CHALLENGES IN THE FORMATION OF MARINE ENGINEERS. GOALS AND OPPORTUNITIES IN THE EDUCATION AND TRAINING OF MARINE TECHNOLOGY.

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Keywords: Training of marine electrical technology, electric ships, smart grids, big data, marine engineers, STCW.

Abstract. *The design of merchant ships and super-yachts every day is more complex, due to the continuous technological advances that they incorporate in their systems, either for their own operation and propulsion, as well as for comfort and safety. This evolution leads to an increase in energy demand, requires an increase in electrical services on board, forces these systems to also evolve with new concepts to improve the generation, distribution and demand of consumers. Supervision and regulation systems must optimise these operations, improve their performance and reduce emissions (greenhouse gases). An extensive network of sensors, their supervision, control and data acquisition (SCADA) is required. Overall, it represents a technical and qualification challenge for marine engineers who have to manage these systems. The paper presents how the current curriculums of Bachelor degrees and Master degrees of the Barcelona School of Nautical Studies (FNB), have incorporated the requirements for ship engineer officers and the new Electro-Technical Officer (ETO), in the area related to the function "Electrical, electronic and control engineering" included in STCW Code (2010 Manila Amendments). The new training challenges are also presented, which the current requirements of STCW Code and the IMO model course do not contemplate, and which should be taken into account in the study programs and their subjects in order to complement or expand them.*

1 INTRODUCTION

The strong knowledge, skills and abilities related to the annotated function "Electrical, electronic and control engineering" (STCW Code) [1], are indispensable for the marine engineer of today. The operation of the systems of a merchant ship and super-yachts, every day are technologically more specialised due to the continuous advances. The increase of the automatic systems of supervision, analysis and regulation of the different operations or services on board, is based on the use of computer applications. What it allows the centralised and optimise decision making, among which can be indicated, without being exhaustive: the ship positioning control (DP), energy management with the consequent improvement of performance and emission reduction, safety, comfort on board, reduction of equipment maintenance costs, etc. All those have implied an important reduction or elimination of manual operations, traditional on engineering practice, and with the least possible number of crew members.

The changes that are taking place in the maritime industry also affect sub-sectors (clusters) or new business forms in the maritime world, where Europe has a dominant position. European yacht builders produce 60% of the mega yachts [2], Europeans dominate the emerging market for offshore renewable energy [2]. Catalonia, and especially Barcelona, can achieve a prominent position, providing qualified engineers and high added value maintenance and repair services to the superyacht subsector.

This requires, increasingly, to have specialists, on board and on land, who are able to operate, manage or inspect the vital services of a ship and the systems that compose them, such as:

- Electric Power Plant (including HV generation)
- Electric Propulsion (Azipods, including HV electric machines)
- Distribution network and protections (including HV grids)
- Supervision, control and data acquisition (SCADA) of sensors
- Programming of PLC's for data collection, control and command operations.
- Programming of converters and frequency inverters, for the operation of electric motors.
- Communication networks between computer equipment
- Radio / Radar Communication Engineering

All these services, managed as a set, under concepts such as Smart Grids [3,4,5], Big Data (Voyage data recorders VDR [6,7,8] and System for monitoring, reporting and verification of CO_2 emissions, MRV [9, 10]), should be integrated within the academic knowledge.

The paper presents how the current curriculums of Bachelor degrees and Master degrees of the Barcelona School of Nautical Studies (FNB - UPC), have incorporated the new requirements for the certification of watchkeeping engineers, chief engineer officers and second engineer officers. Focused in the area related to the function “Electrical, electronic and control engineering”, provided in the Manila amendments to the part A of the STCW Code [1] and the consequences for maritime education and training resulting from them. The syllabus established in the IMO model course for the ETO [11] will be a basic reference in the development of the contents of Undergraduate (Bachelor) studies.

2 ACADEMIC DEGREE REQUIREMENTS FOR ENGINEERING OFFICERS

In Spain, the academic requirements to access the professional qualifications of the Merchant Navy are established in Royal Decrees 938/2014 [12] and 973/2009 [13] (both currently under revision update). These requirements, corresponding to the engineer officers, are indicated in Table 1.

