TOWARDS ZERO SHIP EMISSIONS II – PROJECT GREENSHIP

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Keywords: ship emissions, ship energy efficiency management, pollution, climate change, Energy Manager Training Program.

Abstract

IMO's own International Shipping Facts and Figures report 2012 stated the number of vessels across the globe of 100 Gross Tonnage and over was 104,304, with cargo carrying vessels being 55,138 and expressed concern about the exponential increase of CO_2, NO_2, CH_4 and so forth in recent year. The EU responded by setting targets. The EU 2050 objectives set some intermediate targets for Eco-Efficient Vessel Emission Reduction for key pollutants: CO_2: >80% (-30% by 2020), NOx: 100% (-80% by 2020), SOx: 100% (-80% by 2020) and Noise Reduction: -3dB. A review of current research (Ziarati et al, 2018) clearly shows that the targets set for 2020 by both IMO and EU were not achieved and the 2050 goals are also unlikely to be achieved. The Industry is taking steps to reduce its air pollution and carbon footprint due to recent and upcoming IMO and EU regulations; IMO GHG study, Buhang et al (2009) reports that IMO has introduced some limits but has been unable to monitor ship emissions.

EMSA has tried the use of satellites and drones to monitor ships, which pollute the sea but has been unable to monitor ship emissions and waste discharge at sea effectively due to technical difficulties and also vastness of the oceans.

As the regulations and technologies governing energy efficiency on board ships becomes more complex it is realised by both the IMO and the shipping industry that seafarers need specific training to a much higher level in these fields. There needs to be a position specifically for managing, checking and controlling a ship's emissions for gases that are harmful to human health and the environment, an "Emissions Manager". As this is a brand new position, there are

neither defined competences for this role nor any specific knowledge, understanding or proficiency for it.

The paper gives full account of IMO efforts in recent years in setting legislation for key pollutants and reports on a new job specification for the Emissions Manager and proposes that an e-course being developed by several EU member states for the training of key ship officers and crew on how to minimise and monitor harmful emissions. The corresponding programme concerned with the current practice of managing emissions as well as the principle of making ships energy efficient. The new training programme targets both current cadets and existing seafarers in order to complement their skills.

1. Introduction

The global warming of planet Earth is well known by all concerned. This is mainly due to human action through the industries that use hydrocarbon fuels from crude oil. Fortunately, society in general is well aware of the impact on the environment and in particular by the maritime transport. Without being the biggest polluter of the planet, only 2.7% of the total CO_2 emitted, a reduction in greenhouse gases of 80% by 2050 is the aim of the IMO.

Reducing air pollution by focusing on greenhouse gases is a task that is not the only responsibility of national and international governments and government agencies, etc. Adoption of regulations that avoid and reduce air pollution also requires the collaboration of the industry. Without the support of the manufacturers of the energy systems used in the propulsion and auxiliary services of the ship, ship designers and shipbuilders and finally of the seafarers who have to operate these systems efficiently it would not be possible to help meet the goals of the IMO, as the representative of all maritime countries.

It is a well known that once the ship's hull is designed and built, few, if any, improvements can be made to reduce its drag and fuel consumption. The same also can be said of the propulsion and auxiliary machineries, since their effectiveness is and will be what the manufacturer has achieved when designing them.

Whilst it is true that once a ship is constructed little can be done to reduce fuel consumption or ship emissions nevertheless much can be done to keep its fuel consumption at an efficient level. For this reason, it is necessary to ensure that the crew has the necessary knowledge to operate the ship efficiently, including knowing when to slow steam or make use of wind, tide and currents. Therefore, the ‘Toward Zero Ship Emission’, the GreenShip project was initiated to ensure ships run efficiently and produce the minimum emissions.

2. IMO GHG Studies

IMO, has been mindful of the need to reduce GHG from ships, and has conducted four studies on air pollution by CO_2, NO_2 and CH_4 from ships. The First IMO GHG Study on GHG emissions, published in 2000, and estimated that ships engaged in international trade in 1996 contributed to about 1.8% of the world's total anthropogenic CO_2 emissions. The Second IMO GHG Study, published in 2009, estimated that international shipping emissions in 2007 were 880 million tonnes, 2.7% of the global total anthropogenic CO_2 emissions. The Third IMO GHG Study, published in 2014, estimated that international shipping emissions in 2012 were 796 million tonnes, 2.2% of the global total anthropogenic CO_2 emissions. The Study also updated the CO_2 estimates for 2007 to 885 million tonnes, or 2.8%.

The most recent estimates included in this Fourth IMO GHG Study 2020 show that GHG emissions of total shipping have increased from 977 million tonnes in 2012 to 1,076 million tonnes in 2018 (9.6% increase) mostly due to a continuous increase of global maritime trade. The share of shipping emissions in global anthropogenic GHG emissions has increased from 2.76% in 2012 to 2.89% in 2018.

It can be concluded that even with IMO's concern about reducing fuel consumption on board ships, its four studies only focus on the amount of fuel consumed by ships and not on the measures that should be taken to reduce it. However, it is of great interest and a great step forward, to be aware of the amount of CO_2 that shipping releases into the atmosphere. However, in line with IMO's concern to reduce pollution, this intergovernmental organisation has created a course called "Train the Trainers" in which the measures that should be applied on board ships are studied in order to achieve the 2050 target of reducing GHG by 80%.

