by national and international maritime laws, regulation and standards.

ERS training is absolutely not to teach the trainees how to start and stop the engines or recording the operating parameters to the engineering logs. ERS training is really a serious education facility which can be used by all lecturers who are teaching marine systems and machineries scientifically.

ERS education systems are the most important and effective educational tools, if they are well designed and assimilated by teachers. In case of abnormal situations that occur, the student can quickly analyze, interpret, make decision and gain the ability to apply this decision. It is not easy to give ERS training because the educational background of the trainee is very important. In order for this training to be beneficial, the student must have successfully completed basic vocational courses such as automation, electricity, diesel engine, thermodynamics auxiliary machineries, refrigeration, turbines, etc.

Otherwise the student will not understand what the ERS instructor tells and what he or she sees on the screens. For this reason, it is very important for educational institutions to take this issue into consideration when preparing their semester lesson plans.

Fig.1 is one of the samples which represents the importance of ERS training in making decision and taking action after analysis and defining to correct the problem seen on the ERS graphics monitor.

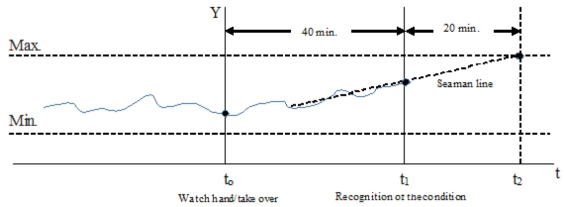

Figure 1. Analyzing, defining, decision making and action graphics for any parameter depending on time. (*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017)*

At t_o Engineering Officer takes over the engineering watch. Dynamic trajectory working already on the pc screen represents any t-dependent variable-y.

Officer on watch (OOW) monitors in 40 minutes that the y-trend continues to increase. At t_1 he/she starts to analyze the situation and tries to understand the reason of abnormal increasing of variable-y. t_o is a critical time to analyze and define the problem. OOW is aware of that there is 20 minutes more to make decision and take action to correct the fault before variable-y reaches the maximum limits allowable. t_o is also the point where educational background comes forward to solve the problem with his/her knowledge gained in previous years at school. If variable-y represents the exhaust temperature relevant one of the diesel engine cylinders, OOW will start to think on the AFR, fuel property, exhaust valve condition, turbo charger, injector and many other reasons which really effects the combustion process primarily and dominantly. And so on...

Even this little scenario describes the importance of ERS training. If OOW is not able to make proper analysis and definition to find the fault he/she will not be able also to make decision for a corrective action to rectify the fault. As a result, main propulsion power diesel engine will slow down automatically while the ship is passing a channel or maneuvering to avoid a collision.

Methodology

There may be different opinions for the

establishment of an effective ERS training system. This article is a research and study on the dominant factors and parameters involved in a good ERS training system investment. The cluster model we have prepared for the optimization of ERS training contains nine dominant factors and sixty-four parameters. Number of factors and nodes in the model may vary.Tab.1

$$Y_1^n = a_{11}^n X_1 + \dots\dots\dots + a_{19}^n X_9$$

$$Y_2^n = a_{21}^n X_1 + \dots\dots\dots + a_{29}^n X_9$$

$Y_1^n =$ any investment model preferred to be analyzed

$a_{11}^n =$ degree of importance of the factor specified

$X_1 =$ dominant factor specified

Investors, looking for any preferred ERS training system, need to optimize their projects to achieve their goals. Therefore, the dominant factors which are influencing the efficiency of ERS training process must be selected correctly and qualitative regression analysis must be done accordingly.

Applied groups

ERS training groups should be correctly identified. The remaining parameters are almost all proportional to the accuracy of this decision. Classroom-type ERS training is perfect for the schools and/or universities due to it has the ability as well as capability to assign different ships and scenarios to different students at the same time.Fig.2 On the other hand, the engine control room training option is suitable for both team and collective trainings with bridge.Figs.3 Individual type of ERS training is very effective for training the watch officers.Fig.4 High voltage training can be done in a room designed specially. Fig.5

Modelled ships

ERS training modules should be common, simple, authentic and user friendly. For this reason, the most used ship types should be selected for modelling. General cargo, Container, LNG / LPG, Tanker, Chemical tanker, CPP and Azipod propulsion type ships will be good enough for ERS training. ERS systems can also be developed for special purposes.

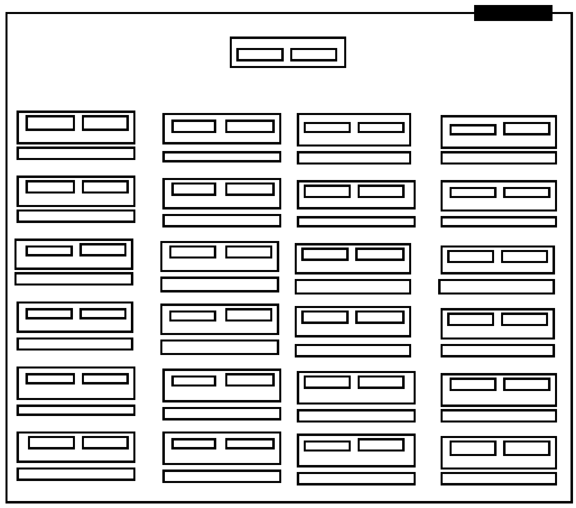

Figure 2. ERS Training-Classroom for 24 trainees. *(Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017)*

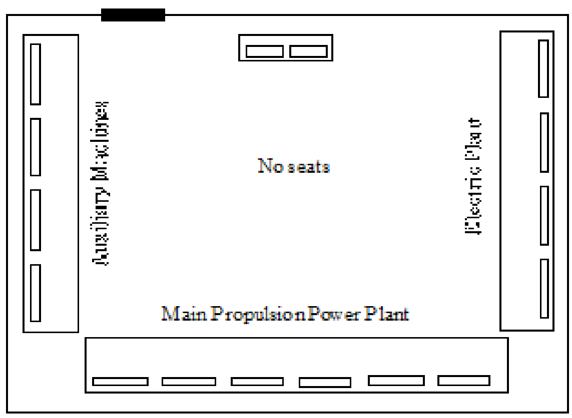

Figure 3. ERS training-Engine control room for 6 trainees. *(Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017)*

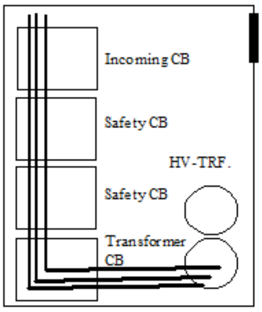

Figure 4. ERS- Watch Officer training room

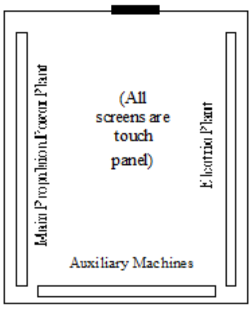

Figure 5. ERS-High Voltage training room

(*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017*)

Operational conditions

Vessels can be at sea, in port, in canal passage, at the shipyard, at the dock, or in an emergency condition during their lifetime. Scenarios to be prepared for a good ERS training need to include normal operations, system and machine failures and emergencies. For this reason, we think that scripts should be prepared by software companies under the guidance of marine engineers who have gained experience in ocean-going ships.

