Резюмета

на научноизследователските трудове на английски език на

гл. ас. д-р инж. **Гинка Христова Иванова**

за участие в конкурс за академична длъжност „Доцент“, в професионално направление 5.5 Транспорт, корабоплаване и авиация по научна специалност „Електрообзавеждане на кораба”, към катедра „Електроснабдяване и електрообзавеждане“ при Електротехнически факултет на Технически университет-Варна, обявен в ДВ бр.13/ 07.02.2023г.

<u>Опис</u>:

Резюмета по показател В.4 - хабилитационен труд – научни публикации в издания, които са реферирани и индексирани в световноизвестни бази данни с научна информация………4

[1 Rachev, S., Ivanova, G., Koeva, D. Vector Control of Pump Unit Electric Drive with Medium Voltage Induction Motor, 2020 12th Electrical Engineering Faculty Conference “BulEF 2020”, DOI 10.1109/BulEF51036.2020.9326032, ISBN 978-172819439-4... 5

[2] Ivanova, G., Donev, I., Kostova, I., Study on the Relationships between Optimal Speed, Route and Energy Consumption in Passenger Ship, 2020 12th Electrical Engineering Faculty Conference “BulEF 2020”, DOI 10.1109/BulEF51036.2020.9326022, ISBN 978-172819439-4........................ 6

[3] Ivanova, G., Donev, I., Kostova, I., Study of the Influence of the Physical Environment on the Design and Operational Indices of Energy Efficiency EEDI and EEOI, 2020 12th Electrical Engineering Faculty Conference, “BulEF 2020”, DOI: 10.1109/BulEF51036.2020.9326018, ISBN978-172819439-4…………………………………………………………………………....7

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[5] Ivanova, G., Gyurov, V., Analysis of the Energy Balance and Electric Consumption of Luxury Yacht for Charters, 2021 17th Conference on Electrical Machines, Drives and Power Systems, ELMA 2021 - Proceedings, 2021, DOI 10.1109/ELMA52514.2021.9503080, ISBN 978-166543582-6……………………………………………………………………………………...9

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Резюмета по показател В.4 - хабилитационен труд – научни публикации в издания, които са реферирани и индексирани в световноизвестни бази данни с научна информация

[1] Rachev, S., Ivanova, G., Koeva, D. Vector Control of Pump Unit Electric Drive with Medium Voltage Induction Motor, 2020 12th Electrical Engineering Faculty Conference “BulEF 2020”, DOI 10.1109/BulEF51036.2020.9326032, ISBN 978-172819439-4

When working with powerful pumping units with medium-voltage asynchronous motors, possible mechanical shocks at start-up and load pulsations must be taken into account. Any abrupt change in torque on the motor side, or on the load side, leads to mechanical loads and fatigue in the shafts. Sudden changes in torque can lead to hydraulic shocks in the piping system. This is one of the factors, together with the thermal overload, preferably of soft-start methods, by using a soft-start or a frequency converter. The latter provides an additional advantage - it can cover changes in load resistances during operation and also allows you to quickly go through any resonant frequencies at start-up and avoid operation at these frequencies. The need for speed control is obvious when the technological process itself requires it. In circulating centrifugal pump units in systems with low static head, the reduction of the speed, respectively the flow, leads to a reduction of the energy consumption.

Drives can save an average of 40% of the electricity a motor uses as well as reduce related CO2 emissions. Since industry accounts for one-third of the world's electricity consumption and electric motors consume 65% of industrial electricity in regions such as the EU [2], the potential global energy savings from a wider use of drives would be substantial. The complete system of differential equations representing a mathematical model of an electromechanical system of an electrically driven pump set consists of five equations - four to model stator/rotor currents and the fifth equation is the equation of motion. The correctness and accuracy of the simulation results can be confirmed by performing measurements in operation of such pumping systems. Unfortunately, these are often pumps working in places with a different level of security and limited access - thermal power plants (TPP), nuclear power plants (NPP) where the access of outsiders is limited or prohibited entirely. The model used to determine motor losses is only simplified. In fact, the loss structure also includes core losses as well as losses in the power module of the frequency converter. In addition, the magnetic system of the motor is always subjected to saturation, which leads to an increase in losses in the area of rated currents.