Table 1: Academic degree requirements for engineering officers *

Second Engineer Officers	Electro-Technical Officers	First Engineer Officers	Chief Engineer Officer
Bachelor degree in Marine Technologies	Bachelor degree in Marine Technologies + Knowledge required of Section A-III/6 of the STCW code	Bachelor degree in Marine Technologies + Master degree in Management and Operation of Installations Energy Maritime	Bachelor degree in Marine Technologies + Master degree in Management and Operation of Installations Energy Maritime

* Note: For simplicity, only degrees of the current syllabus in FNB are indicated in the table.

3 SPECIFIC STCW ELECTRICAL, ELECTRONIC AND CONTROL REQUIREMENTS FOR ENGINEERING OFFICERS

The mandatory minimum requirements of competence, knowledge, understanding and proficiency, for certification of the officers in charge of an engineering guard or as service engineers (second officers), electro-technical officers, first engineer officers or as chief engineer officers. They are established in accordance with the chapters and sections of the STCW Code [1], indicated in the summary of table 2.

Table 2: Specific STCW electrical, electronic and control requirements for engineering officers

Second Engineer Officers	Electro-Technical Officers	First Engineer Officers	Chief Engineer Officer
Minimum STCW code requirements in syllabus	Minimum STCW code requirements in syllabus	Minimum STCW code requirements in syllabus	Minimum STCW code requirements in syllabus
Section A-III/1 (1)	Section A-III/1 (1) and Section A-III/6 (1)	Section A-III/1 (1) Section A-III/2 (2)	Section A-III/1 (1) Section A-III/2 (2)

Note: (1) Operational and (2) Management requirements [1].

4 GENERAL DESCRIPTION OF THE CURRICULUM DEGREE AND MASTER DEGREE OF THE TECHNICAL UNIVERSITY OF CATALONIA – FNB SCHOOL

This section describes how specifically the function “Electrical, electronic and control engineering”, provided in the STCW Code [1], mandatory minimum requirements for engineering officers, are incorporated into the academic studies.

The current curriculum of the Bachelor degree and Master degree structure the subjects to ensure a flexible organisation, being able to respond with efficiency objectives in training schedule and incorporate all the functions provided in the STCW Code [1].

4.1 Curriculum Structure of the Bachelor Degree in Marine Technologies (GTM)

The following table 3 shows the distribution of credits, depending on the types of subjects and assigned credits. Table 4 reflects the number of credits that incorporate training competencies for the function “Electrical, electronic and control engineering at the operational level” for Second Engineer officers and Electro-Technical officers (table 2).

Table 3: Distribution of subjects and credits (GTM)

Types of subjects	Credits number (ECTS)**
Basic training	60
Compulsory	132
Optional	6
Internship	30
Final Project	12
Total credits	240

** Note: European Credit Transfer System

Table 4: Distribution of competences STCW

Competences STCW Code	Credits number (ECTS)**
Electrical, electronic and control engineering, for Second Engineer Officers	34,5 (14,4%)
Electrical, electronic and control engineering, for Electro-Technical Officers	30 (12,5%)
Total credits (GTM)	64,5 (26,9%)

The transposition of competences in subjects in the academic degree, are represented in summary form in the figures 1 for Second Engineer officers and the figures 2 for Electro-Technical officers, respectively.

4.2 Curriculum Structure of the Master Degree in Management and Operation of Installations Energy Maritime (MUGOIEM)

The following table 5 shows the distribution of credits, depending on the types of subjects and assigned credits. Table 6 reflects the number of credits that incorporate training competencies for the function "Electrical, electronic and control engineering at the management level" for First engineer officers and Chief Engineer officer (table 2).