Training center features

Another important point in an effective ERS training is the architectural design of the training rooms together with interior facilities which includes multi-media, data and power cabling, lighting, air-conditioning and audio-vision equipment. Fig.6 and Fig.7

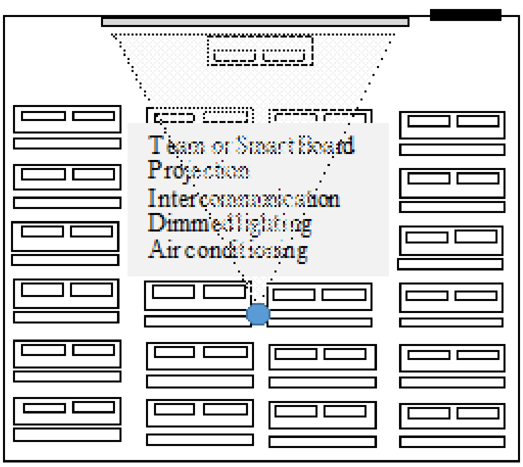

Figure 6. ERS training Classroom-interior design. (*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017*)

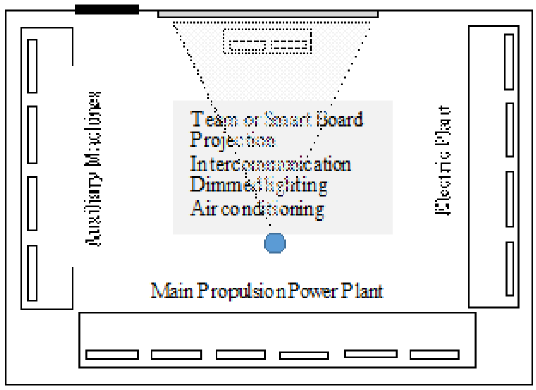

Figure 7. ERS training-Engine control room-interior design. (*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017*)

Hardware and Software features

Hardware as well as software of each ERS training room must be separate and not linked to any other networks. All the units need to be specified in proper seizes in order to make it easy for the trainees to see, read and use. Servers must have enough capacities to run the existing and additional programs, modules and scenarios without any problem.

Overloaded ERS systems are becoming a source of many problems due to the multiprocessing point and fast data flow. One of the major problems is the system interruption which needs to re-start the system and scenario. This cause loss of time, concentration and desire of the trainee. For this reason, we expect each ERS training room to have its own independent server with sufficient capacity and speed to establish a sustainable training quality.

All elements of the ERS training rooms must be ergonomic in order the students be able to operate, monitor and read any instrument in the ERS system easily. We recommend wider desk-top monitors not tire the trainees eye.

From the instructors' point of view, ERS training does not cover only the scenarios but, also oblige the instructor to explain some issues using the touch-panel boards which are more practical, recordable and quicker to use rather than the classic boards.

Module combinations will facilitate multi-purpose applications and provide flexibility on ERS group trainings. The size and partition of the desk-top pc monitors must have planned well in terms of easy understanding and learning of the objects that the trainee will command and control. Fig.8 and Fig.9 This type of display setup allows the trainees to easily follow the scenarios and observe the behavior of the circuit elements after sending commands from the system panel. Vice versa, the command and control elements if placed on different screens and scattered ERS systems forces the trainees to spend their times to stroll between the menus which makes the events unnecessarily difficult to understand. This type of designs may not create serious problems on board ships. However, these types of negativities during the learning phase lower the ERS trainings' quality and create confusion. The aim of the ERS training is not to teach the haphazard designs of the suppliers but to teach the automatic control principles and to solve the problems in the shortest time.

We recommend the ERS designers to coop with marine engineers experienced in ERS operations. This cooperation will ease the designing process of the ERS training systems under the light of international maritime laws, regulation and standards.

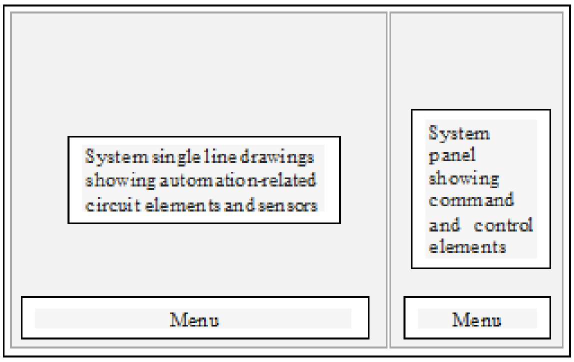

Figure 8. System drawings, command and controls. (*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017)*

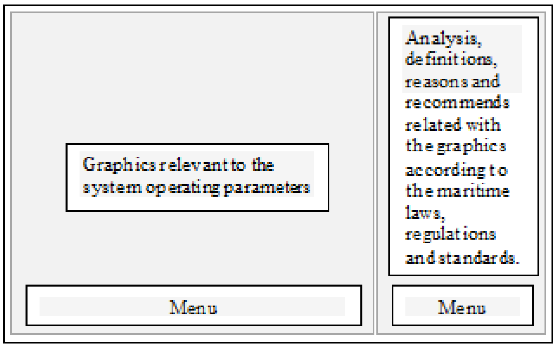

Figure 9. Analysis and definitions of the trends. (*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017)*

Assessment methodology

The evaluation of trainees as well as ERS training is the main objective of this acquisition. Therefore, Catalogue forms, syllabuses, course plans and programs needs to be prepared under the light of IMO and STCW codes and standards. National regulations regarding with ERS trainings must also be taking in account. These source of data as well as literature regarding with ERS training (e.g. manuals, drawings, data tables, calculations, formulas, etc.) must be saved in the ERS library.Fig.10
All kind of records relevant to the training groups as well as trainees must be recorded and kept for official purposes.Fig.11 All kind of data should be in printable format using MS Office programs via a suitable printer connected to ERS systems established in the training rooms.