3. The STCW Code

The minimum mandatory standards for seafarers' training are set in the Seafarers' Training, Certification and Watchkeeping (STCW) Code. A review of the minimum training requirements in STCW Code shows that both in chapter 2, corresponding to the deck department and chapter 3, corresponding to the engineering department, the knowledge and skills contained in them, at both operational and management levels, address the design, operation and maintenance of onboard equipment. Although there is a specific focus on good practices and their safe operation there is little on aspects relating to reducing emissions or fuel consumption. For this reason, the current and future seafarers must have specific training in the field of ship design and construction, efficient operation and maintenance of the ship, in brief, in the GHG reduction and greater awareness of fossil fuels impact on the environment.

In addition, as part of the battle to reduce GHG to a minimum, fuels other than fossil based must be considered such as hydrogen, ammonia and bio-fuels or electric provided emission elsewhere is not increased.

4. MARPOL Convention

The MARPOL Convention is entirely dedicated to the protection of the marine environment. Annex VI of this instrument establishes the measures to reduce air pollution including from GHG, CO_2, NOx and others such as PM and SOx. Regulation 20 and 21 of Annex VI of MARPOL: Energy Efficiency Design Index attained (EEDI attained) and EEDI required. As of January 1, 2013, every new ship must comply with an energy efficiency level according to the type of ship. This energy efficiency level is the Energy Efficiency Design Index (EEDI) and is has been gradually adjusted every five years. This has encouraged the use of more energy-efficient equipment and machinery, encouraging constant innovation and development of all the factors that affect fuel consumption and ship efficiency. The EEDI does not define a specific technology but focuses on a specific figure for a specific ship design, expressed in grams of CO_2 per ton of ship capacity and mile; the lower the EEDI, the higher the energy efficiency. By not restricting the technologies, ship designers and builders have some flexibility.

The equation for the EEDI is concerned with the basic amount of CO_2 produced by the main and auxiliary engines and elements of efficient energy generation such as shaft generators. Innovative energy efficient systems such as air lubrication systems, Flettner rotors or waste heat recovery systems could be considered for reducing fuel consumption hence engine emissions.

With the EEDI, an absolute value of the amount of CO_2 per ton mile of fuel burned is obtained. The ship will emit with the equipment and technologies with which the ship has been equipped for, but it does not tell how to maintain this Index, as poor operation and maintenance of the equipment can cause an increase in the index, which means consequentially an increase in fuel consumption.

In very simple terms, EEDI can be represented by:

$$EEDI = \frac{emissions\ of\ CO_2}{ship\ capacity}$$

Source: IMO MEPC.322(74)

Main engine

Auxiliary engines

$$EEDI = \frac{\left(\prod_{f=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE^*}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacidad \cdot f_w \cdot V_{ref} \cdot f_m} +$$

Efficient and innovative energy for power generation

$$\frac{\left(\left(\prod_{f=1}^{n} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacidad \cdot f_w \cdot V_{ref} \cdot f_m}$$

Efficient and innovative energy for propulsion

$$- \frac{\left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME^{**}}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacidad \cdot f_w \cdot V_{ref} \cdot f_m}$$

Source: IMO MEPC.322(74)

Regulation 22 of Annex VI of MARPOL: Ship Energy Efficiency Management Plan (SEEMP); as of January 1, 2013, states that it is a requirement for ships over 400 GT operating internationally. As for ships of 5,000 GT or more, no later than December 31, 2018, these must include in the SEEMP a description of the methodology that will be used to collect the data required under regulation 22A on Collection System of data on the fuel consumption of ships.

The purpose of the SEEMP is to establish a mechanism for the ship to improve efficiency during its operation, i.e. in its operational phase. In this way, it seeks to optimize the performance of the ship to consume less fuel and produce less CO_2 emissions. The SEEMP is an individualized plan that must be adapted to the characteristics of each ship.

The SEEMP consists of two parts: the first tries to provide guidelines to monitor the ship's efficiency over time; and for this, it uses four phases: planning, implementation, monitoring/self-evaluation and improvement. The second part deals with the methodology for collecting data.

The first part gives us the measures to improve energy efficiency. Greater energy efficiency means that the same amount of work is done by using less energy. As a result, less fuel is consumed hence emissions of all combustion exhaust gases are reduced.

Thanks to technology and engineering, there is a wide variety of options to increase the efficiency of ships and thus reduce CO_2 emissions. These measures can be divided into two groups. On one hand, the design measures would be part of the construction process of new ships or existing ships that go through a “refit” process. On the other hand, operational measures to optimise the ship such as trip planning, fleet management, energy management on board, speed optimisation, use of emerging alternative fuels, etc can be considered to any type of ship, either existing or new.

However, there are many more options besides these. The options shown do not result in the same efficiency in all ships, nor are they applicable to all ships.

