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EDUCATION TOOLS FOR ELECTRO-TECHNICAL OFFICER (ETO) – PART II

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Abstract. Actual development and international activities to reduce CO_2 footprint lead to increasing application of power electronic systems at seagoing ships. Introduction of batteries and belonging power management functions require from people on board a lot more electro technical understanding. This has to be reflected in the educational path as well. During IMLA conference 2021 the University of Applied Sciences, Technology, Business and Design, Dpt. Maritime Studies, Systems Engineering and Logistics (SAL) presented already ideas to improve maritime electrical education. Useful experimental setups in Electrical systems, harmonics of onboard system and understanding of hybrid ships part of the course to prepare trainees for their future job onboard. The presented paper below should be some kind of update to 2021. Focus is still set to practical education in laboratory. New courses of studies with international students have been integrated at SAL. So also new labs for international students on handling technology will be presented in detail.

Keywords: Electro-Technical Officer ETO; Education; Laboratories; Maritime Electrical Education; Maritime Electrical Engineer.

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1. INTRODUCTION

Electrical systems in seagoing ships still rapidly changing. Not only into passenger ships large scale electrical drives have been implemented. As a latest result Argentina is ordering a full electric ferry with only battery storage system, what actually has the very highest over all efficiency employing green energy. The number and the complexity of electrical consumers has also increased significantly.

Control systems have been grown from a handful of sensors with local alarms to more than 10,000 sensors per ship with online connection to fleet monitoring centers. So normal education path for ship operating officer is not sufficient any more. Even more green technology will not work without automation. Nowadays AI is often referenced word.

According to this development the Manila amendments to the STCW has defined the special training course for ships electrical engineers the so called Electro-technical officer (ETO) described in [1]. Considering that even now in the IMO there is an international discussion ongoing to increase further educational contend.

This presentation based on the first article [1] is intended to extend the view at the ongoing development on board. In opposite to that there is a certain feeling that at the educational side number of institutions offering ETO training is decreasing. Many of our finalists have been in contract with cruising companies like AIDA from Carnival corporation already at the beginning of their studies.

1.1. Definitions – Manila Amendment 2010 STCW

Definitions for electrical training in the widely more general defined requirements and the principle course of studies have been referenced in [1]. Compared to [1] institutions to do ETO training have slidely changed, a (possibly uncomplete) list is this:

- Southampton, Solent University' https://www.solent.ac.uk/courses/undergraduate/marine-electrical-and-electronic-engineering-beng
- Gdynia, Faculty of Electrical Engineering
- Paço de Arcos, Portugal, Bachelor Degree Maritime El. Engineering
- Further offers in EU cannot be found anymore here: https://www.marinetraining.eu/providerover-view

It is hard to believe that opportunities for education for these upcoming technologies is reducing. Training of skills for 21st-century in Marine Engineering Technology is not a closed process, it needs a lifelong learning in the maritime context. This is also valid for teachers.

We explained in [1]: The requirements for ETOs future knowledge require also Engine Room Simulator (ERS) training. This will need continuous development of ERS what also allows application for research and development.

In the STCW/Manila we find here: "Manage operation of electrical and electronic control equipment" we find only general: "Marine electro technology, electronics, power electronics, automatic control engineering and safety devices".

1.2. New Copmonents in Ships

There is still no list of components given. One of the most growing areas of technology is in the eyes of MSL not covered: new power components entering ships are:

- Large scale frequency converters in ships drives
- Frequency converter for auxiliary drives like any pumps or fans
- Exhaust gas scrubbers and washing systems and their controls,
- Batteries, power controllers and chargers for hybrid drives
- Electrical Starters for diesel Engines (e.g. Emergency generator)
- Ignition systems for LNG engines

Power management (PMS) as well, here a lot of new functions enter the ships as:

- Widely extended complex power management systems including
- Automatic power recovery after Black Out
- Automatic and manual operated electrical shore connection systems.

To teach the required contend practically it's very difficult to get access to proper experimental setups. So new test setups have been introduced but also often simulation is preferred. This is valid for Power Systems as well as for all Automation Systems.

2. NEW LABS

UW and here MSL in [1] have invested in a number of modern experiments in the recent years:

1 The first new setup has been frequency converter with an Asynchronous Motor and a load generator. Here and the students get familiar with

commissioning of FCs, the input of parameters and the definition of limitations and protection functions.

2 A current source converter (CSI) used in a shaft generator system has been available. Due to the fact that a cycle converter has the same structure, this has been adopted to simulate a drive system also.

3 One setup presents a ships drive with a double winding motor,

4 a second part simulates a POD drive.

5 One experiment on electrical starters including measurements at a real test setup

6 Ships Engine Simulator experiments with updated models for hybrid ships and on board Power Management Systems (PMS) and here we have a lot of new safety functions:

7 Load dependent start and stop of gensets

8 Heavy Consumer Request to switch on heavy consumers a thrusters or transformers

9 Replacement of faulty gensets by Standby gensets

10 Disconnecting unimportant consumers

11 Separation of power grid areas if one of them has a fault

12 Automatic load reduction of heavy consumers, e.g. main drives

13 Also new PMS optimization function have to be explained

14 „Peak shaving“

15 „Battery only“

16 „max-economy“

17 Blackout recovery

18 Regenerative systems consisting of solar cell, fuel cell, batteries, heat store and/or hydrogen storage experiment

New modern experimental setups in the last five years are:

1 Simulation model of single-phase transformer

2 Simulation model of asynchronous motor

3 The first setup of frequency converter with an Asynchronous Motor has changed to a setup where students are themselves doing wiring and commissioning of drive system.

Ships Engine Simulator experiments of hybrid ships have been updated with models of batteries and extended Battery- and Power Management System functions (PMS).

2.1. Ships Onboard System Handling

Existing Ships drive system has been extended by remote control handles to train handover control functions from either Engine control room (ECR) or bridge to local panel control.

Figure 1. Remote panels

To do so a couple of procedures is applied. In this case a so called lever match can be shown. If control is at bridge and it should be moved to ECR than a signal is given to change control stand. Only if new location control handle does match the old value from former control stand, PLC is accepting the change to the new control stand. Doing so fast changes in the reference value are prevented.