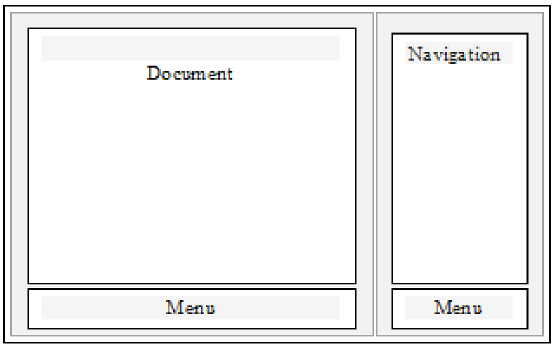

Figure 10. ERS Library. (*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017)*

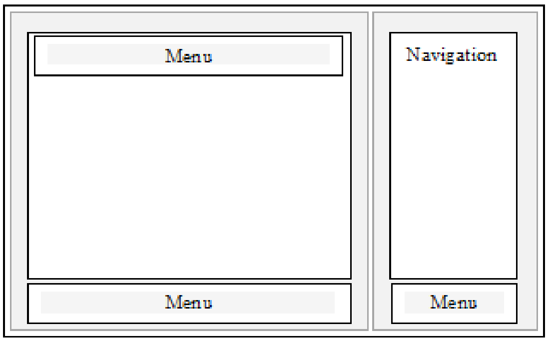

Figure 11. Groups and trainees' records. (*Tolunay KAYAARASI; Süleyman ÖZKAYNAK, Piri Reis University, 30, June,2017)*

Conclusion

It is very clear that there is no other opportunity except than ERS to train the seafarers properly and get them ready to take responsibilities in order to manage any kind of situation on board ships. This is possible only if they learn properly how to monitor, analyze and define the events and make decisions for corrective actions in order to rectify the faults on time in quality. ERS is able to satisfy these requirements if designed properly and used by experienced marine engineers.

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6. KONGSBERG, K-Sim® Engine - Engine Room Simulator

7. COMPUTER – BASED TRAINING FOR SEA – GOING ENGINEERS. Cengiz DENIZ 1Ahmet PAKSOY, 2M. Nusret SARISAKAL 3 1Istanbul Technical University, Maritime Faculty, Tuzla, Istanbul, TURKEY 2Istanbul University, Engineering Faculty, Maritime Transport and Management Department, 34850, Avcilar, Istanbul, TURKEY 3stanbul University, Faculty of Engineering, Computer Engineering Department 34850, Avcilar, Istanbul, TURKEY

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INTEGRATION OF LEARNING ANALYTICS APPROACH INTO MARINE ENGINEERING PROGRAMS THROUGH ENGINE ROOM SIMULATORS

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Abstract: Learning analytics approach in higher education is a contemporary technique to enhance the student outcomes. It is relatively a new statistical approach to conduct comprehensive analysis on the educational data sets. This paper briefly reviews the existing learning analytics applications and their potentials to identify adaptation requirements to simulator-based courses in marine engineering programs. The conceptual framework for the integration of the learning analytics approach into engine room simulator (LAERS) is developed to enhance student outcomes along with the relevant competency items in STCW A-III/I.
Keywords: marine engineering, simulator training, learning analytics.

MOTIVATION

The training programs taught in MET institutions should be comply with the minimum requirements cited within STCW Code as amended in 2010 [1]. The Code briefly describes the relevant functions in different phase such as operations, management and support levels. Besides, competencies and criteria for evaluating competence in detail are identified. At this insight, the learning outcomes are highly depending upon synthesizing the criteria aligning with the knowledge, understanding and proficiency to consistently prove whether the competencies are achieved or not. Trough practical trainings (i.e. simulator supported courses), the assessment is more reliable when the measurable or quantifiable sub-criteria are defined.

However, the following problems of existing assessment approaches in the maritime practical trainings are identified: i) the assessment systems are generally so simple, ii) the assessment results might be subjective, iii) there is no mechanism to gather the task-based evidences along with the maritime practices, iv) the lack of detailed student performance reporting system in practical trainings, v) the unification problem in conceptualizing the scenario in maritime practical trainings, vi) the evidence based debriefing sessions are during practical training is not effectively conducted, vi) the learning outcomes from maritime practical trainings are not clearly guaranteed.

In addition to various requirements, the Manila amendments especially emphasized on the development of simulator infrastructures and e-learning platforms [2]. In this respect, the role of instructors [3] has been discussed from different perspectives. Recently, the international maritime authorities have been concerned with such matters from training assessment pedagogy perspective. The following IMO model courses were developed to support the learning outcomes: IMO Model Course 6.10 Train the Simulator Trainer and Assessor, IMO Model course 6.09 Training Course for Instructors, IMO Model Course 1.30 On-board Assessment, etc.

Furthermore, the consistency of student competency assessment systems especially for the practical trainings are always negotiated in national/international audit and accreditation facilities in MET institutions (i.e. EMSA inspections). On the other hand, course development and update procedure is one of the critical processes in MET institutions due to continuous changes in technical, regulatory and operational aspects along with the maritime industry expectations.

The initial focus of this research is to identify adaptation requirements of learning analytics approach to simulator-based courses in marine engineering programs. The next section briefly introduces the existing studies and ongoing projects in learning analytics. Then, the framework of the proposed approach to conduct learning analytics in engine room simulator (LAERS) is given.

LEARNING ANALYTICS

Learning analytics, used to analyse the patterns, is recognized a systematic tool to improve education process. The learning analytics processes or presents the traces by two main approaches; i) pointing out patterns or computing indicators via algorithms, ii) steering the learning process via information visualization [4].

A wide review of the recent studies on the learning analytics applications [5] has classified the techniques used such as surveys, statistics, non-statistics, data mining, machine learning, information visualization, social network analysis, content analysis, natural language processing, group concept mapping, pattern information analysis, ethnographic analysis.

On the other hand, the objective of the learning analytics studies includes monitoring and analysis, prediction and intervention, assessment and feedback, adaptation, personalization and reflection [5]. In fact, the application of analytics in higher education might lead to following benefits: improving student retention, helping students' progress, enhancement in teaching, matching students to programs and employment, improving student's experience, developing an effective administrative system, etc. [6]. For example, the activity patterns of the students provide valuable solutions to predict and improve the student performance [7]. Besides the studies, a number of projects are proposed to support and promote learning analytics applications in different fields.