While both the EEDI and the SEEMP are indicators of improvement of the ship's energy efficiency, providing the values that can be achieved by reducing fuel consumption and the steps that can be taken to do so; they do not explicitly provide the means to enable maintaining and lowering these indices. The above entails that the only way to maintain and lower these values is through adequate training of seafarers, in addition to creating the position of the manager for the efficiency of the equipment and other elements related to the fuel consumption on board ships. To this end, the core of the GreenShip project incorporates a specific training course on energy saving of ships that clearly and concisely explains to future ship managers the energy consumed by the ships throughout its life cycle. The course provides knowledge of all the applicable technology and its efficient use, measures taken in the design, redesign, operation and maintenance of the ship's energy equipment.

5. Emission and Energy Manager Training Programme

The GreenShip course addresses the need for:

a) Qualified personnel to implement regulations and technologies;

b) Emission control and energy efficiency of ships through cost savings and more efficient use of fuels;

c) The mobility and enhancement of employability in the global labour market for EU/worldwide seafarers and cadets who take the qualification either as part of their initial studies or as part of a continuing Vocational Education and Training (VET), for career development;

d) IMO SEEMP and related requirements of Maritime and Education and Training (MET providers to offer courses that are relevant and comply with latest regulations and requirements of the industry and address new skills gaps that are emerging with the latest technologies, requirements and practices for maritime emissions control and energy efficiency and

e) The integration and development of e-learning and digital skills into the EU’s MET so that they can design and deliver e-learning materials as an online learning platform for the maritime officers who can truly benefit from online access to learning and training materials.

6. Teaching, Learning and Assessment Strategy

a) This is a standalone maritime emission and energy management training programme delivered using an e-learning platform that can be integrated into an existing maritime education training programme or delivered as a training module for seafarers and those involved in the shipping industry and maritime administration;

b) This training is competence based incorporating several learning outcomes;

c) The programme is in line with relevant IMO rules and regulations and compliant with European Credit Vocational Education and Training (ECVET), and with the Institution of Marine Engineering, Science and Technology (IMarEST) Continuous Professional Development (CPD) requirements;

d) It contains a set of assessment criteria based on the learning outcomes;

e) The assessment is part of the learning strategy and there is a provision for online self-assessment followed by several in class assignments supported by scenario based final assessment; and

f) The assessment has marking criteria awarding the trainee the grade of 'Competent' or 'Referral (not yet competent)'. The course is made up of the following components.

7. Ship Emission Manager Job Specifications

Ship emission manager is primarily responsible for managing all aspects of emissions management on board vessels. The manager is expected to:

i. Have knowledge, understanding and application of IMO emissions requirements/regulations;

ii. Be familiar with all emissions management systems on board and IMO and national regulations in place including Energy Efficiency Operation Index, EEOI, and Energy Efficiency Design Index, EEDI, with a specific knowledge of toxins produced by the ship engines as well as other machinery;

iii. Have skills in emission reduction and energy saving practices including engine propulsion, heating cooling and so forth;

iv. Be familiar with the ISM practices, and company specific measures including aspects relating to any quality standards which may relate to ISO 29000 or ship specific standards such as ISO 58000; and

v. Be aware of IMO's MARPOL, SOLAS, and related standards including aspects concerning maritime environment protection.

8. Ship Emission Manager Training Specifications

The aim is development of the training specifications are:

i. Provide specific education, awareness and training that is in line with national and international legislations;

ii. Enable effective and efficient management of emission control and monitoring processes energy transformation systems used on board ships and the reduction of consumption with a view to saving energy, reducing emissions and improving the overall quality of emission management practices;

iii. Facilitate the initial assessment on board ships and identify areas in order to improve effective and efficient emission control and monitoring processes as well as transformation of energy and its use, with regard to the key processes concerning SEEMP, and in particular EEOI and EEDI and Energy Efficiency Existing Ships Index, EEXI.

9. Chapters and Learning Outcomes - Summary Content

The online training manual will primarily include five chapters of the training programme and one of the chapters (introductory) will provide the IMO and EU rules and regulations regarding energy efficiency and emissions. The training programme produced will include a full curriculum, which takes into account the ECVET system, delivery guidance, as well as sample learning materials. The training programme will also include provision for web based assessment tools. The content of the training programme contains primarily information on the IMO EEDI, EEXI; EEOI, SEEMP and good practices in other industries such as automotive and aerospace. The course will be evaluated by a recognised professional body.

The project will also take into account IMO model course 1.38 – Marine Environmental Awareness (2011). This is to ensure there are no overlaps.

9.1. Chapter 1

This chapter describes the challenges faced in reducing global warming and reports on aspects concerning climate change. The focus is on IMO and EU efforts and rules/regulations. It describes all IMO and EU's measures and regulations and gives practical examples of each measure and/or rule, assess compliance with international legislations and requirements, monitor different indices such as EEDI, EEXI, EEOI and assess compliance with inspection, approval and accreditations.

