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A Full Mission Simulator of the Ship's Automated Electric Power System for Training and Competence Testing of Marine Engineers

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Abstract: This article describes practical preparation of marine engineers on the full mission simulator complex of the ship's automated electrical power plant. A full mission simulator complex of the ship's automated power management system meets International Convention STCW (Standards of Training, Certification and Watchkeeping) 78 (with Manila amendments 2010) requirements in 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 of technical maintenance of real ship's equipment (high voltage installations included) and means of automation. The simulator's complex is designed for 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 watch-keeping 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 simulator's complex provides adequate reproduction of operational situations on technical side of real ship electric and automation equipment provides training on monitoring, control and management diesel-generator sets in hand, semi-automatic and automatic modes of power station, control and management of electromechanical systems, as well as the set of tasks upon parameterization, visualization and etc. Besides number of combinations of monitoring, control and management tasks, the simulator's complex provides an opportunity to simulate various practical fault conditions. It allows students to focus on the work of automatic control system in emergency situations and to work out correct actions for a watch-keeper on searching, localizing of faults and troubleshooting of equipment.

Key words: Full mission simulator, ship's automated electric power system, practical training and proficiency testing, training courses subjects.

1. Introduction

The navigation safety along with other factors is largely determined by the reliability of operation of ship systems "human-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 power management systems, cargo and navigation systems are integrated into a single general ship automation system, and 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 ship's engineers to ensure the required maintenance level 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 modern computer control,

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monitoring and communication technologies, providing both watch-keeping and non-watch maintenance of ship complexes and systems.

The International Convention STCW 78 with the Manila Amendments 2010 [2, 3] have 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 of a vessel. In this regard, the urgency of practical training is growing, which should be carried out in approved laboratories and training complexes of 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 operational requirements of the vessel and ensuring its survivability and safety, cannot be realized on board in sufficient for future specialist volume. Therefore, the development and creation of specialized, really functioning (not virtual) and maximally close to the ship configuration of simulator complexes based on real equipment and modern micro-controller control technologies, will solve very important tasks of preparation and training for future ship engineers [4-6].

2. The Main Idea and Realizing Method of Simulation

The main idea and approach, which we relied on when developing and creating a simulator complex, is that plausibility 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 modern configurations, should be used. That has been approved by the main marine classification societies and therefore can be used on ships. Moreover, it is precisely the specific ship's technical means and systems, and not their virtual counterparts, 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 on capacities of the department of ship electro mechanics and electrical engineering of the National University "Odessa Maritime Academy". Comprising of simulator of the ship's automated electric power plant and simulator of PLC (programmable logic controller)-based control and modeling 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 operating modes corresponding to the actual configuration and layout of the ship's automated 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 (ship engineers and electrical officers) concerning the technical operation of the real ship's equipment and automation means.

3. Appointment, Equipment and the Simulator Capabilities

The simulator's complex is designed for 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 watch-keeping 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. The simulator's complex provides adequate reproduction of operational situations on technical side of real ship automation equipment, provides training on monitoring, control and management of diesel-generator sets in hand, semi-automatic and automatic modes of PMS, control and management of the electromechanical systems (electric drives), as well as the set of tasks upon parameterization, adjusting, visualization, etc. Besides number of combinations of monitoring, control and management, the simulator's complex provides an opportunity to simulate various practical fault conditions. It allows the student (cadet) to focus on the work of the automatic control system in emergency situations and work out correct actions of watch-keeper on searching, localization of fault and troubleshooting of equipment.

Thus, the full mission simulator complex (PMS) designed for training and proficiency testing of marine specialists (electro-technical officers and marine engineers) is fully consistent with Sections "Electrical, electronic and control systems" and "Maintenance and repair" of Standards A-III/1, A-III/2, A-III/6 of the International Convention STCW-78 with the Manila amendments, as well as with relevant competence required for 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 is combined into a single control network with the support of 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 [7-9].

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 V 7.40.

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

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

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

Various converters such as AC-DC, AC-AC, frequency converters such as FR-A740, FR-A540, Altivar 71 from Mitsubishi Electric and Schneider Electric are used as power converters. The direct current generator serves as an operating mechanism (load) for each of 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.