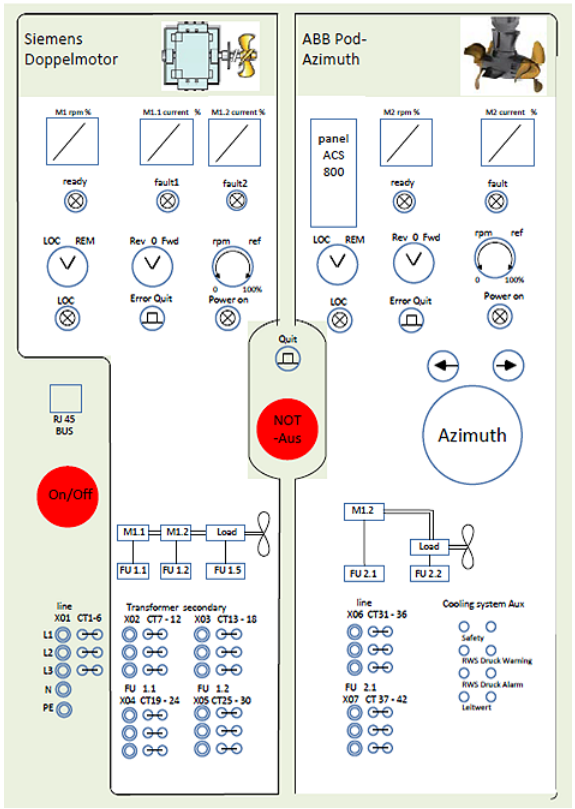

Figure 2. Scheme of local control panels.

2.2. Introduction to Harmonics

In actual ships electrical systems modern power electronic components lead to harmonics in grid voltage. Main sources of harmonics are LED's and frequency converters. To make students familiar with that, a lab has been introduced dealing with that.

In the ships drive lab setup there is a three winding transformer. This will be investigated to show the influence of such systems on harmonic distortion.

In Figure 3 one can see how current measurement is done. All connections from transformer are routed through the panel door to outside as small cable loops. This gives opportunity to connect current probes to the wires. To be seen in the right back of the picture. Voltages can be connected to the PX8000 directly or via High voltage probes to an oscilloscope. From 4 channels of PX8000 1 can be connected to primary side, 2 to secondary side.

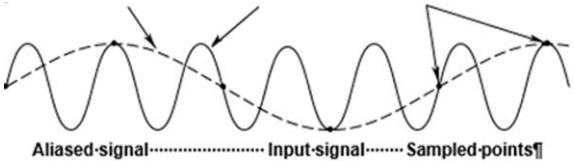

Figure 3. Harmonics in signals [2]

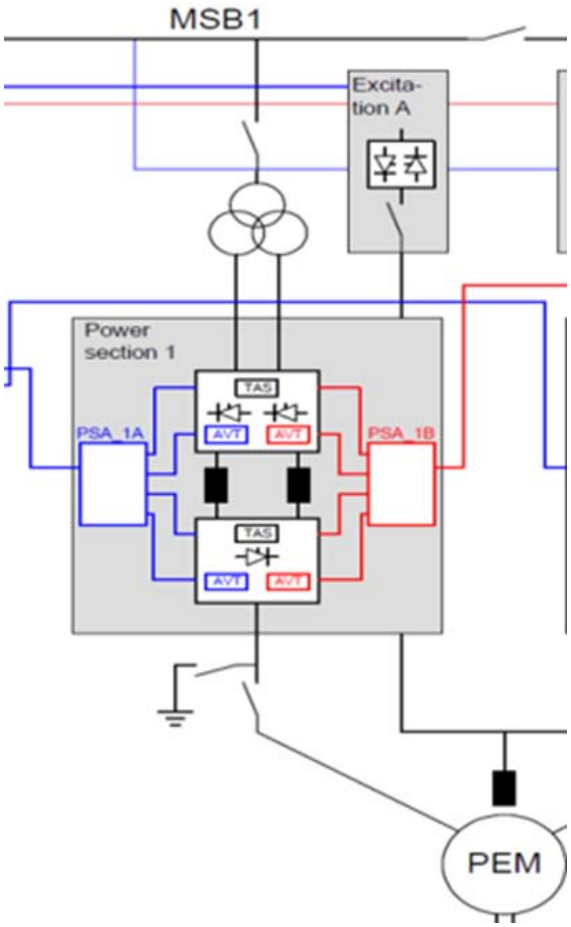

Figure 4. Power schematic

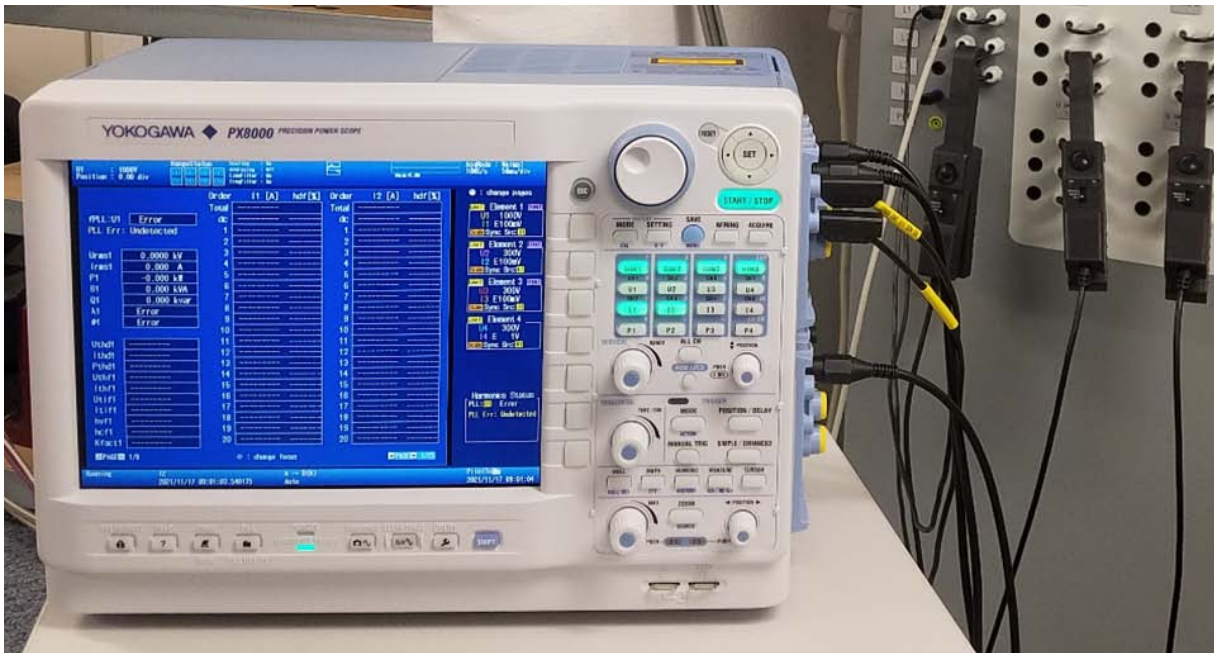

Figure 5. PX8000 harmonics measurement and connection to experimental setup.