Just to name a few, the followings are addressed [8]: LACE (Learning analytics community exchange), PELARS (Practice-based experiential learning analytics research and support), SHEILA (Supporting higher education to incorporate learning analytics), STELA (Successful transition from secondary to higher education by means of learning analytics), LAEP (Implications and opportunities of learning analytics for European educational policy, BEACONING (Breaking educational barriers with contextualised pervasive and gameful learning), RAGE (Realising an applied gaming ecosystem), WATCHME (Workplace-based e-assessment technology for competency based higher multi-professional education). The mentioned projects have strength the utility of the developed systems on learning analytics in different platforms. For instance, the WATCHME project [8] has developed and tested an Electronic Portfolios (e-portfolio) to extend the data sources along with the learning facilities. It offers a competency development monitoring model, just-in-time feedback system, and visualization tools [9].

Considering the existing theory and practices of the learning analytics, the next section extends it to the targeted marine engineering competencies given in engine room simulator environment.

LAERS FRAMEWORK

In marine engineering programs, various competency items defined within STCW A-III/I and AIII/II are expected to be delivered by tasks, exercises, and scenarios in full mission engine room simulator [10]. In generic framework, the learning analytics is mainly established based on six dimensions such as stakeholders, objectives, data, instruments, external limitations and internal limitations [11]. Considering the six dimensions, Figure 1 proposed the specialized elements of LAERS framework.

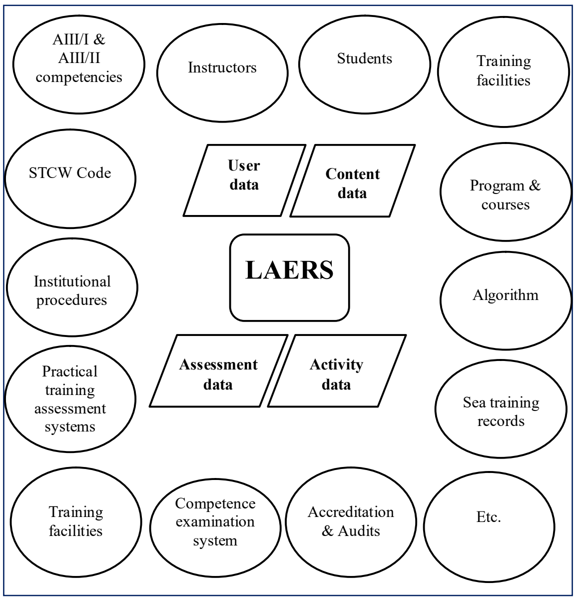

Figure 1. LAERS Framework

In the framework, the number of elements can be extended if the developed algorithm is capable of processing the defined features. The data requirements in this framework are the significant aspect to enable competence visualizations specific to marine engineering. In those cases, the assessment system should measure the level (degree) of competencies rather than providing direct judgements (fail or success) or simple grading methods. In broad manner, the data sources normally include historical documents, rules and regulations concerning MET, syllabi, handouts, sample questions, field notes, an ethnographic study in a maritime college and interviews conducted with experienced mariners and course lecturer [12]. As one of the learning management systems modules, the virtual learning environments (VLE) concept classifies the datasets in five different categories: i) user data, ii) content data, iii) assessment data, iv) activity data, v) event data [13].

In this stage, this study just considers to develop assessment data as one of the datasets category in learning analytics. In STCW basis, it requires to define a new loop (function, competency, criteria) to produce new datasets. To illustrate an assessment data, a competency description (expected to demonstrate with approved engine room simulator courses) is considered. As an example; maintaining a safe engineering watch is selected as main competency. It requires to promoting knowledge of engine-room resource management principles. The system is structured on the evaluation criteria entitled “team member(s) share accurate understanding of current and predicted engine-room and associated systems state, and of external environment” described under Section A-III/I. Then, additional sub-criteria which can be monitored and evidenced with an operational scenario in ship engine room, is required. Here, the learning analytics approach seeks for the control points on which the data is gathered along with the tasks. Comparing the traditional assessment systems, the learning analytics approach enables to identify the relationships among the sub-criteria sets, knowledge, understanding, and proficiency items of the targeted competency in the focused function. The suitable scale (quantitative or qualitative) is also considered for each observation and data points (tasks). Besides practical task scores, the attendance hours, midterm questions, final exam questions, term project scores, the extensions to the related courses, etc. might be considered to strength the assessment data.

CONCLUSION

This study initiates a LAERS framework to enhance learning outcomes derived from engine room simulator supported courses in marine engineering program. Assessment data, as a dataset category in learning analytics approach, is introduced for engine room simulator courses. In this cycle, it seems that the LAERS has potential to clarify uncertainties for evaluating competencies. The proposed LAERS approach in this study is valuable for the MET institutions to strength the competency - based system in practice. The further studies might include the other datasets categories and the detailed descriptions of the defined features in the proposed LAERS framework.

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USAGE OF SIMULATOR AS AN ENERGY EFFICIENT OPERATON OF MAIN ENGINE PRACTICE

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Abstract: Engine Room Simulators take a crucial part in education of marine engineering students. Energy efficiency education is one of the topics that can be practiced at Engine Room Simulators to maintain safe, green and energy efficient operation. Energy efficiency is a subject that must be totally understood and implemented to whole ship. Chemical energy of fuel is converted to mechanical energy and rotational power in Main Engine system, so running of ME at optimum parameters is directly related with the energy efficiency. In this paper, operation of Main Engine in the simulator practice, parameters such as injection time, injection pressure, scavenge temperature, scavenge pressure, compression pressure, are observed for to investigate the effect on fuel consumption. These parameters have critical role in combustion phenomena. By the changing of these parameters, fuel consumption, generated power and cruise speed vary and naturally total EEOI changes. Total energy efficiency affection is investigated by the changing of these parameters. With measuring and figuring out of the results, it helps trainees to comprehend the phenomena of combustion and gain efficient main engine operation principles.

Keywords: main engine, efficient engine operation, combustion parameters.