9.2. Chapter 2

This chapter deals with the systems and sub-systems of emission production, dispersion and monitoring on board ships identifying the differences in each main type of ships. It focuses on the ability to:

i. Identify the emission measures of different types/sizes of ships and their designs;

ii. Assess safety concerns in different environmental conditions;

iii. Identify operational requirements at sea/in port and their environmental impact;

iv. Assess fuel emissions from vessels such as CO_2, NOx, SOx and PMs from the combustion of fuels and their compliance with legislations and

v. Identify different types of emissions generated from incinerated waste from cruise vessels and compliance with environmental requirements.

9.3. Chapter 3

This chapter focuses on the core part of the emission management programme namely, how emissions are reduced to a minimum while maximizing energy efficiency, by means of, mechanisms such as slow steaming, wind direction and strength monitoring as well as energy saving records for future management decisions. The competence developed are the ability to:

i. Implement ship's emission management, assess different ship emission management options;

ii. Assess fuel emissions management systems of ships regarding CO_2, NOx, SOx and PMs from the combustion of fuels and their compliance with relevant legislations;

iii. Identify different types of waste discharges generated from incinerated waste mainly from cruise vessels in compliance with environmental requirements, audit and inspection requirements including ISO 50001 and/or ISO 14001 as well as EU Monitoring, Reporting and Verification (MRV), Directive (EU) 2015/757, as well as the IMO fuel oil consumption data collection system and

iv. Develop the outline of company emission management plan in compliance with IMO SEEMP.

9.4. Chapter 4

This chapter describes the marine propulsion system and emission monitoring. The abilities developed are:

i. assessment of different ship

ii. evaluation emission generation and its use on board;

iii. assessment of the fuel emissions from ships regarding CO_2, NOx, SOx and PMs from the combustion of fuels and their compliance with legislations; communicate and manage conflicts with regards to effective and efficient use of engine energy usage and

iv. development of the outline of a company engine emission management sub-plan in compliance with IMO SEEMP

9.5. Chapter 5

This chapter concerns navigation and examples of savings emanating from the application of good practices. The competences developed are ability to:

i. Describe good practice in navigation that help to save energy and reduce emissions;

ii. Provide guidance to crew with regards to any changes at sea and weather conditions;

iii. Identify the navigation and operational requirements at sea/in port and their environmental impacts; and

iv. Communicate and manage conflicts with regards to effective and efficient use of overall use of energy.

9.6. Chapter 6

This chapter concerns port operations and air pollution. In port areas, air pollution is primarily due to ships. However, other equipment use energy hence contributes to air pollution in port areas. For example cargo loading devices, trucks and other transportation units, buildings and energy needed for these buildings and harbour crafts that provide additional services to port and shipping companies. The abilities develop are:

i. Ship times in port and just-in-time operations as well as improved cargo handling;

ii. Other measures for avoiding ship waiting times in port,

iii. Technologies for port air quality improvements and GHG emission reduction,

iv. Ship in port operational energy efficiency measures, 5) onshore power supply facilities; and

v. Green port initiatives and port environmental programmes.

10. Conclusion

The position of ship emission manager on board is very necessary as a specialist to reduce the consumption of fuel and the generation of GHG. Another conclusion is that all crew should receive training on the efficient use of fuels onboard. Finally, the use of EEDI, EEXI, EEOI and SEEMP is fundamental, but, it is necessary that the crew on board receives the most appropriate education and training on how to best operate and maintain all fuel consuming systems on board to achieve the maximum efficiency and optimum related indexes.

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USING ARTIFICIAL INTELLIGENCE (AI) METHODS TO COMBAT CLIMATE CHANGE at MARINE PORTS

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Abstract

Marine ports operations are often associated with a variety of externalities including air pollution, noise, accidents, vibration, land take and visual intrusion. Climate change is considered to be a crucial challenge that mankind has to confront nowadays Special attention has to be paid to the emissions of greenhouse gasses from freight transport. When berthing at a port a vessel needs considerably large amount of electric power to support its operations such as loading, unloading, lighting, cooling, etc. The power is usually supplied by auxiliary machinery and the fuel used causes several gasses emission that results in air pollution. Furthermore, this kind of engines produce noise pollution to a neighbourhood. The negative factors have an impact on the working environment and the quality of life of the citizens living in an area adjacent to a port.

A universal method of shore-to-ship electrification, also known as Cold Ironing, has been recently applied for connection between all the types of ships or on-land electrical systems with different frequencies – 50 and 60 Hz. Although the cold ironing is a way to reduce ships' emission and air pollution of a port and its neighboring areas consequently, the fact that the

ship is connected with a grid is a disadvantage. The disadvantage lies in its holistic approach to combat climate change. The electrical grid is powered by fossil fuels so the total contribution to air emission is limited. The zero emissions' port approach using a smart grid technology approach connected to renewable energy sources. The electrical grid is used only as a backup source in a situation where there is a deficit in power balance. The offered energy sources, found in nature, are wind, solar, geothermal, tidal and wave energy while there is also energy in biomass and earthquakes. Although there are so many of them, the challenge is the conversion to electricity and the efficiency of the converting systems. The use of such sources for commercial electrical supply is only possible with the new "Smart Grid" concept. The optimal control of such systems soon will require up-to-date algorithms with the use of artificial intelligence(AI).
In the paper, an overview of AI methods for smart grid energy management optimization are presented for ports discussing the potential application of each algorithm to zero-emission port concepts.

