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

Pavel Kovalishin [a], (Dr.-Ing.At the Navigation Department, the Head of International Relations Department, pavelkovalishinkaliningrad@mail.ru).

Nikitas Nikitakos [b], (Professor at Department of Shipping, Trade, and Transport)

Boris Svilicic [c], (Full Professor at Faculty of Maritime Studies)

Jinnan Zhang [d], (Msc.,Lecturer at the Marine Engineering College)

Andrey Nikishin [a], (Dr.-Ing. At the Department of Electrical Equipment of Ships and Electrical Power Engineering)

Maksim Kharitonov [a], (Dr.-Ing. At the Department of Electrical Equipment of Ships and Electrical Power Engineering)

[a] BFFSA of KSTU, Kaliningrad, 236029, Russia

[b] University of the Aegean, Chios,82100, Greece

[c] University of Rijeka, Croatia 51000, Croatia

[d] Dalian Maritime University, 116000, China

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).

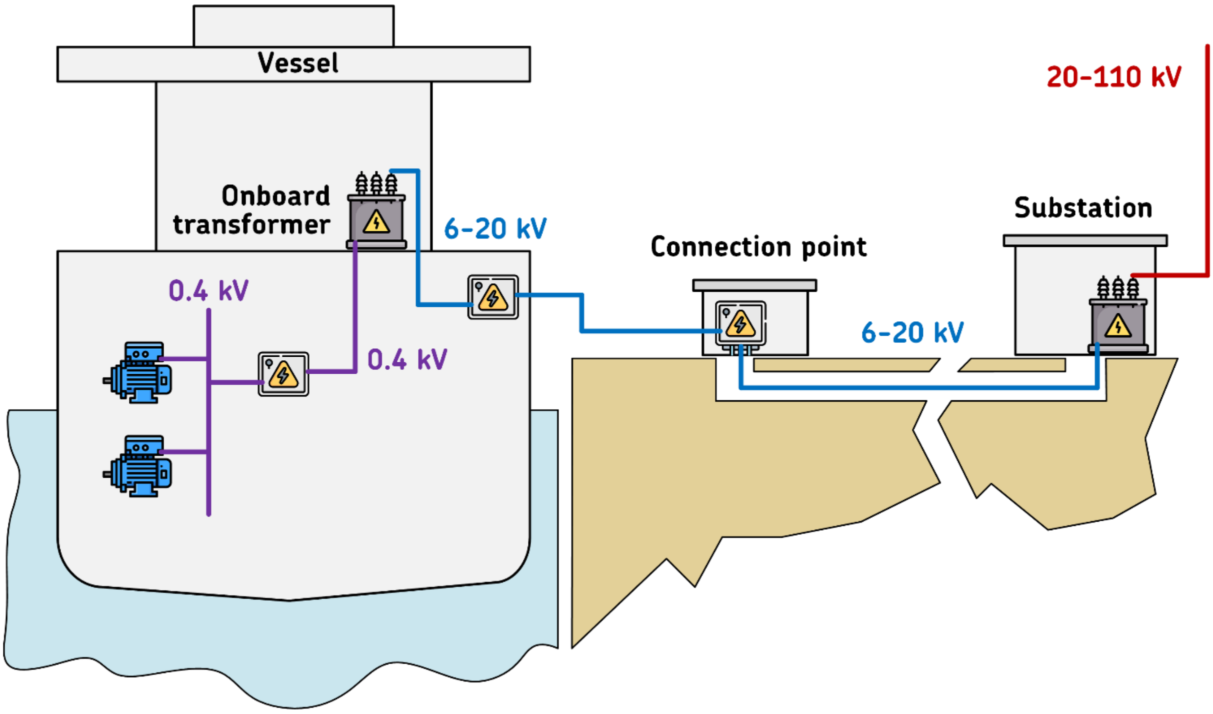

Figure. 1. General arrangement of cold ironing [2][1].

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.