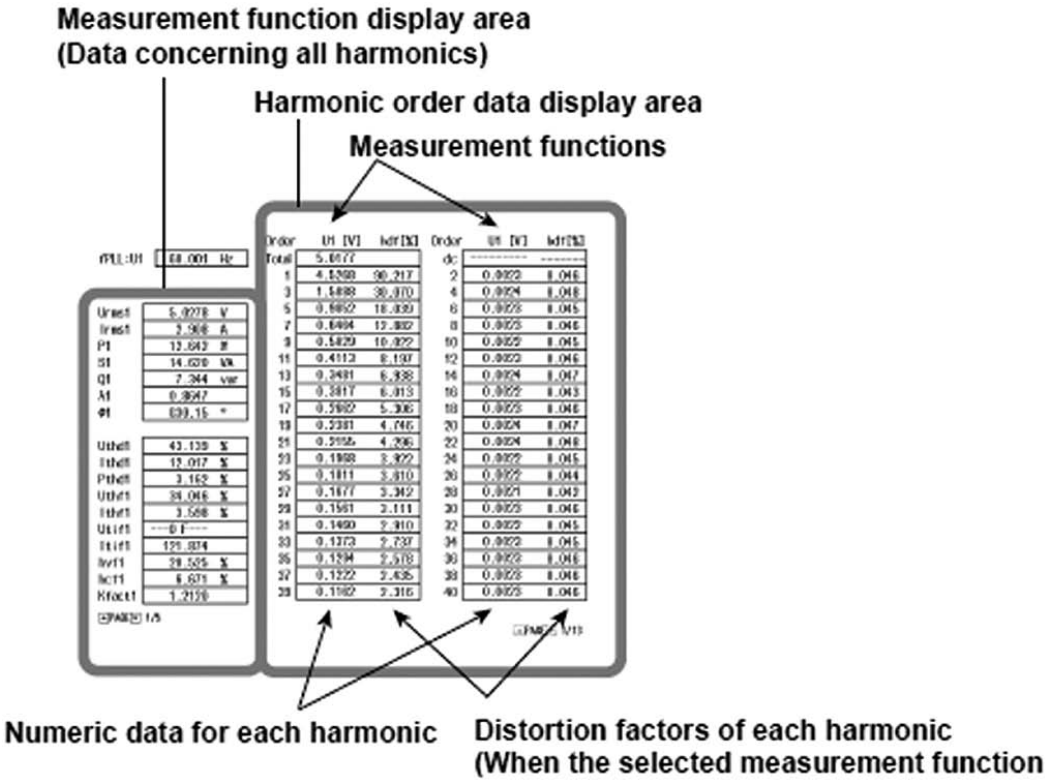

Figure 6. Numeric display for harmonics in PX8000 [2]
Values will be given in amps and in %. Also a scope view is possible and shows differences clearly.

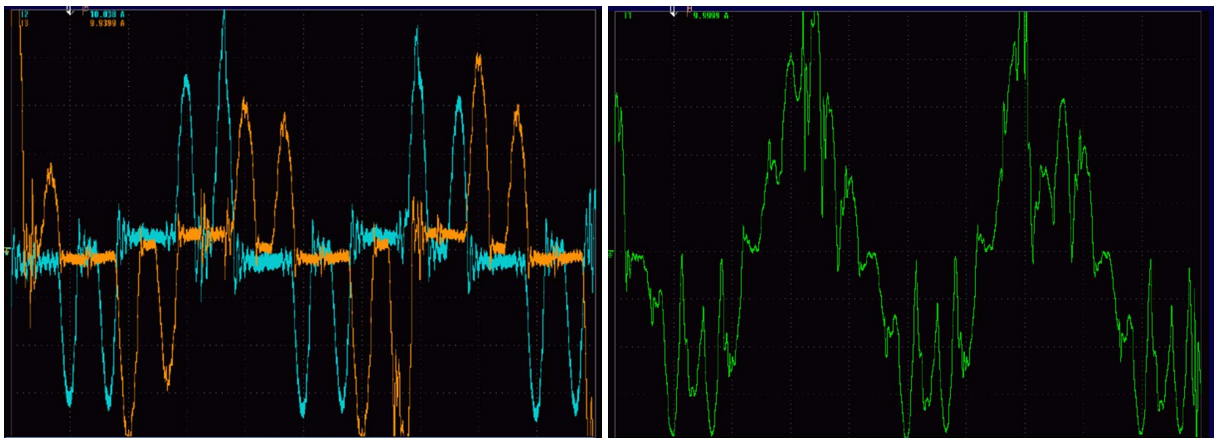

Figure 7. Secondary side (left) and primary side (right), Grid side with visible reduction.
The right part shows a more "sinusoidal function" with less harmonics, what is clearly documented in the displayed list.
So students get familiar with the real wave forms in power electronic systems.

2.3. Hybrid Ship With Battery System in Ships Engine Simulator (SES)

Generators and E-motors had been modelled already before. But updated SES models nowadays include also electrical storage systems (ESS, batteries). To model PMS under operation, they have to comprise power consumption of auxiliary systems like pups, fans, batteries, scrubbers etc.

Similar systems are under investigation in Research work, so modern results come into education as well. As an excitable input for models is the schedule of a ferry. From here you can derive speeds at the different etaps of the travel what is defining drive power consumption. This will be little influenced by the wind and wether condition. Together with hotel- and auxilary loads consuption is defined.

Influence of time table (ships speed) and route on charging cycles and thus battery aging can be estimated. In Peak shaving PMS-mode all diesel generators should run with 100% load. If ships load is higher than the number of diesel generators battery is supplying difference. By this it will be discharged. If lower state of charge (SOC) is reached, one more diesel generator is started, now we have "overproduction" and the difference is charging battery until it is fully charged or max. SOC is reached. Over 5 hours the behavior looks like following plot.