Table 5: Distribution of subjects and credits (MUGOIEM)

Types of subjects	Credits number (ECTS)**
Compulsory	75
Master's Thesis	15
Total credits	90

** Note: European Credit Transfer System

Table 6: Distribution of competences STCW

Competences STCW Code	Credits number (ECTS)**
First engineer officers and Chief Engineer Officer	20 (22,2 %)
Total credits (MUGOIEM)	20 (22,2 %)

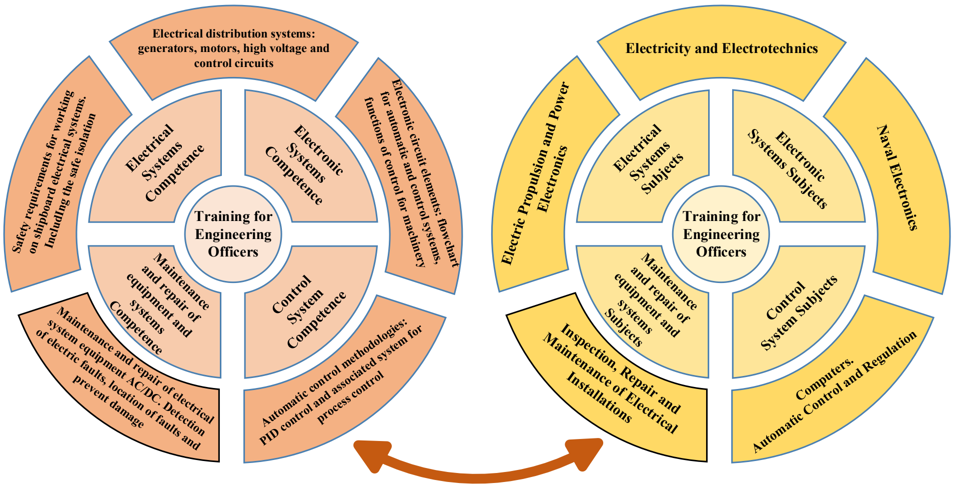


Figure 1: Transposition of competences in subjects of the Bachelor degree (GTM)

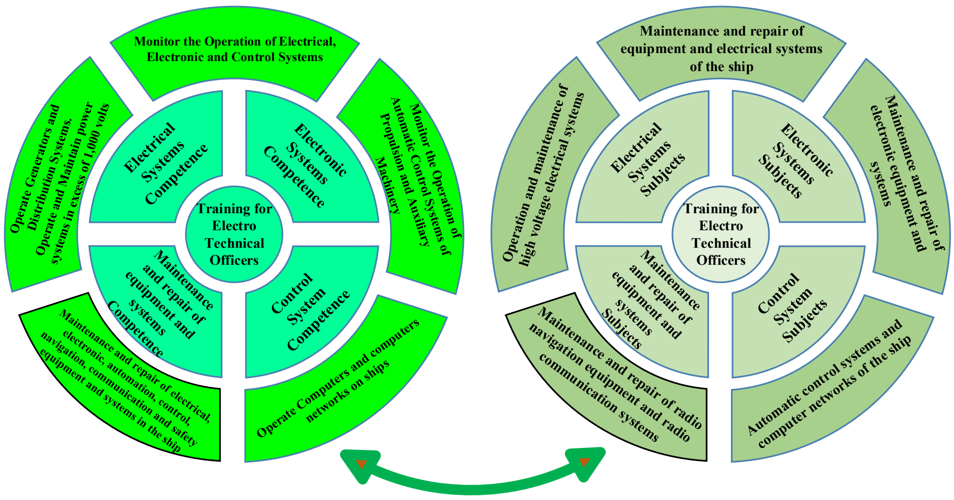


Figure 2: Transposition of competences in subjects for training ETO

5 TECHNOLOGICAL ADVANCES IN SHIPS, NEW TRAINING NEEDS AND CHALLENGES IN ACADEMIC TRAINING FOR FNB SCHOOL

In this section, we will describe briefly some of the changes that are taking place in the electrical systems of ships (power plant and propulsion), the control and automation systems and the necessary networks for the collection of information in the efficient management of energy and the control and reduction of emissions. These new advances and technological realities on board, cause a reduction of crew and necessarily forced to have highly specialised marine engineer's officers, capable of facing them.