Ships are the most cost advantage transportation way in the world however, this way has negative effect on air pollution derived from exhaust gas emissions such as sulfur dioxide (SO_2), carbon dioxide (CO_2) and nitrogen oxides (NO_x). IMO (International Maritime Organization) forces maritime sector to decrease carbon footprint which can be achieved by decreasing total fuel consumption. Ship energy efficiency is the most important issue that must be considered, beginning from the design to operation of the ship. Measurement of energy efficiency of any ship operation under different conditions, EEOI (Energy Efficiency Operational Indicator) is the main instrument must be observed to evaluate and the compare of the performance of the operations. The recent issue that shipping companies must accomplish in their commercial ships, and fulfill the responsibilities and provisions of MARPOL (International Convention for the Prevention of Pollution from Ships) Annex VI stated by IMO. EEDI (Energy Efficiency Design Index) is calculated for specified cruise speed and load for a ship whereas in operation, this index must be altered as EEOI which differs by routing, weather, aging of hull & propeller, wearing out of machinery and its components, load conditions, etc.

Two stroke marine diesel engines are highly preferred engine type in maritime sector, as a consequence of their high thermal efficiency, and fuel cost advantage brought together.

Many energy efficiency practices have been engaged in operation to reduce EEOI, which also means to reduce fuel consumption and emissions emitted from the engine, or increase transport work for per unit fuel. Planning of the course, fleet management, renewable energy, reduction of power are some of them [1,2].

The study had been conducted on engine room simulator, powered by a twelve cylinder two stroke marine diesel engine. Neptune Engine Room Simulator Sulzer RTA Container L11-III data was used in this study. Specifications of Diesel engine used in this study given in ERS brochure given in Table 1 [3]. Reference data were obtained at normal conditions without any malfunction. Any different parameter conditions as injection pressure, injection time, scavenge temperature, scavenge pressure and compression pressure, engine operating parameters observed. These data compared with the reference data. Reference data operating conditions and variables which are observed in this study listed in Table 2 at the normal conditions at load of machinery full a head. Energy efficiency consideration, and systemic parameters were investigated at marine engine operation to figure out effect of these variations to assist training of efficient operation in engine room simulator for trainees. It helps to comprehend combustion understanding and impose this phenomenon on the subconscious mind for the trainees. To achieve this objective some of parameters must be monitored and examined by students and trainees such as turbocharger speed, exhaust manifold pressure, in-cylinder gas temperature, maximum in-cylinder pressure, brake specific fuel oil consumption, indicated power by engine, total heat release extracted a unit of fuel as well as exhaust gas temperature since energy loss from exhaust gases depends on mass flow of exhaust gas and its temperature. The temperature increment is mainly taking a root from decrement of inlet air quantity [4]. And also relation between changing parameters with each other must be observed, scavenge pressure after air cooler could be vary with any defectiveness or injection pressure change adjusted by tension of spring in injector, leads injection time variations.

1. Injection Pressure

Injection pressure performs a high speed of fuel from the nozzle of injectors, and a high flow rate of fuel in to the cylinder. At the combustion area, air inside the cylinder and fuel injected by the injector collide with each other and after atomization of fuel, the combustion initiates. The higher injection pressure, the better fuel atomization is.

Table 1. Specifications of Sulzer RTA engine with 12 cylinders given in brochure [3]

Main Engine Data	
Type	Sulzer RTA84C
Cylinder bore	840 mm
Piston stroke	2400 mm
Number of cylinders	12
Number of turbochargers	3
Continuous serv. rating of ME	48,600 kW
Corresponding engine speed	102 RPM
Mean indicated pressure	17,9
Scavenge air pressure	2,4
Turbine speed	9500 RPM
Propeller type	Fixed
Number of propeller blade	5
Propeller pitch	0.9 P/D
Specific fuel oil consumption	171 g/kWh
Fuel type	730 cSt (50ºC)

Table 2. Operating conditions at Full a head load without any malfunction of Sulzer RTA engine simulator

Data must be observed		
Opening Injection Pressure	420	bar
Mean injection Pressure	571	bar
Injection Time	-1,8	CA
Scavenge Temperature	41,16	°C
Scavenge Pressure	2,76	bar
Compression Pressure	96,7	bar
Engine RPM	102	rpm
ME Mean Engine Indicated Power	48540	kW
ME Mean Engine Effective Power	44470	kW
Specific fuel oil consumption	180,5	g/kW
ME Cylinder Effective Power	3702	kW
ME Cylinder Indicated Power	4046	kW
Effective Mean Pressure	16,39	bar
Indicated Mean Pressure	17,91	bar
Exhaust Manifold Pressure	2,59	bar
Exhaust Manifold Temp	401	°C
Turbocharger Speed	8760	rpm
Max Incylinder Pressure	137,4	bar
Fuel injected mass/stroke	107,38	g
Heat in Fuel	7295	kW
Heat to Exhaust	2801	kW
Heat to water	549	kW
Heat to oil	219	kW

Many studies have been conducted to reveal injection pressure effect on combustion [5,6,7,8,9]. By the reason of higher jet flow of fuel which interacts with air inside. Also composition of air in-cylinder is crucial parameter for combustion, density affected by pressure and temperature of charge air which are mentioned in this study also. Possible causes to decrease of injection pressure listed as, nozzle opening pressure decrease, wear of needle of injector, wear of injection cam which changes geometry of injection profile, retention of injection pump. Reduced injector opening pressure is adjusted by a spring pressure, could be also means that, achieve the opening pressure before optimum pressure value, therefore injector could be opened at advanced crank angles, mentioned in injection time.

2. Injection Time

Injection time has a great impact on parameters as maximum pressure, exhaust temperature in diesel engines [10,11], which are main values taken in to consideration to calculate power production as a primitive calculation. Advancing or delaying injection times change time of maximum pressure time and expansion curve of pressure volume diagram as well as maximum pressure and exhaust temperature at the end of expansion if compared with maximum value of with reference values of optimum injections. Injection time could be shifted by deformation of injection cam, defective engagement of roller part via engine shaft or cam shaft as well as reduction in spring tension of injector. It can be clearly seen that studies conducted before [12], both pressure and temperature maximum or mean are increased at advanced injection timings. On the contrary it has opposite effect at delayed injection timings [13].

3. Scavenge Temperature

Scavenge temperature could be increased by the reason of any air cooler system failure or reduction in cooler efficiency such as decreasing in cooler heat transfer area, corrosion of material or any clog in it. Therefore, increasing of coolant fluid temperature, as sea water or fresh water, or insufficient amount of coolant circulation bring on inadequate cooling of scavenge air which is undesired condition for combustion [14].