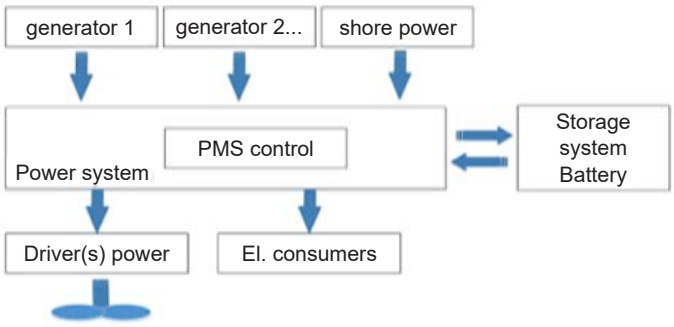

Figure 8. PMS model

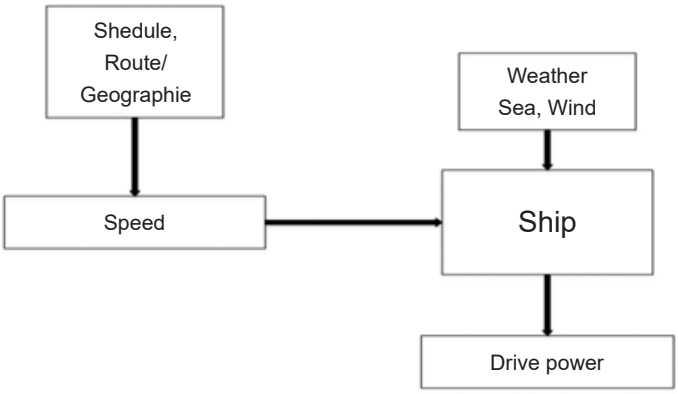

Figure 9. Hybrid ships model and outside influences to ship

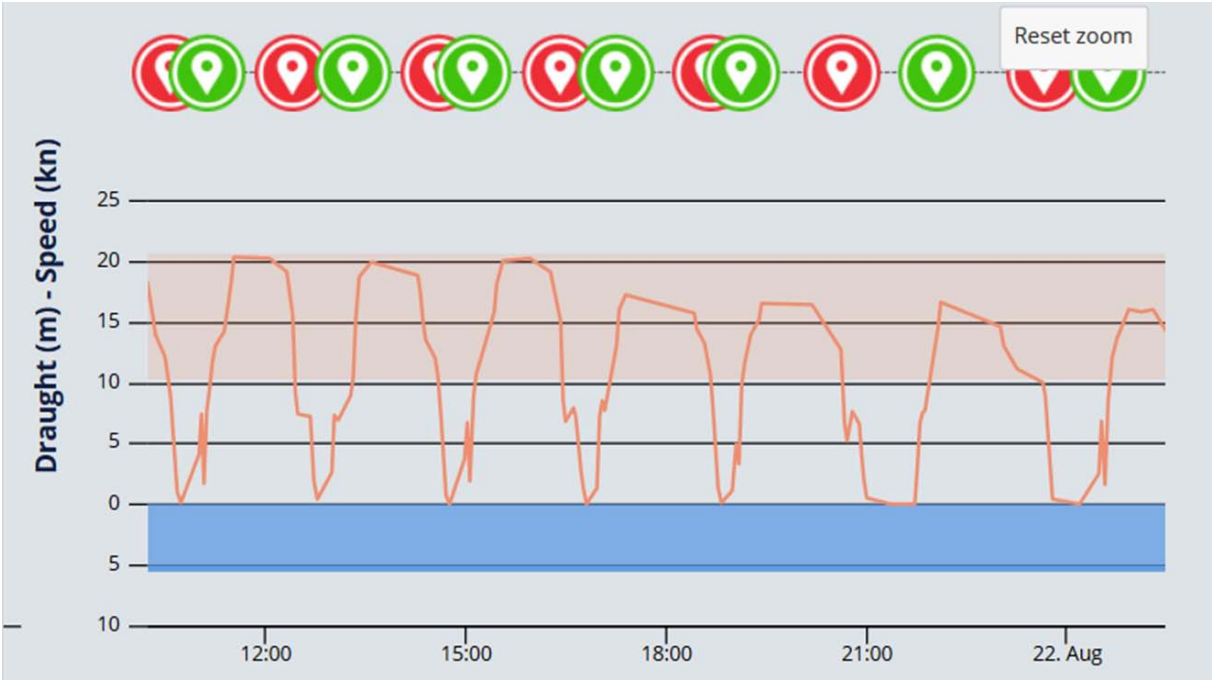

Figure 10. Ships speed definition from time table

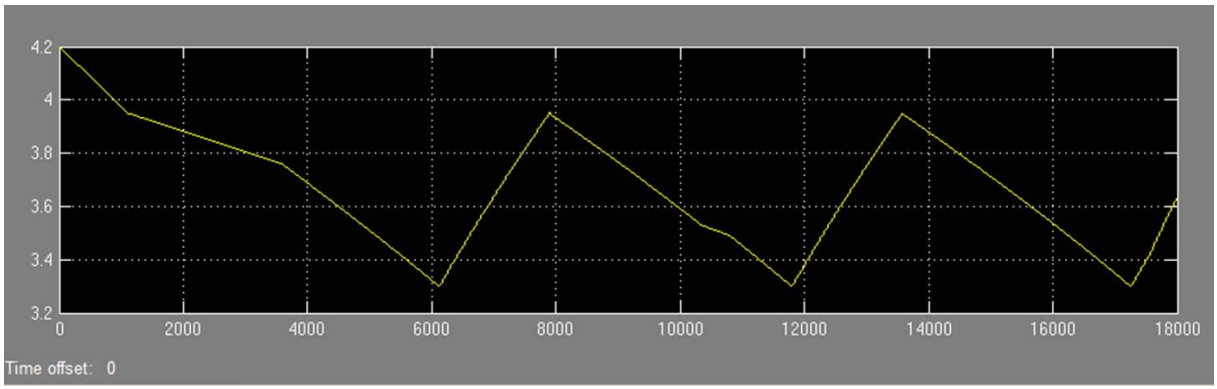

Figure 11. Ships battery cell voltage (Yellow)

One can see that the battery is three times discharged and recharged, the voltage is going up and down together with starting and stopping one more diesel generator.