PMS (power management system) is based on the micro-controllers-C6200 and M2500 from SELCO company, micro-controllers PPM from DEIF company,

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

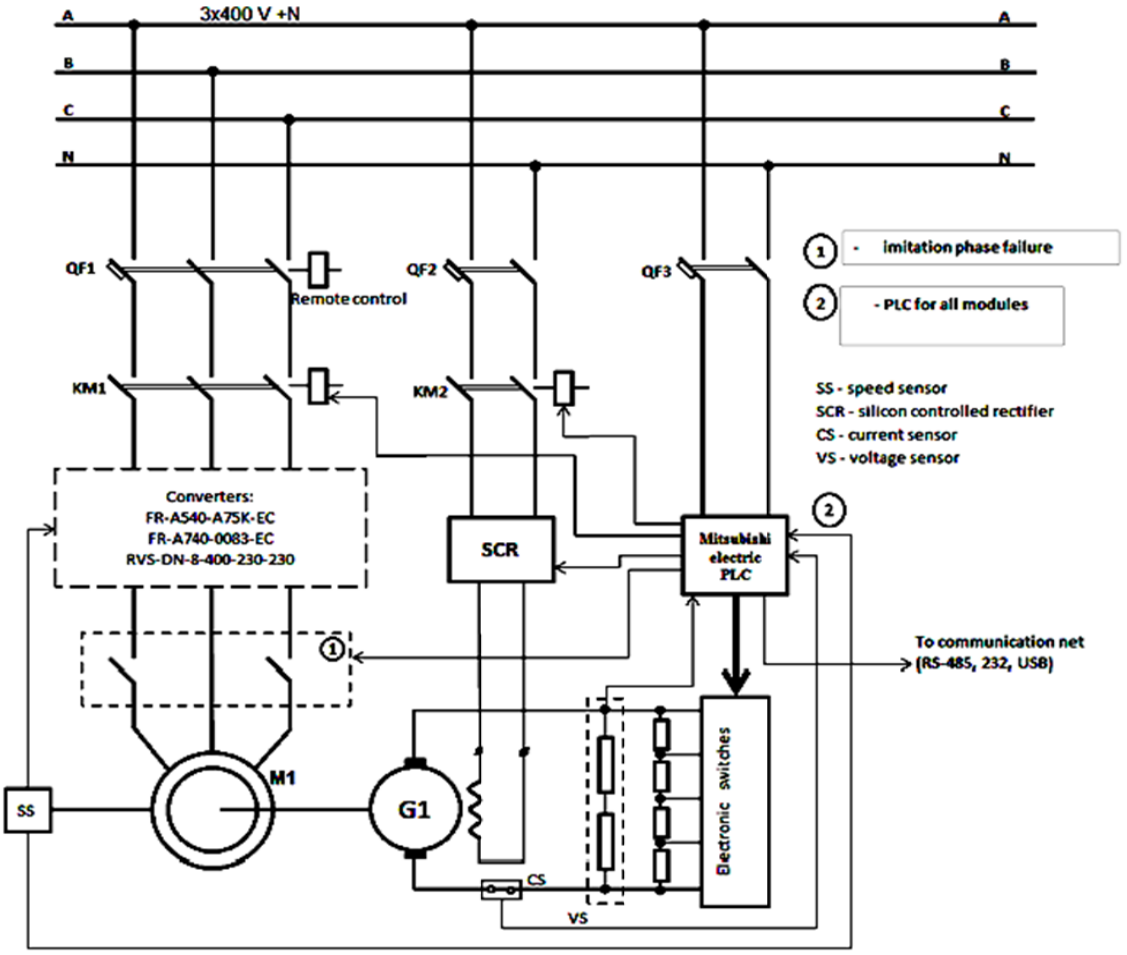

Fig. 2 Electromechanical module (electric drive) with PLC controlled load.

embedded in each generator section and section of shore supply (see Fig. 3).