4. Scavenge Pressure

Scavenge pressure reduction has crucial effect on air fuel ratio (AFR) and compression pressure which have great effects on combustion. Turbine fault or compressor fault could be the reason of problem as well as air leakage at scavenge area. By considering in more detail, deterioration of turbine geometry and pollution caused by exhaust gases or wear of turbine blades are the main sources of decreasing of isentropic efficiency of the turbine or compressor. Since turbo charger whole effect on the systems of internal combustion (IC) engines, as a result of defective processes in other areas, any variance at the optimum values could be observed such as scavenge air pressure could be exposed to increase by combustion phenomena at conditions which are retarded injection, injector fouling, deteriorated compression process [4]. Any scavenge air pressure variation changes the excess air ratio in the cylinder whether the mixture lean or rich inside the cylinder that affect total heat release from the fuel, maximum pressure and temperature. Hence, it can be said that fuel consumption, produced power and also emissions are influenced by the scavenge pressure [13,15].

5. Compression Pressure

Compression pressure variation is caused by compression ratio or clearance between cylinder wall and piston rings. Furthermore, head gasket thickness, cylinder head geometry variation or any geometrical change in piston to crank joint could affect the compression ratio since these values affect in-cylinder dead volume. Compression ratio is directly related with the maximum pressure and temperature. Combustion phenomena is affected by all parameters ignition delay, total heat release which are influenced by pressure and temperature affected by compression ratio already.

Results and Discussion

Injection pressure reduction due to injection pump wear is simulated at the simulator for computer based training, at the mentioned simulator. Since pump wear exist in fuel injection system it is difficult to reach injection pressure for the pump therefore, injection time is delayed. Changing of the parameters is demonstrated in Table 3. Pump mean injection pressure reduced 571 bars to 552 bars.

Table 3. Parameters variation at a condition low injection pressure

Injection Pressure Reduction			
Mean injection Pressure	bar	↑ 571	↓ 552
Injection Time	CA	↓ -1,8	↑ 0,1
Scavenge Temperature	°C	↓ 41,16	↑ 42,06
Scavenge Pressure	bar	↓ 2,76	↑ 2,95
Compression Pressure	bar	↓ 96,7	↑ 102,67
Engine RPM	rpm	↑ 102	↑ 102
ME Mean Engine Indicated Power	kW	↑ 48540	↓ 48520
ME Mean Engine Effective Power	kW	↑ 44470	↓ 44400
Specific fuel oil consumption	g/kW	↓ 180,5	↑ 185,6
ME Cylinder Effective Power	kW	↑ 3702	↓ 3697
ME Cylinder Indicated Power	kW	↑ 4046	↓ 4040
Effective Mean Pressure	bar	↑ 16,39	↓ 16,35
Indicated Mean Pressure	bar	↑ 17,91	↓ 17,87
Exhaust Manifold Pressure	bar	↓ 2,59	↑ 2,77
Exhaust Manifold Temp	°C	↓ 401	↑ 417
Turbocharger Speed	rpm	↓ 8760	↑ 8880
Max Incylinder Pressure	bar	↑ 137,4	↓ 119,77
Fuel injected mass/stroke	g	↓ 107,38	↑ 110,43
Heat in Fuel	kW	↓ 7295	↑ 7502
Heat to Exhaust	kW	↓ 2801	↑ 2970
Heat to water	kW	↓ 549	↑ 582
Heat to oil	kW	↓ 219	↑ 229

Power produced by the engine decreases in this condition and fuel chemical energy goes out through exhaust gas. It is seen that temperature increases in exhaust port therefore, produced power by turbine and speed of turbine increases by the increasing of the exhaust temperature. Both exhaust temperature and heat to exhaust values are rising 401°C to 417°C and 2801 kW to 2970 kW respectively for per cylinder. Retarded injection and reduced injection pressure affect combustion pressure directly. Maximum pressure reduce 137,4 to 119,7 bars. Effective power of the engine is related with the pressure inside the cylinder and time of maximum pressure which are both in reduction trend. In the light of this information it is clearly seen that fuel consumption increases 180,5 g/kW to 185,6 g/kW because of low and retarded pressure curve.

As observed in Table 4., advancing of injection time results in increase of maximum pressure. Injection starts at 4,2 crank angle (CA) before top dead center (BTDC) from 1,8CA BTDC. This condition effect seen as increase of both effective and indicated power rise.

Table 4. Parameters variation at a condition advanced injection time

Injection Time Advanced			
Mean injection Pressure	bar	↑ 571	↓ 570
Injection Time	CA	↑ -1,8	↓ -4,2
Scavenge Temperature	°C	↑ 41,16	↓ 40,7
Scavenge Pressure	bar	↑ 2,76	↓ 2,69
Compression Pressure	bar	↑ 96,7	↓ 94,4
Engine RPM	rpm	↑ 102	↑ 102
ME Mean Engine Indicated Power	kW	↓ 48540	↑ 48840
ME Mean Engine Effective Power	kW	↓ 44470	↑ 44520
Specific fuel oil consumption	g/kW	↑ 180,5	↓ 178,57
ME Cylinder Effective Power	kW	↓ 3702	↑ 3712,7
ME Cylinder Indicated Power	kW	↓ 4046	↑ 4072,6
Effective Mean Pressure	bar	↓ 16,39	↑ 16,41
Indicated Mean Pressure	bar	↓ 17,91	↑ 18,01
Exhaust Manifold Pressure	bar	↑ 2,59	↓ 2,52
Exhaust Manifold Temp	°C	↑ 401	↓ 397,42
Turbocharger Speed	rpm	↑ 8760	↓ 8725
Max Incylinder Pressure	bar	↓ 137,4	↑ 149,8
Fuel injected mass/stroke	g	↑ 107,38	↓ 106,4
Heat in Fuel	kW	↑ 7295	↓ 7225,6
Heat to Exhaust	kW	↑ 2801	↓ 2722,7
Heat to water	kW	↑ 549	↓ 547,9
Heat to oil	kW	↓ 219	↑ 219,8

On the contrary retarded timings of injection has opposite effects on combustion and parameters observed in this study. Retarded injection condition demonstrated in Table 5. That injection time delayed 1,8 CA BTDC to 2,2 CA after top dead center (ATDC). Despite maximum pressure in cylinder change dramatically, there are worthless change at the mean effective pressure in both cases.

Starting of combustion early in advanced injection leads temperature decrease in exhaust gases, which means low heat loss from the exhaust gas. Turbine speed and scavenge pressure decreased since low heat capacity of exhaust gases at a advanced injection condition, at delayed injection opposite effects are exist in the Table 5. Fuel consumption decrease 180,5 g/kW to 178,5 g/kW with a effect of pressure rise in cylinder and increase to 186,8 because of pressure drop in cylinder at advanced and retarded injection times respectively.