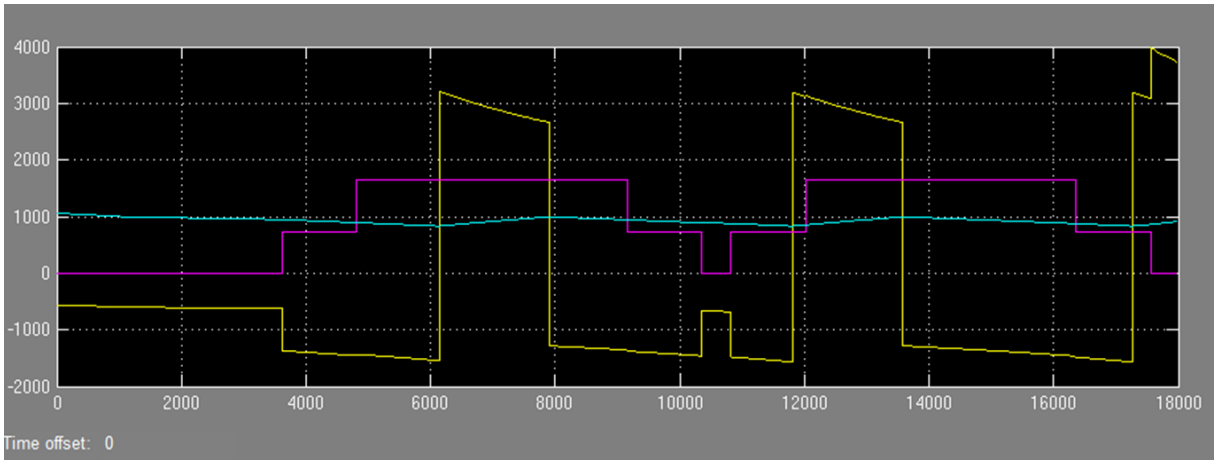

Figure 12. Ships mode and battery voltage
Light blue: battery voltage, yellow: Battery power,
Pink: ships mode (scaled number) 0 = harbor, 1(800) = maneuvering, 2 (1600) Sea mode

2.4. Laboratory Education at Ships Simulator

The simulator, to be seen in Figure 14 is presenting the overall control system of a large passenger ship. The automation system model is very close to reality due to same human machine interface (HMI) as on board. All energy generating and consuming components are simulated. More than 200 different failure scenarios are created. A lot of realistic situations, such as a part loss of propulsion or blackouts in different subsystems can be trained. To increase the safety of the passenger ship one new scenario is introduced into the educational path:

By any mistake the only one generator, which is supplying the ship in harbor will be stopped. The students now have to reenergize the ship. But only if the handling sequence is right energy will be coming back stable. But training purpose this can be done in two different ways:

a) with and

b) without PMS

Version a) is mostly very simple. The students only have to wait. Without PMS version b) they have to act very carefully and they have to do every step manually. This gives more understanding and more safety to do that on board of a ship in a real situation. In preparation of this lab students will get familiar with all generator protection functions including short circuit at a standalone Stamford generator and control panel.