5.1 Power plant, electric propulsion, distribution network and protections

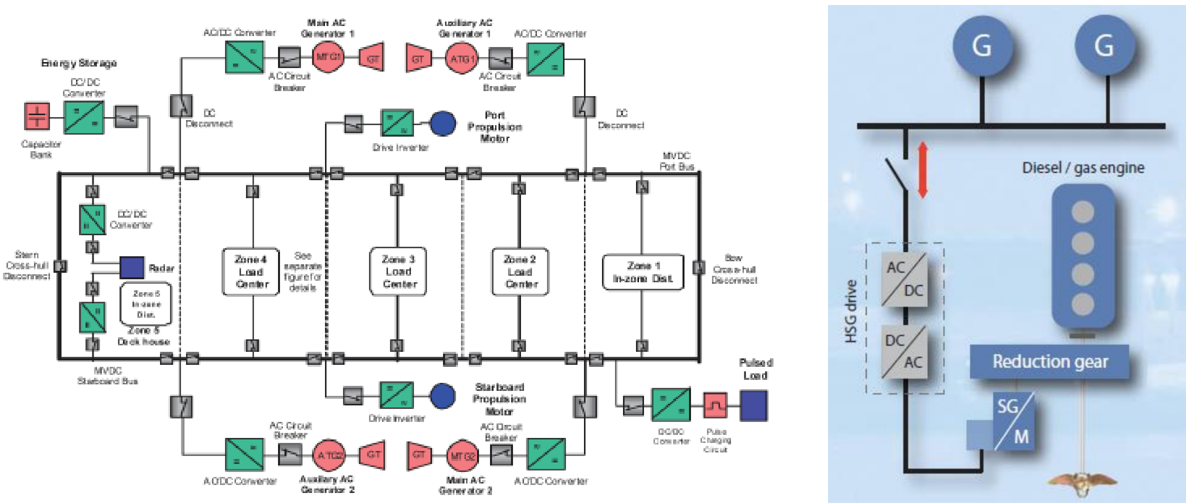
The extensive electrification of the ship's systems, including its propulsion, known as "all electric ship" (aes). is a consequence of the need for more efficient ships and of proven advantages, such as: superior dynamic control, improved maneuverability, greater flexibility of engine location, reduction of fuel consumption (thanks to the optimal adjustment of the number of thermal engines in service), reduction of vibration, high automation of the engine room. these events have caused significant changes in the entire design of the ship, so that, currently, 100% of the newly built cruisers are electrically propelled and a similar evolution occurs for other classes of offshore vessels such as supply ships, drillers, platforms, layers of pipes / cables, icebreakers, megayachts [14], evolution that can move towards direct current (dc) generation systems [3, 4, 14]. examples of new technological applications [3, 4, 14, 15, 16], that need focused training on:

- Great powers of generation and propulsion in high voltage
- Distribution in HV, facility security, monitoring of partial discharges (PD)
- Distributed generation (DG) and new criteria in the application of protections
- Generation in direct current (HVDC) and the large difficulty with DC circuit breakers
- Permanent magnet synchronous generator or motor (PMSG / PMSM)
- Management of the starting transients of the large electric motors
- Shore Connection or Cold Ironing On-board installation

5.2 Power electronic converters

The introduction in the ships of power electronic devices, such as power electronic converters (rectifiers, frequency inverters, phase controllers, variable speed drivers, starters, real-time machine control systems, etc.), has allowed us to redesign completely the structure of the systems of generation, distribution (Fig. 3a) and use of energy on board [3, 4, 14, 15]. The electric power feeds all the loads on board (propulsion, hotel and auxiliary), with electrical machines that can act as propulsion engine or help as generators at key moments (Fig. 3b). More than "present a classification of power electronics converters and areas of their application on ships", actually is necessary a deeper knowledge of its use. Need of specifically and focused training on:

- Configuration of parameters
- Selection of speed reference (local or remote)
- Frequency of output settings (upper limit and lower limit)
- Selection of direction of rotation (local or remote)
- Enabling ramps. Acceleration and deceleration ramp settings
- Connection of peripheral devices (contactors, relays, etc.)
- Custom U/f ratio settings
- Programmable protection functions settings (against blocking, internal fault, etc.)
- Pre-programmed faults settings (thermal, overcurrent, short circuit, overvoltage, etc.)
- Setting limits of operation (power, timed functions, load curves, energy optimisation)
- Control of the power flow and load sharing between the various power sources



a) Zonal distribution. Source [14]

b) Grid with HSG drive. Source: Rolls-Royce marine web

Figure 3: New configurations of grids in ships

5.3 Supervision and control of operations. Data acquisition (PLC's and SCADA)

Typical SCADA system consists of one more field data interface devices usually PLCs which interface to field sensing devices (level meters, water flow, valve position, temperature, pressure, power consumption, etc.), local control switch boxes and actuators device, all them provide information that can tell how well the systems performs. A communication system is used to transfer data among field data interface devices, control units and the computers to the SCADA central host which is a central computer server. The benefits of SCADA systems provide operational costs reduction, immediate knowledge of system performance, an improvement on system efficiency and performance, increasing equipment life, reducing the cost of repairs, frees up personnel for other task, facilitating compliance with regulatory agencies through automated report generating. Need for specific and focused training on:

- Know the communication protocols (Profibus, Modbus, industrial Ethernet network, Standard protocols of IEC)
- Communication between Client and Server. Modes SDO (Service Data Objects) and PDO (Process Data Objects)
- Programming and development of practical applications with PLCs
- Operations with an external control signal

5.4 Smart Grids and Big Data

The future of 'smart ships', requires having of smart grids for harnessing of the all the information and data that comes from of operational control, of voyage, the emission control and energy efficiency measures, during ship navigation, and focus this under Big Data applications. As the name implies, Big Data (data mining) gathers large volumes of information from a variety of sources and various statistical analysis and machine learning techniques are implemented under such data analytics, often at great speed, supported by database management [5, 6, 8]. This transformation has been possible thanks to the growing application and development of advanced sensor technology that allows generating and collecting large data volumes of fuel, traffic, cargo, weather and other data on board a ship [8, 17]. The analysing this information with effective systems still faces some challenges.

They also benefit from this technology, the management of the respective emission control regulations or efficiency index [6, 7, 8, 9, 10], such as:

- Regulations for the reduction of CO_2 emissions:
  - Energy Efficiency Design Index (EEDI)
  - Energy Efficiency Operational Indicator (EEOI),
  - Ship Energy Efficiency Management Plan (SEEMP)
  - The system for monitoring, reporting and verification (MRV), UE regulations
- Ozone Depleting Substances (ODS), Particulate Matter (PM), Volatile Organic Compounds (VOC's), Sulphur Oxides (SOx) or Nitrogen Oxides (NOx) limits
- Voyage data recorder (VDR)

This regulations and controls are forcing shipping operators to think more seriously the emissions performance from maritime transport fuel.

6 CONCLUSIONS

The current curriculums of FNB have to absorb not only the STCW requirements but also improve academic qualities and qualifications for marine engineers in order to provide flexibility in employment opportunities and give them the real competence to face the challenges of the future.

The marine engineer increasingly needs a very specialised electro-technical training, which should lead to establishing new levels of official training for them.

The contents pointed out in section 5 should be incorporated in the programs, to keep them updated concerning technological advances. Many of them have already been incorporated in the FNB, in particular, the contents indicated in sections 5.1, 5.2 and 5.3, have been incorporated into the subjects of ETO specialisation courses and the 20 credits provided for the function "Electrical, electronic and control engineering at the management level", in the master. However, besides all and these advances, we aren't lose sight of the convenience to improve and consolidate them.

The Smart Grids and Big Data, pointed out in section 5.4, it continues to be a pending challenge and to require the complicity of more areas involved, and of a multidisciplinary team of professors, for to face this new technological leap, already present in the sector.

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