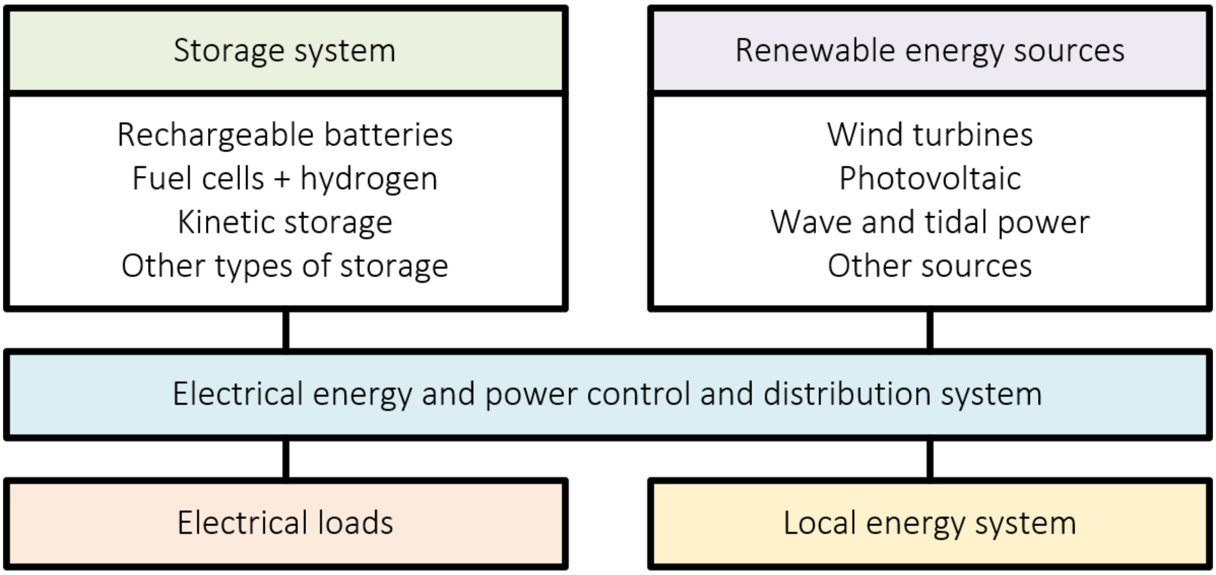

Figure 2 Schematic diagram of marine port power supply system microgrid concept [6], [1].

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

REFERENCES

[1] Nikishin, A. J., & Kharitonov, M. S. (2021, March). Modernization of marine ports electrical power supply systems in the framework of zero-emission strategy. In IOP

Conference Series: Earth and Environmental Science (Vol. 689, No. 1, p. 012018). IOP Publishing.

[2] Tzannatos, E. “Cost assessment of ship emission reduction methods at berth: the case of the Port of Piraeus, Greece”, Maritime Policy & Management, Vol. 37, No. 4, pp. 427-445, 2010.

[3] N. Nikitakos I. G. Dagkinis, P. Kofinas D. Papachristos Green Logistics - The concept of Zero Emissions Port based on PSO’ Proceedings of the Maritime and Port Logistics of the XXIII International Conference MHCL 2019 pp. 38-42

[4] Beley, V., Nikishin, A., & Gorbatov, D. (2018, September). Strategy of Metropolis Electrical Energy Supply. In International Conference on Advanced Engineering Theory and Applications (pp. 870-879). Springer, Cham.

[5] Momoh, J.: Smart Grid: Fundamentals of Design and Analysis, IEEE Press, 2012.

[6] Nikitas Nikitakos’ Green logistics: The concept of zero emissions port’ FME Transactions, 2012, pp. 201-206

[7] Anthony Roy , François Auger , Jean-Christophe Olivier , Emmanuel Schaeer and Bruno Auvity ‘Design, Sizing, and Energy Management of Microgrids in Harbor Areas: A Review’ Energies 2020, 13, 5314; doi:10.3390/en13205314

[8] European Commission. Commission Recommendation of 8 May 2006 on the promotion of shore-side electricity for use by ships at berth in Community ports. Off. J. Eur. Union 2006.

[9] Kotrikla, A.M.; Lilas, T.; Nikitakos, N. Abatement of air pollution at an aegean island port utilizing shore side electricity and renewable energy. Mar. Policy 2017, 75, 238–248.

[10] Fang, S.; Wang, Y.; Gou, B.; Xu, Y. Towards Future Green Maritime Transportation: An Overview of Seaport Microgrids and All-electric Ships. IEEE Trans. Veh. Technol. 2020, 69, 207–219

[11] Ahamad, N.B.; Othman, M.; Vasquez, J.C.; Guerrero, J.M.; Su, C.-L. Optimal sizing and performance evaluation of a renewable energy based microgrid in future seaports. In Proceedings of the 2018 IEEE International Conference on Industrial Technology (ICIT), Lyon, France, 19–22 February 2018; pp. 1043–1048.

[12] Omitaomu, O.A.; Niu, H. Artificial Intelligence Techniques in Smart Grid: A Survey. Smart Cities 2021, 4, 548–568. https://doi.org/ 10.3390/smartcities4020029

[13] Askari, M.; Keynia, F. Mid-term electricity load forecasting by a new composite method based on optimal learning MLP algorithm. IET Gener. Transm. Distrib. 2019, 14, 845–852.

Liu, Z.; Sun, X.; Wang, S.; Pan, M.; Zhang, Y.; Ji, Z. Midterm power load forecasting model based on kernel principal component analysis and back propagation neural network with particle swarm optimization. Big Data 2019, 7, 130–138.

Cover Letter IAMUC 2021

Dear Sirs,

This is to certify that the full paper Using Artificial Intelligence (AI) methods to combat climate change at marine ports by Pavel Kovalishin, Nikitas Nikitakos, Boris Svilicic, Zhang Jinnan, Andrey Nikishin and Maksim Kharitonov is to be submitted to the International Association of Maritime Universities Conference (IAMUC 2021) proceedings –within 8- Marine Pollution And Climate Change New Challenges.

The authors of the paper represent the IAMU Member University- Baltic Fishing Fleet State Academy of Kaliningrad State Technical University and the paper to be officially reviewed .

Regards,

Authors