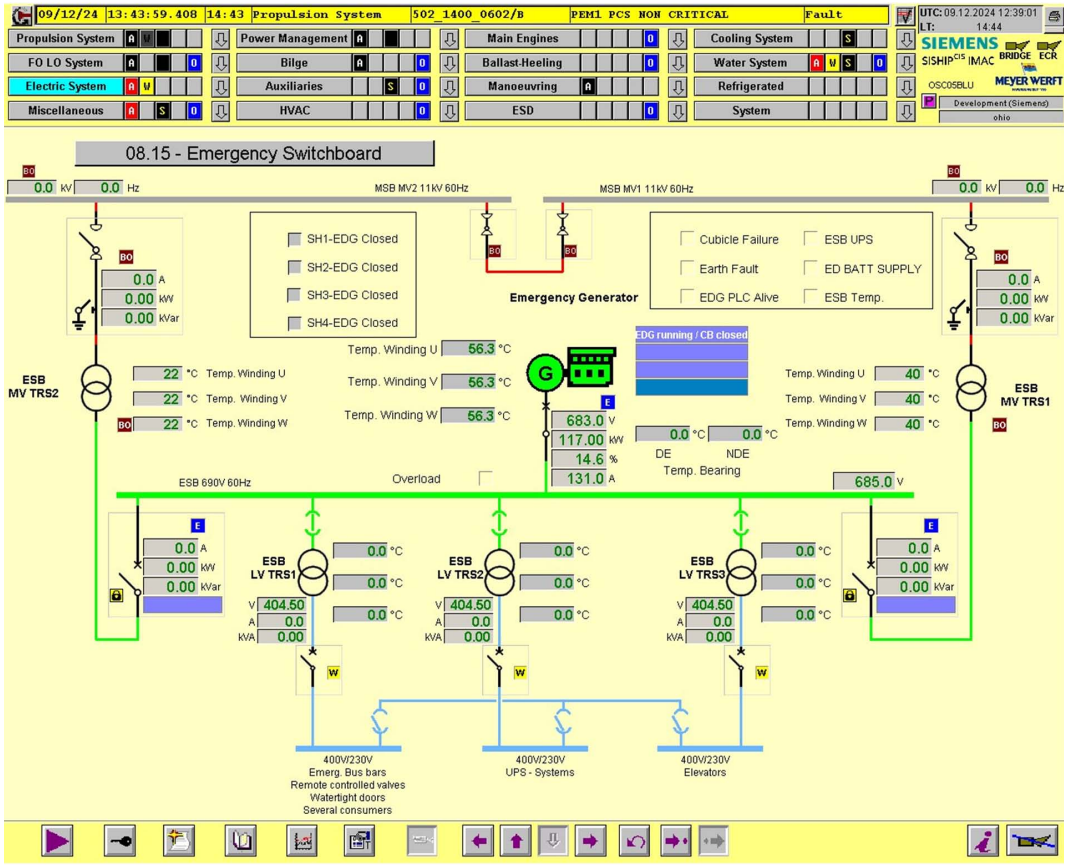

Figure 13. Emergency switchboard 690V in Emergency Generator Operation Condition

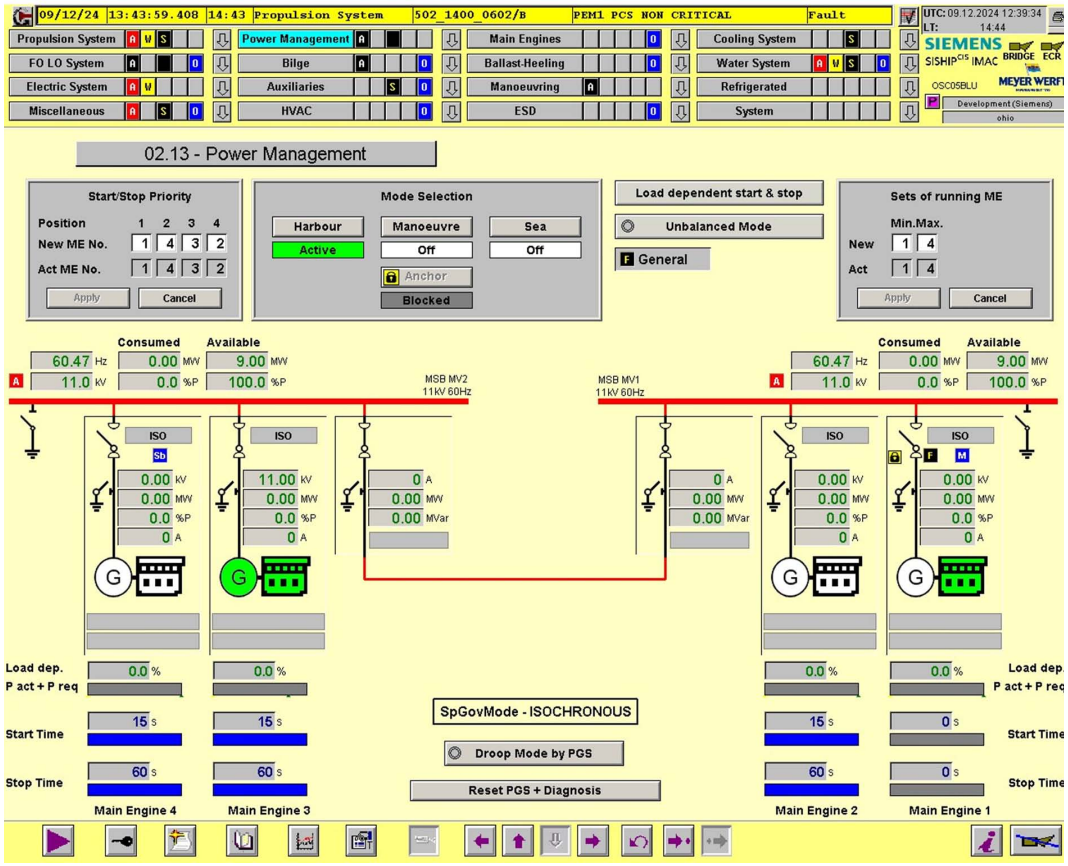

Figure 14. Main – Medium Voltage Switchboard in normal condition (reproduced Siemens Simulator Manual)

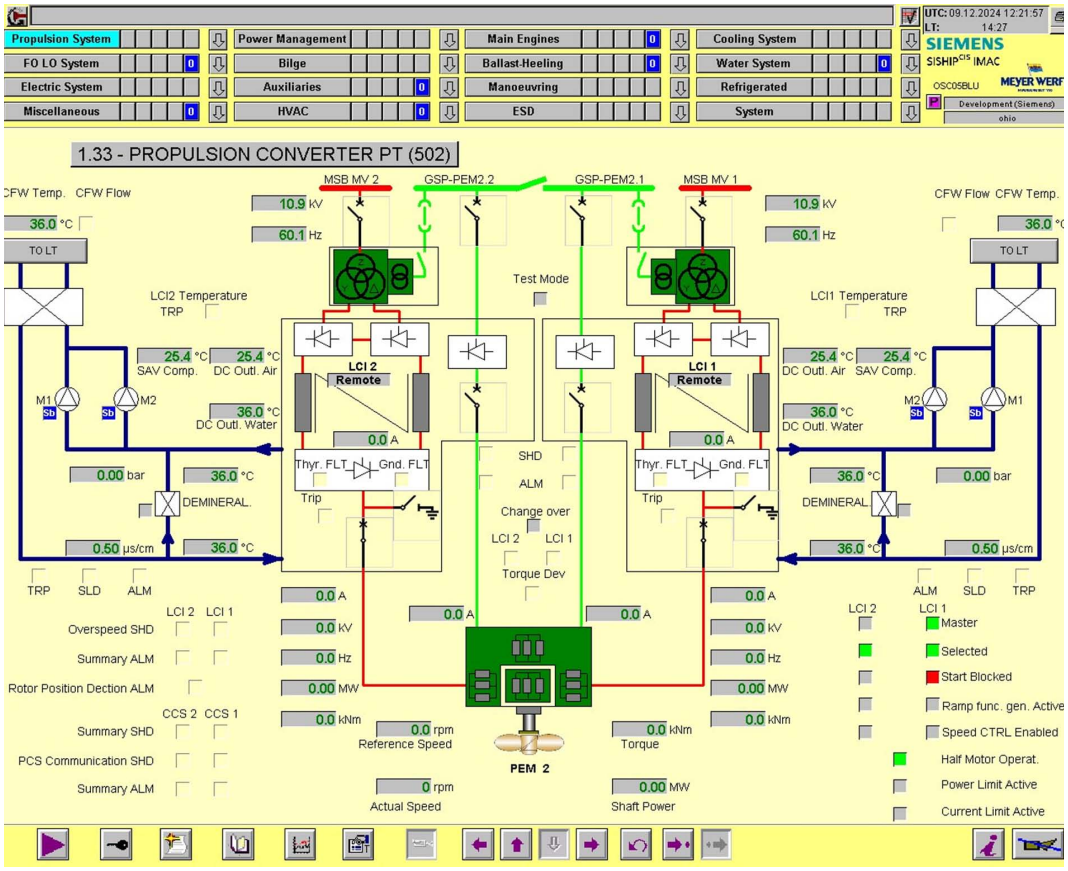

Figure 15. Propulsion Converter in normal condition (reproduced from Siemens Simulator Manual)