Table 5. Parameters variation at a condition retarded injection time

Injection Time Retarted			
Mean injection Pressure	bar	↓ 571	↑ 573
Injection Time	CA	↓ -1,8	↑ 2,2
Scavenge Temperature	°C	↓ 41,16	↑ 42,23
Scavenge Pressure	bar	↓ 2,76	↑ 2,99
Compression Pressure	bar	↓ 96,7	↑ 103,74
Engine RPM	rpm	↑ 102	↑ 102
ME Mean Engine Indicated Power	kW	↑ 48540	↓ 48490
ME Mean Engine Effective Power	kW	↑ 44470	↓ 44360
Specific fuel oil consumption	g/kW	↓ 180,5	↑ 186,86
ME Cylinder Effective Power	kW	↑ 3702	↓ 3698,2
ME Cylinder Indicated Power	kW	↑ 4046	↓ 4041,4
Effective Mean Pressure	bar	↑ 16,39	↓ 16,36
Indicated Mean Pressure	bar	↑ 17,91	↓ 17,88
Exhaust Manifold Pressure	bar	↓ 2,59	↑ 2,81
Exhaust Manifold Temp	°C	↓ 401	↑ 421,9
Turbocharger Speed	rpm	↓ 8760	↑ 8900
Max Incylinder Pressure	bar	↑ 137,4	↓ 117,9
Fuel injected mass/stroke	g	↓ 107,38	↑ 111,23
Heat in Fuel	kW	↓ 7295	↑ 7556,9
Heat to Exhaust	kW	↓ 2801	↑ 3013,5
Heat to water	kW	↓ 549	↑ 590
Heat to oil	kW	↓ 219	↑ 232,3

Scavenge temperature has minimal effects in combustion. There are minor changes in observed parameters that scavenge pressure increase 2,76 bar to 2,84 bar as a result of temperature increase in exhaust 401°C to 407 °C and exhaust pressure 2,59 bar to 2,65 bar. Increase of temperature of scavenge air lead total increase of all temperatures in the system which seen in Table 6. There is worthless change in specific fuel consumption at the engine.

Reducing of scavenge air pressure causes reducing in both compression and maximum pressures. As a result of pressure drop in the cylinder leads to pressure reduction in the exhaust manifold also. Total mass of the air inside the cylinder is exposed to same amount of the heat release so temperature of the exhaust gas increases crucially, with a temperature rise, speed of turbocharger increases and forces to rise up scavenge air pressure in the scavenge area. This is balancing effect of turbocharger engines. There is a little increase in fuel consumption.

Table 6. Parameters variation at a condition increased scavenge air temperature

High Scavenge Temperature			
Mean injection Pressure	bar	↑ 571	↑ 571
Injection Time	CA	↑ -1,8	↑ -1,8
Scavenge Temperature	°C	↓ 41,16	↑ 51,28
Scavenge Pressure	bar	↓ 2,76	↑ 2,84
Compression Pressure	bar	↓ 96,7	↑ 99,21
Engine RPM	rpm	↑ 102	↑ 102
ME Mean Engine Indicated Power	kW	↓ 48540	↑ 48640
ME Mean Engine Effective Power	kW	↓ 44470	↑ 44520
Specific fuel oil consumption	g/kW	↓ 180,5	↑ 180,55
ME Cylinder Effective Power	kW	↓ 3702	↑ 3706,4
ME Cylinder Indicated Power	kW	↓ 4046	↑ 4049,7
Effective Mean Pressure	bar	↑ 16,39	↑ 16,39
Indicated Mean Pressure	bar	↑ 17,91	↑ 17,91
Exhaust Manifold Pressure	bar	↓ 2,59	↑ 2,65
Exhaust Manifold Temp	°C	↓ 401	↑ 407,2
Turbocharger Speed	rpm	↓ 8760	↑ 8819
Max Incylinder Pressure	bar	↓ 137,4	↑ 139,58
Fuel injected mass/stroke	g	↓ 107,38	↑ 107,47
Heat in Fuel	kW	↓ 7295	↑ 7302,3
Heat to Exhaust	kW	↑ 2801	↓ 2787,9
Heat to water	kW	↓ 549	↑ 561,4
Heat to oil	kW	↓ 219	↑ 223,6

Table 7. Parameters variation at a condition reduced scavenge air pressure

Low Scavenge Pressure			
Mean injection Pressure	bar	↓ 571	↑ 572
Injection Time	CA	↑ -1,8	↓ -2,3
Scavenge Temperature	°C	↑ 41,16	↓ 38,86
Scavenge Pressure	bar	↑ 2,76	↓ 2,42
Compression Pressure	bar	↑ 96,7	↓ 86,52
Engine RPM	rpm	↑ 102	↑ 102
ME Mean Engine Indicated Power	kW	↑ 48540	↓ 48520
ME Mean Engine Effective Power	kW	↑ 44470	↓ 44400
Specific fuel oil consumption	g/kW	↓ 180,5	↑ 181,05
ME Cylinder Effective Power	kW	↑ 3702	↓ 3700
ME Cylinder Indicated Power	kW	↑ 4046	↓ 4044
Effective Mean Pressure	bar	↑ 16,39	↓ 16,38
Indicated Mean Pressure	bar	↑ 17,91	↓ 17,9
Exhaust Manifold Pressure	bar	↑ 2,59	↓ 2,28
Exhaust Manifold Temp	°C	↓ 401	↑ 455
Turbocharger Speed	rpm	↓ 8760	↑ 9323
Max Incylinder Pressure	bar	↑ 137,4	↓ 129,4
Fuel injected mass/stroke	g	↓ 107,38	↑ 107,75
Heat in Fuel	kW	↓ 7295	↑ 7319,9
Heat to Exhaust	kW	↑ 2801	↓ 2786
Heat to water	kW	↓ 549	↑ 575,8
Heat to oil	kW	↓ 219	↑ 235,2

As demonstrated in Table 8. Compression ratio reduction causes total increase in fuel consumption about 4g/kW. Other operational values are not change dramatically since increase of scavenge pressure balances this effect. Exhaust manifold pressure and temperature increases which leads increase of rotational speed of turbine that forces to increase scavenge pressure.