The main power plant consists of two diesel-generator sets, model GMS10PX of power link machine company, synchronous brushless generator rated 8 kW, with rated voltage 380/220 V. Prime movers of generators No. 1 and No. 2—Diesel Engine of PX380G type. The dieselsoperations are maintain maintained by

Fig. 3 Controllers of PMS.

the controllers M2500 from SELCO, which are embedded in each synchronous generator section. 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 from Schneider Electric is used for power supply and for control of the drive motor of shaft generator (simulation of the drive shaft on a real ship, depending on main engine operation, 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 PFC (power factor correction) system consists of 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 corresponding programming environment Unity Pro S V7.0 (see Fig. 4) is chosen as a platform for visualization and remote control of 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 one part of simulator complex and consists of actually functioning devices that are as close as possible to modern configurations of marine control equipment and means of automation. So, the laboratory fully meets the standard requirements for simulators (Section A-I/12, Part 1—performance requirements), STCW 78 with Manila Amendments.

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 in Fig. 5.

All installation, including separate units and control systems is incorporated in common communication

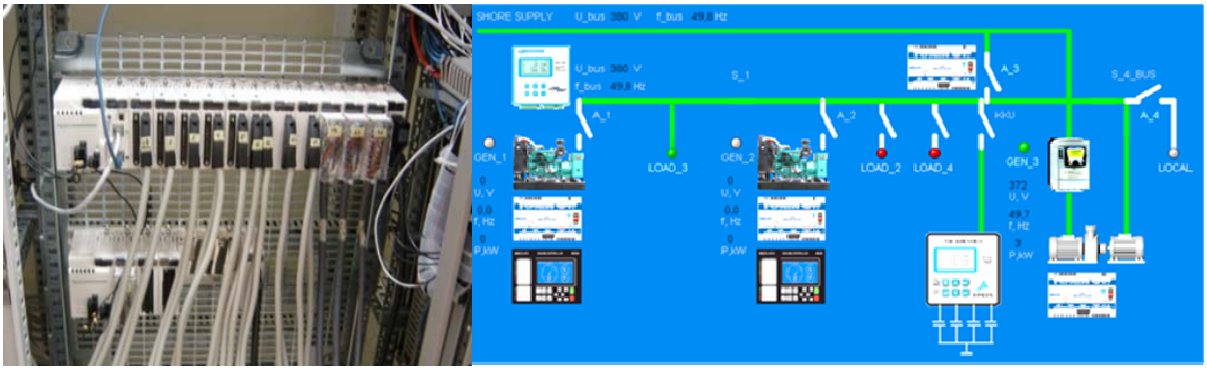

Fig. 4 Example of visualization SCADA control and monitoring of the training complex.

Fig. 5 Laboratory stand of PLC laboratory.

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 are fully cover minimum qualifications, knowledge, understanding and proficiency for marine electro-technical officers and for marine engineers.

4. Training Courses Topics

Training and competence testing programs for ship electro-technical officers and marine engineers are carried out on the basis of the simulator complex equipment [10, 11]:

- 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.

5. Educational Tasks

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

(1) Skill development of analysis of ship electrical power management system, modern layout of PMS, electric power distribution, including high-voltage; Research and practical testing of operator's actions in different control operational and emergency modes of power plant; Alert messages and operator's work with alarms and events log; Research of specific features of protective settings and controller's parameters, generator cut-out switches, skill development of connectivity issues and micro-controller installation for the purposes of typical power plant automation; Research, protective 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; Protective settings and controller's parameters with the use of appropriate software and

troubleshooting.

(2) Operating skills acquisition with the modern PLC based on controllers of such recognized makers 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 micro-controllers; Connection to micro-controllers and use of additional devices (digital operator, remote display, PC); Sample program development of different types for PLC that addresses 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 micro-controllers, local controlled objects with the remote-control arrangement and monitoring system, using real equipment and automation means.

(4) The utilization 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 marine transport means. Certainly, it will contribute to quality improvement of education and training of scientific personnel.

6. 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 "maintenance 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 actual 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 repairs, and is consistent with the purposes of training, besides it enables demonstration of these skills in order to assess competencies.

The simulator provides controlled operational conditions including emergency situations corresponding to the goals and tasks of training, as well as it enable simulation of various operational situations.

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

The simulator allows the teacher (instructor) to 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 of complex machinery and 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 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 bears in mind that it is not always possible to simulate all kinds of emergencies and regimes in marine conditions.

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