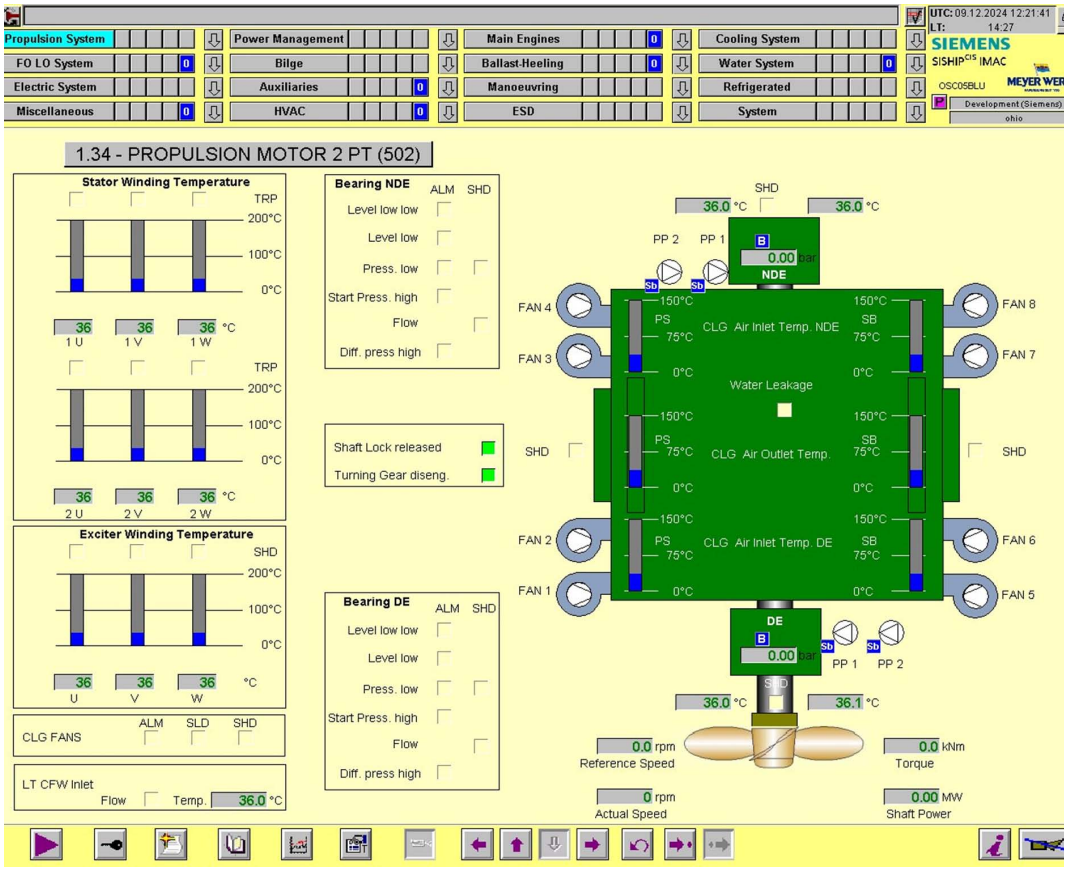

Figure 16. Propulsion Motor in normal Conditon (reproduced from Siemens Simulator Manual)

Another scenario shows a partial failure of the drive due to a critical fault in one of the drive inverters. The student is confronted with a large amount of information at the same time. He must decide how to proceed. Clarify the situation – is it possible to operate the ship with the given reduced propulsion power? Interpreting alarm messages in order to localize the fault and make the right decisions to solve the problem. The special feature of the simulator is that every fault can be simulated down to the process level (sensors), thus enabling an absolutely realistic fault simulation.

2.5. Lab "Complex Ship Operation"

Finally there is one big lab to sum up all educational results. The sudents are put in groups, technical and nautical groups are working together. The operate a "virtual ship" including ECR bridge communication. Especially ETO candidates have on especial day, answering only electrical problems from the above mentioned fields. The procedure is similar to a ships day. Briefing in the morning, start to work, and being interrupted by some high priority problem. The students have to prepare working fields by managing spare parts, planning sequence of working steps...

3. INTERNATIONAL EDUCATION

In cooperation with Indonesian University Institut Teknologi Sepuluh Nopember (ITS) a maritime double degree course of studies has been introduced [3]. Half of the lessons is held by HS-Wismar, and for one semester ITS-students come to Warnemünde to get familiar with a lot of labs and experiments.

To improve and ease understanding of ships electrical components and to prepare experimental labs four virtual labs based on a simulation are introduced:

1 Induction

2 Transformer

3 Synchronous uncontrolled generator

4 Synchronization

Nr 1 and 4 can easily been realized applying information from the Internet.

Nr. 2 and 3 as model based simulations. The students can change rated data of machine before testing in the left lower part of the screen. During test some sliders used to change parameters similar to do experiments in reality. For Transformer one can adjust input voltage and frequency. Applied load can be adjusted in the same way by sliders for ohmic or inductive or mixed loads.

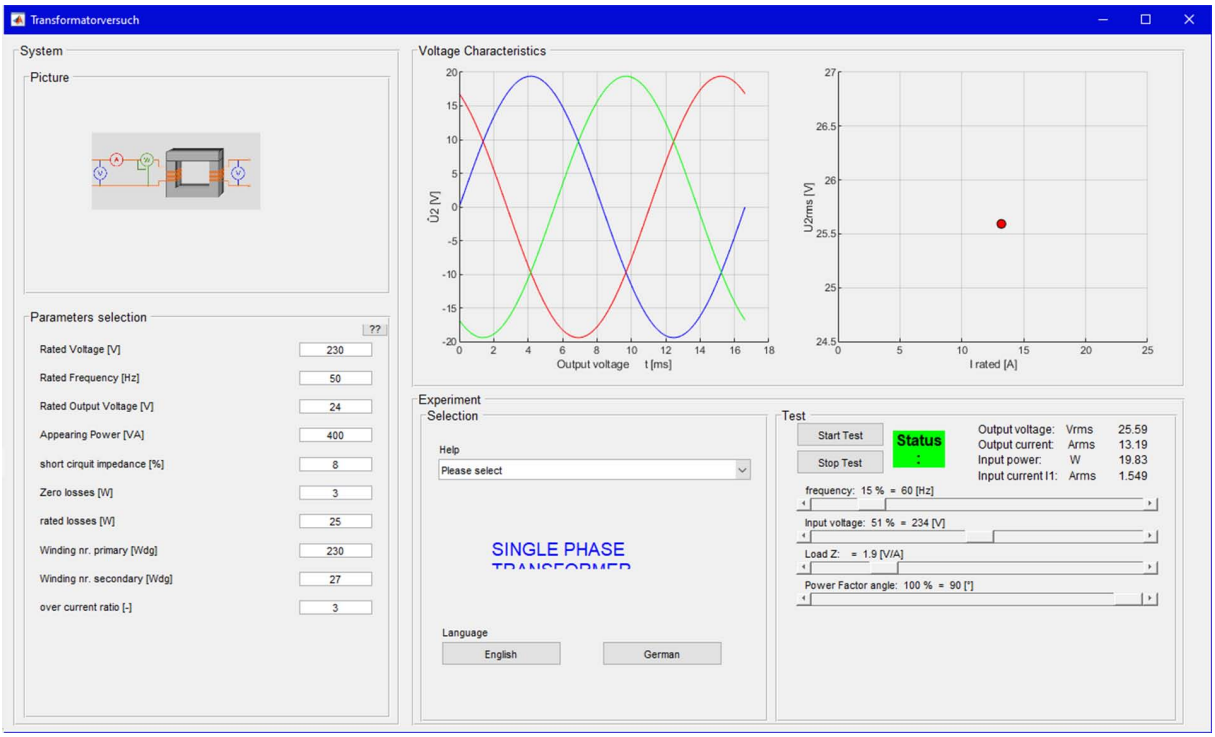

Figure 17. View of Transformer model simulation.
Output voltage for desired load points can be read and plotted.