Keywords: artificial intelligence, climate change, cold ironing, smart grid, green port, zero-emission port

Introduction

In our days, all this cosmogonic change will significantly affect shipping not only in its mode of operation but also in the various support actions, as in our case with ports. The term artificial intelligence (AI) refers to the IT industry that deals with the design and implementation of computer systems that mimic elements of human behavior that imply even elementary intelligence: learning, adaptability, drawing conclusions, contextual understanding, problem-solving, etc. Artificial intelligence is a crossroads between multiple sciences, such as computer science, psychology, philosophy, neurology, linguistics, and engineering, to synthesize intelligent behavior, with elements of reasoning, learning, and adaptation to the environment while usually applied on specially designed machines or computers.

The new interesting approach is to use AI methods for the optimization of marine port operation with the zero-emissions criteria. Development of such algorithms will require first a review and analysis of existing AI approaches to provide the optimal one based on allotted tasks of ports sustainable and economical operation.

1. Basic classification of AI systems

AI is divided into symbolic artificial intelligence that attempts to simulate human intelligence algorithmically using high-level symbols and logical rules and into sub-symbolic artificial intelligence that seeks to reproduce human intelligence using elementary numerical models that synthesize inductive intelligent behaviors with the sequential self-organization of simpler structural components ("Behavioral artificial intelligence") simulating real and brain function ("Computational intelligence") or are the application of statistical methodologies.

Conventional artificial intelligence involves machine learning methods, which are characterized by rigorous mathematical algorithms and statistical methods of analysis and divided into:

- Experienced or specialized systems (**Expert systems**), which implement programmed logic routines, designed exclusively for a specific task, to draw a conclusion. To this end, large amounts of known information are processed.
- **Case-based reasoning**. The solution to a problem is based on the previous solution of similar problems.
- **Bayesian networks.** They are based on statistical analysis for decision-making.
- **Behavior-based AI.** Method of shredding the logical process and then manually constructing the result.

Computer artificial intelligence is based on learning through repetitive processes (configuration). Learning is based on empirical data and non-symbolic methods. It can be distinguished in:

- **Artificial neural networks**, with very powerful pattern recognition capabilities. They simulate the function of the neurons of living beings.
- **Fuzzy logic systems**. They are decision-making techniques under uncertainty. They are based on the existence of non-strictly segregated situations, the severity of which is taken into account on a case-by-case basis. There are already many applications of these techniques.
- **Evolutionary computation**. Their development arose from the study of living organisms and relate to concepts such as population, mutation and natural selection

(survival of the fittest) to more accurately solve a problem. These methods can be further distinguished into evolutionary algorithms and swarm intelligence, such as algorithms that simulate the behavior of an ant community.

Focusing mainly on machine learning, we have the following analysis. It should be clarified that, in general, the field of machine learning develops three ways of learning, analogous to how man learns: supervised learning, unsupervised learning and supportive learning. In more details:

- **Supervised Learning** is the process where the algorithm constructs a function that represents given inputs (set of training) in known desired outputs, with the ultimate goal of generalizing this function to inputs with unknown output. Used in problems:
    - Classification
    - Prediction
    - Interpretation
- **Unsupervised Learning**, where the algorithm constructs a model for a set of inputs in the form of observations without knowing the desired outputs. Used in problems:
    - Association Analysis
    - Clustering
- **Reinforcement Learning**, where the algorithm learns an action strategy through direct interaction with the environment.
- **Ensemble methods** combine results from multiple learning algorithms or different initial data to obtain better overall performance

Having this basic introduction, the case of using artificial intelligence for the efficient energy management of green ports will be presented below, specifically after an introduction to zero emission port the main port attributes related energy management will be examined and an overview of particular AI techniques will be discussed

2. Green port concept

A "Green port" concept implies environmentally friendly and sustainable operations of the port infrastructure and berths. This framework represents an important trend in port development in recent years. Emissions from ships' auxiliary engines at a berth to supply power to vessel consumers are estimated to be ten times higher than emissions from port operations. Possibilities for their reduction is also much more significant [1]. One of the most viable options for a substantial decrease of greenhouse gases emissions at ports is the implementation of cold ironing.

Shore-to ship electrification; also known as Cold Ironing, is an old expression from the shipping industry that first came into use when all ships had coal-fired iron-clad engines. The term cold ironing refers to the gradual cooling of the iron engines and eventually their complete cooling. This happens when a ship ties up at the port and there is no need of feeding the fire of the iron engines. Cold ironing, in the meaning of shore-to-ship electrification, has been used by the military at naval bases for many years when ships are docked for long time periods. For example in Russia, it was popular to use the systems at local ports since the early 70s of the 20th century. As the world's vessel fleet is increasing, calls at ports are becoming more regular. Furthermore, hoteling power requirements have increased, and thus the concern of onboard generator emissions during docking periods has become the main air pollution issue. These are:

- Connection to the electrical grid and electrical energy transfer 20-100 kV to a local station when transformed to 6-20 kV.
- The electrical energy of 6-20 kV is delivered from the local station to the port's terminal station.
- There is a frequency conversion from 50 Hz to 60 Hz, depending ship's type.
- Next distributed to all electrical connections of terminals. For safety reasons, it is required special cable handling. This mechanism could be electro-mechanic or electrohydraulic.
- Onboard of the ship-specific adaptation for connection is required.
- Depending on the power of the ship, the voltage is transformed to 400 V. The transformer usually is placed in the engine room.
- The two systems are coordinated to work in parallel. There are practical problems associated with the procedures some of them are:

Frequency: The electricity of a ship can 50 Hz or 60Hz according to the ship type while the frequency of the European Union electrical grid is constant to 50 Hz. Some equipment of many ships which is designed to operate at 60 Hz may be able to operate at 50 Hz as well. This equipment is only limited to lighting and heating and is a small amount of the total power demanded by the ship. Motor-driven equipment like pumps and cranes, will not operate at their design speed and that will lead to damaging effects on the equipment. Consequently, a ship using 60 Hz electricity will require the conversion of the frequency of the European grid from 50 Hz to 60 Hz via a frequency converter. Voltage (M/V onboard): The difference in voltage between shore power and ship's power requires a specific onboard transformer (Fig. 1).

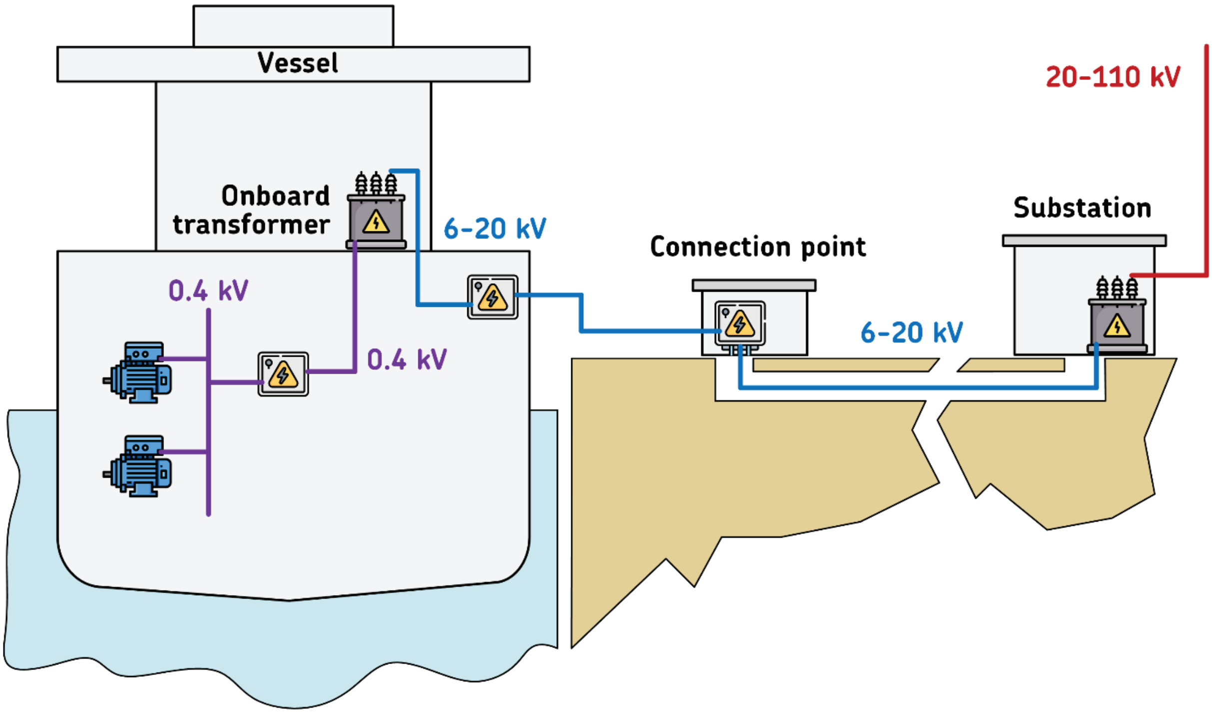

Figure. 1. General arrangement of cold ironing [2][1].

Safety: Cold ironing produces a high risk of injuries due to the requirement of direct handling of very heavy and cumbersome HV cables & connectors. Health is also a disadvantage by requiring handling of heavy loads in awkward positions, cold ironing exposes, in the long term, quayside personnel to back injuries. Non Compliance with National regulation, especially the European Directive 90/269/EEC3 is also an issue.

Several ships' types - berthing procedures: There are a variety of onboard power demands, system voltages, and system frequency vessels when they are at berth.

The vessel types usually are the Container vessels, Ro/Ro-and Vehicle vessels, Oil and product tankers, and finally cruisers. The docking pattern of each kind of ship and the usage of cranes is also a problem. Additionally, table 1 shows a summary of power demand for typical types of ships.

Table 1. Summary of Power Demand [3].