Table 8. Parameters variation at a condition reduced compression

Low compression			
Mean injection Pressure	bar	↓ 571	↑ 572
Injection Time	CA	↑ -1,8	↑ -1,8
Scavenge Temperature	°C	↓ 41,16	↑ 41,8
Scavenge Pressure	bar	↓ 2,76	↑ 2,9
Compression Pressure	bar	↑ 96,7	↓ 96,4
Engine RPM	rpm	↑ 102	↑ 102
ME Mean Engine Indicated Power	kW	↓ 48540	↑ 48570
ME Mean Engine Effective Power	kW	↑ 44470	↓ 44450
Specific fuel oil consumption	g/kW	↓ 180,5	↑ 184,56
ME Cylinder Effective Power	kW	↑ 3702	↓ 3695
ME Cylinder Indicated Power	kW	↑ 4046	↓ 4038
Effective Mean Pressure	bar	↑ 16,39	↓ 16,37
Indicated Mean Pressure	bar	↑ 17,91	↓ 17,9
Exhaust Manifold Pressure	bar	↓ 2,59	↑ 2,72
Exhaust Manifold Temp	°C	↓ 401	↑ 415
Turbocharger Speed	rpm	↓ 8760	↑ 8861
Max Incylinder Pressure	bar	↑ 137,4	↓ 133,7
Fuel injected mass/stroke	g	↓ 107,38	↑ 109,76
Heat in Fuel	kW	↓ 7295	↑ 7456,8
Heat to Exhaust	kW	↓ 2801	↑ 2935
Heat to water	kW	↓ 549	↑ 575,16
Heat to oil	kW	↓ 219	↑ 228,02

Heat loses at the exhaust level and other loses increase in this case. The same power is produced with more the fuel. It is clearly seen that maximum pressure inside the cylinder decreases. This is the result of pressure drop in cylinder.

Conclusion

In the present work, parameters which affect energy efficiency at operation of two stroke large marine diesel engine, were considered to observe their impact to total fuel consumption. It is clearly seen that at operation of diesel engine is very crucial effect efficient operation. To optimize the fuel consumed by marine diesel engine understanding of diesel engine operation must be comprehended by marine engineering trainees or students. Furthermore, shipping companies desire well trained engineers for smooth operation in their fleet [17]. To achieve this objective engine room simulator is an effective tool to foreseeing effects of any defectiveness in marine diesel engine. Arrange of the simulator for this purpose with appropriate conditions and afford trainees to comply with this issues with a consideration of observed values will be practical for improving efficiency attention.

For further studies, to expand the scope of this study additionally many more parameters must be included for monitoring and evaluation such as ignition delay, combustion duration, NOx and Soot emissions and instantaneous heat release rate. Talking about on changing of these parameters and their impact on total fuel consumption as a group of trainees or students with each other will help to improve their understanding on combustion phenomena effect on energy efficiency.

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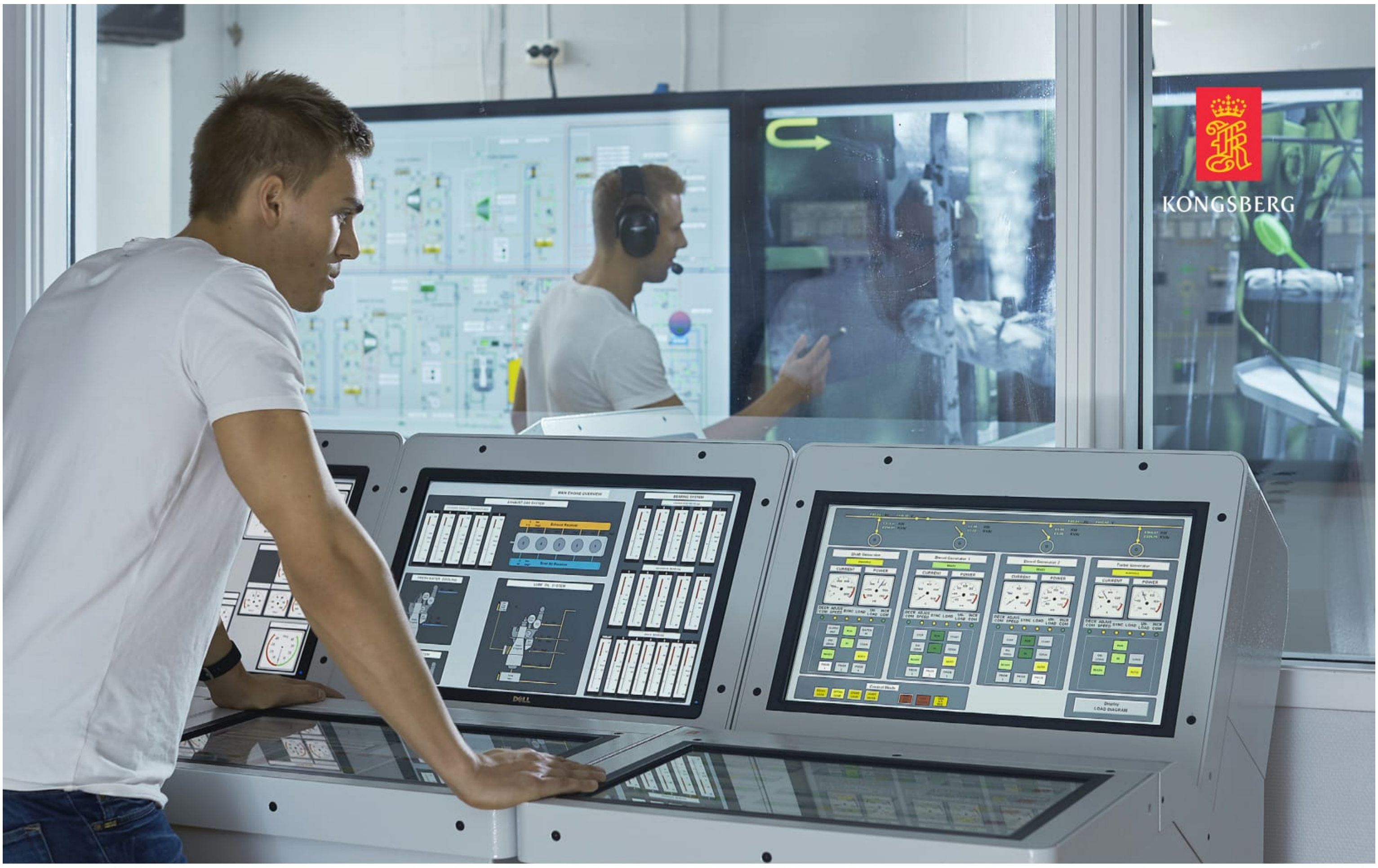

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