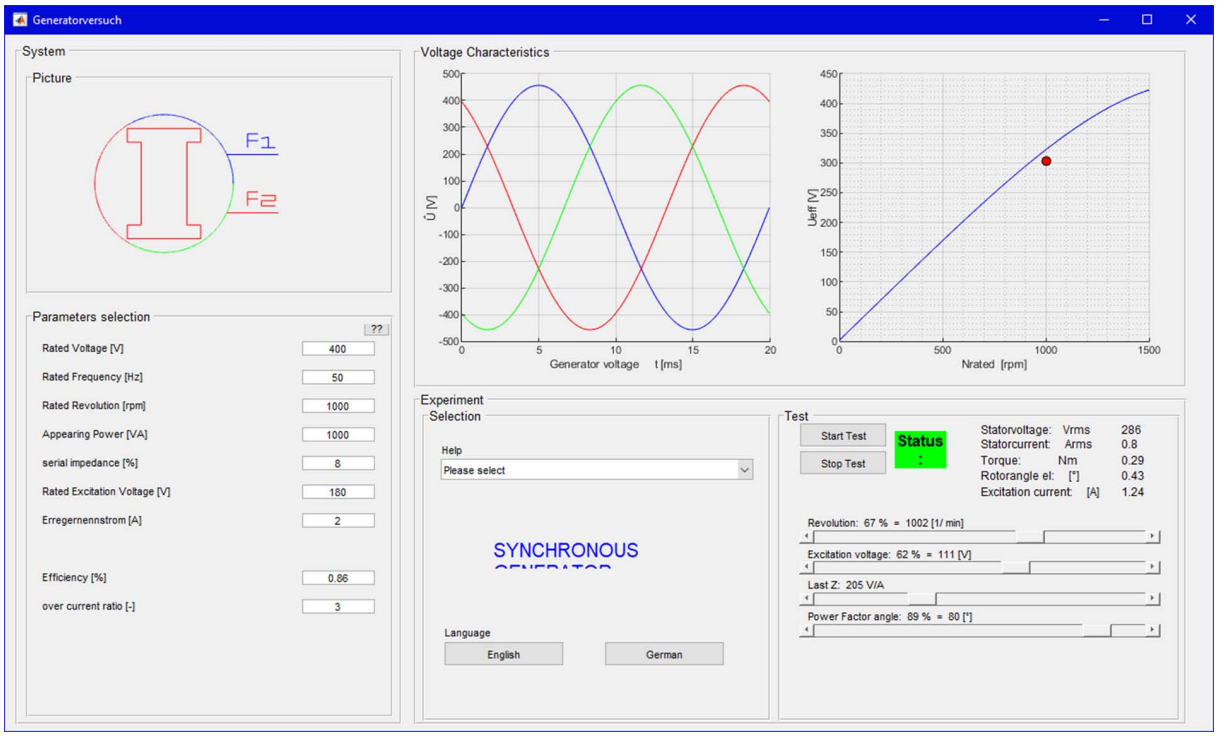

Figure 18. View of Synchronous generator model simulation.
In the graph right Top you can find the no load curve and the actual output voltage for the load defined by the sliders below. Detailed "measurement" values can be found below the graph.

4. ONE MORE ASPECT/FEEDBACK FROM INDUSTRY

A short track educational path is introduced (MSL offers studies for all those persons in one year or two semesters). Sometimes technical officers or electrically working people want to qualify themselves to become an ETO. Either they already have a lot of ship handling knowledge or they are dealing with electrical system since long time. According to the STCW requirements for technical officers extended electrical aspects have to be trained. In opposite to those already electrically educated people some candidates have their roles in watchkeeping. In this case a knowledge in automation, electrical and power systems is needed.

5. RESEARCH WORK

At chair of "Ships electrical engineering" also research work has changed over the recent years. In the field of modelling we actually investigate:

1 optimized energy efficient power management systems on board of ships having electrical drive systems, batteries and fuel cells.

2 Introducing Hydrogen into conventional ships drives

Publications:

- "Entwicklung von Modellen zur Simulation von (FU) Frequenzumrichter-Modern PMS functions are explainded in „Simulationsmodelle für Batterien und Dieselmotoren zur Bestimmung der Energieeffizienz auf Hybridschiffen" (Simulation models for batteries and diesel engines to calculate efficiency on hybrid ships)
- "Simulationswerkzeuge zur Auslegung von Power Management Systemen zur Integration moderner Energiequellen", (Simulation tools for integration of modern green energy sources)

6. SUMMARY

- ETO course in Rostock is still ongoing with about 6 students /year,
- Further ships electrical experiments keep electrical education up to date.
- Shipping Companies still very satisfied with "ETO results" as the finalists are.

7. FINAL REMARK

Education is one part to bring knowledge into the future. Research may help to get/receive results for

future requirements. But since "Club of Rome" book "Endlichkeit der Welt" we know about fragility of earth and a lot of risks we generate by our daily business. But it is very clear, as long as every CEO still tries to extend his business/yield by spending/investing minimum of money (cheapest fuel, transportation of goods from/to the cheapest worker in the world, using cheap material for goods to reduce product life time…) there will not be any improvement for the environmental health or for a better future.

REFERENCES

[1] Rafoth, A., Borchhardt, J., 2021. *New education tools for Electro-Technical Officer (ETO)*, Proceedings of International Maritime Lecturers' Association (IMLA).

[2] IM PX8000-01EN PX8000 Features Guide, Kapitel 2, 4. Ed., pp. 4-3.

[3] https://fiw.hs-wismar.de/bereiche/sal/studiengaenge/marine-engineering-bachelor-deutsch-indonesisch-beng-double-degree/