	Average Power Demand	Peak Power Demand	Peak Power Demand for 95 % of the vessels
Container vessels (< 140 m)	170 kW	1 000 kW	800 kW
Container vessels (> 140 m)	1 200 kW	8 000 kW	5 000 kW
Container vessels (total)	800 kW	8 000 kW	4 000 kW
Ro/Ro- and Vehicle vessels	1 500 kW	2 000 kW	1 800 kW
Oil- and Product tankers	1 400 kW	2 700 kW	2 500 kW
Cruise ships (< 200 m)	4 100 kW	7 300 kW	6 700 kW
Cruise ships (> 200 m)	7 500 kW	11 000 kW	9 500 kW
Cruise ships (total)	5 800 kW	11 000 kW	7 300 kW

3. Green port approach

Marine port power supply system normally is a traditional distribution system with well-developed infrastructure and similar to metropolis energy supply system in terms of complexity [4]. Electricity usage in ports is rising significantly for the last decade and will continue to increase due to operational, regulatory and environmental factors. Control and optimization of such systems become more and more complicated. To reach zero-emission aims and meet challenges regarding sustainability and environmental friendliness of the marine ports, new technologies are coming. One of the possible solutions is use of promising type of power system - so called “Smart Grid” concept [1].

The concept of “Smart Grid” [5] defines a self-healing network equipped with dynamic optimization techniques that use real-time measurements to diminish network losses, sustain voltage levels, rise reliability, and improve asset management. The operational data acquired by the smart grid and its subsystems will allow system operators to quickly recognize the best strategy to secure against attacks, vulnerability, and so on, caused by various contingencies. However, the smart grid first hangs on identifying and researching crucial performance measures, designing and testing suitable tools, and developing the proper education curriculum to equip current and future personnel with the knowledge and skills for the deployment of this highly advanced system.

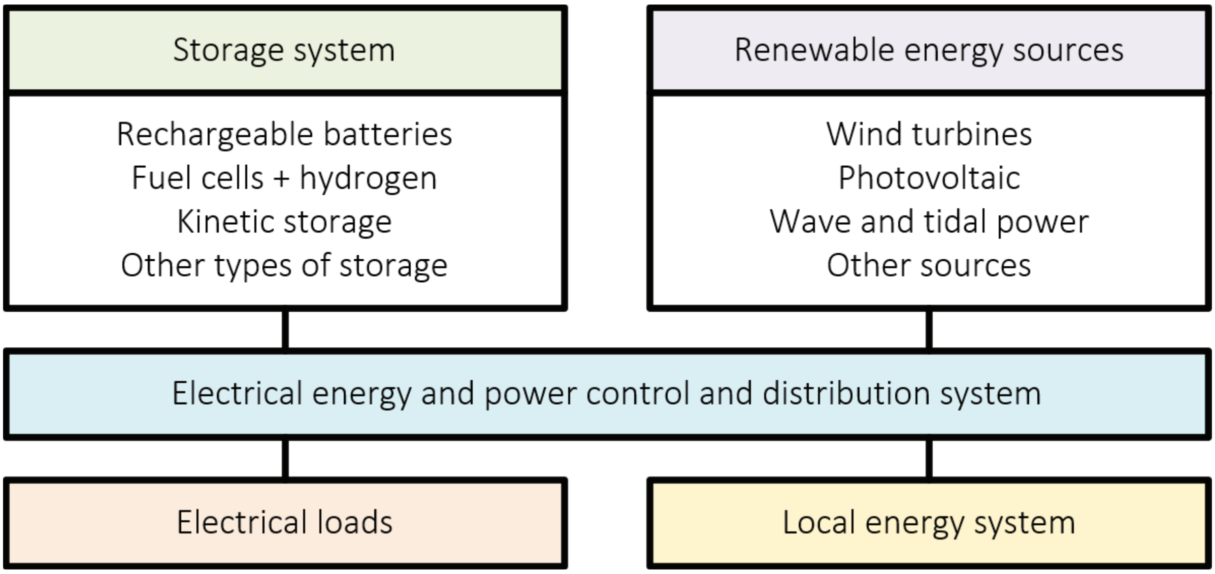

Figure 2 Schematic diagram of marine port power supply system microgrid concept [6], [1].

The control and distribution center is fitted with several renewable energy sources namely offshore wind turbines, PV sources for the park or from the buildings, wave or tidal energy depending on port potential, and geothermal energy according to ports abilities. The center is connected with a permanent electric grid used according to the needs and a digital metering system (in several areas such as docks and port's facilities) to monitor the port's energy demand and so to distribute the required available electrical power. The excessive power produced from renewable sources is transformed to hydrogen or stored in new technologies high-capacity batteries. The hydrogen produced is used for a fleet of electric cars for port's operations. The intention is that 100% power for all ports from renewable sources, and thus the power availability and the weather conditions should be carefully examined. In this case, an optimization algorithm will be very helpful to optimize the size of the power storage devices and the renewable sources. Furthermore, a power management algorithm can provide optimization of the power balance between renewable sources, storage devices, and the electrical grid. It can also perform optimum scheduling of the storage devices to increase the lifetime of such devices like batteries, decreasing maintenance cost and increasing the overall profit in the power market

The main motivations of a zero-energy port system are the following [7]:

- **Pollution reduction**, as required by the new regulations set by IMO and EU [8]. Those new regulations support the replacement of electric energy supply based on fossil fuels by renewable energies. Among them is the cold ironing procedures (i.e., stopping the engines of vessels during berthing) and also minimize the electrification of other auxiliary systems using fossil fuel energy [9]

- **The adaptation of harbors to the technological evolution of vessels and to shore-to-ship requirements**. Replacement of fossil fuels will be a fact for the next years meaning that electrical solutions such as electrical machines and storage systems will be among immediate priorities [10]. Cold ironing systems and the connection with offshore renewable energies will require a specific energy management system Among the potential actors in the future are the electrical vessels that require a specific load and ancillary.
- **The harbor changes required to meet the needs of the forthcoming years**: increasing maritime exchanges and maritime extension of harbor areas, development of electrical transport (vehicles, boats), etc. These loads represent approximately 80% of the annual electrical energy demanded in seaport;
- **The harvesting and use of fatal energy sources that exist in harbor areas**, but are rarely exploited: renewable energy sources such as solar photovoltaic energy or wind energy [11]

4. AI methods for zero emissions port's energy management

In this section, a brief consideration of AI methods potential will be presented based on the state-of-the-art review applied to the smart grid. The main attributes that will be discussed are load forecasting, Power Grid Stability Assessment, Faults Detection, and Smart Grid Security.

Load Forecasting

Renewable energy is dependent on temporal environmental conditions when integrated into a port's electric grid creates uncertainties on scheduling and operations of the electric grid and load forecasting is a key component to keep the system The load forecasting is classified in 3 major categories [12] : (1) short-term LF (STLF), which predicts the load from minutes to hours; (2) mid-term LF (MTLF), which predicts the load from hours to weeks; and (3) long-term LF (LTLF), which predicts the load for years.

- **Short-Term Load Forecasting.** There are many proposals, using the ensemble method, for this particular forecasting, for Short the efficiency and accuracy of STLF can be improved. Many Deep learning-based methods are used to solve similar problems. In recent years, and multilayer deep neural networks (DNNs)DNNs have been used to obtain the potential knowledge for a forecasting model

- **Mid-Term Load Forecasting** is used to coordinate load dispatch, maintenance scheduling, and balance demand and generation There is research on the deployment of a Deep Neural Network model [13] with an optimized training for mid-term forecasting in power systems in power systems and presented the effectiveness of the model. It is also provided a neural network-based model 0 combined with particle swarm optimization (PSO) and showed the feasibility and validity of the model.
- **Long-Term Load Forecasting:** is used to predict the power consumption, system planning, and scheduling of generation units new capacities installations in power systems. Artificial Neural Network is used as the first option and Support Vector Machines and Recursive Neural Networks follows

Power Grid Stability Assessment

The power grid stability assessments are fundamental for ensuring the reliability and security of the power system. Power system stability is the ability to stay at an equilibrium operation state or quickly reach a new equilibrium state of operation after a perturbation. Four different categories belonging to this attribute followed by the suggested AI techniques for their calculation are:

- **Transient Stability Assessment:** Machine learning algorithms using decision trees as a first choice, Support Vector Machines (SVM) and Artificial Neural networks.
- **Frequency Stability Assessment:** Mainly machine learning is used.
- **Small-Signal Stability Assessment:** Convolutional Neural Networks are mainly used for Particle Swarm Optimization (PSO).
- **Voltage Stability Assessment:** Artificial Neural networks, Support Vector Machines and algorithms based on decision trees.

Faults Detection

Mainly it is used for the fault location detection of the system (composed for the main grid and renewable energy sources distributed among several geographic locations) after extracting features by using measurements and compared them with SVR and ANN models.

Smart Grid Security

With the integration of advanced computing and communication technologies, the smart grid integrates distributed and green energy with the power grid by adding a cyber layer to the power grid and providing two-way energy flow and data communication. However, this has exposed the smart grid to numerous security issues due to the complexity of smart grid systems and the inherent weakness of communication technology. The most probable outcomes of smart grid cyberattacks are operational failures, synchronization loss, power supply interruption, synchronization loss, power supply interruption, high financial damages, social welfare damages, data theft, cascading failures, and complete blackouts.

5. Conclusions and future research

Ocean-going marine vessels represent one of the largest, most difficult to regulate, source of air pollution in the world and are also an essential component of the international trade and goods movement process. These marine vessels are similar to floating power plants in terms of electric power, and it has been indicated that the marine vessels are growing in length and they will therefore require greater electric power need. In this paper, it has been shown that shore-side power supply is a really interesting subject matter and that today's marine vessel emission regulation needs to be stricter. Most of the ports worldwide are investigating the possibilities to use shore-side power supply. The new concept of the smart grid using renewable sources requires appropriate energy management which could be facilitated nowadays from Artificial Intelligence Techniques. In the paper, a brief and initial overview of potential methods from AI is presented to facilitate the energy management of the so-called zero-emission port. Among those methods there are some very promising methods suitably fitted for the port's smart grid consisted of several geographically distributed renewable energies. Particle Swarm Optimization looks superior among others and its exploitation for zero emission's port will be among our future research

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