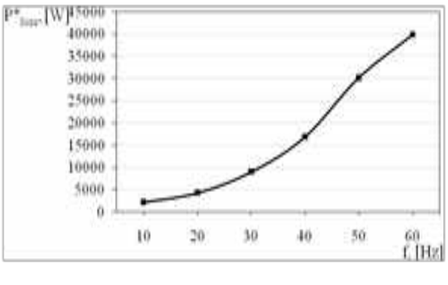


Fig. 5. Electrical power losses when applying indirect vector control.

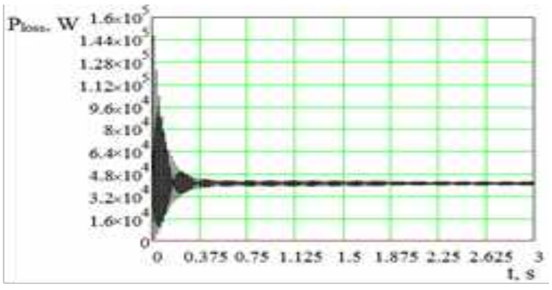


Fig. 2. Electrical power losses as a function of time at DOL starting.

The research examines the energy-saving possibility of an adjustable-speed pump drive. The research as well as the design of such systems as IM electric drive with vector control is quite a difficult task. By changing various parameters, factors and conditions related to the operation of a medium voltage electric motor driving a pump unit, its behavior can be studied.

[2] Ivanova, G., Donev, I., Kostova, I., Study on the Relationships between Optimal Speed, Route and Energy Consumption in Passenger Ship, 2020 12th Electrical Engineering Faculty Conference “BulEF 2020”, DOI 10.1109/BulEF51036.2020.9326022, ISBN 978-172819439-4

The report presents theoretical and experimental studies of the relationship between speed, route and energy costs in passenger ships. With the use of experimental data from voyages of a passenger ship on different routes under different conditions, dependencies have been derived for the analysis of the optimal modes of movement, leading to the realization of maximum savings of electricity and primary energy. Cruise ships differ from other types of ships in their relatively higher consumption of electrical energy (steam and hot water). The Ship Energy Efficiency Management Plan (SEEMP) for all MEPC 62 vessels (July 2011) is linked to the adoption of amendments to Annex VI to MARPOL (resolution MEPC.203 (62), by MARPOL Annex VI Parties, the firstlegally binding climate change treaty, adopted after the Kyoto Protocol. As this breakthrough, MEPC 63 (March 2012) adopted four important guidelines (resolutions MEPC.212 (63), MEPC.213 (63), MEPC.214 (63) and MEPC.215 (63), which address supporting the implementation of mandatory provisions on energy efficiency for ships in Annex VI to MARPOL.

Ship speed has a non-linear relationship with fuel consumption. A ship that sails slower will emit less greenhouse gases than a ship that sails faster. Cruise ships sail in different hydrometeorological conditions and itineraries and therefore it is necessary to make a separate analysis depending on the operating mode of the main and auxiliary engines. The study presents an analysis of the energy balance of an A1 class passenger cruise ship sailing in the Caribbean region.

The main parameters of the ship are gross tonnage 73000 GRT, length 268 m., Passengers 2500 people and crew and support staff 1200 people. The power supply is provided by 6 Wartsila VASA 2200 kW/6.6 kV generators and an Detroit Allison 400 kW/0.46kV emergency generator. The generators are powered by their own diesel engines and are not connected to the ship's main drive. Electricity consumers are divided into two main groups - consumers hotel part (premises, restaurants, bars, common areas and cabins), powered by six three-winding substations 6.6 / 0.46 / 0.23 kV and main system consumers (consumers in the engine room). For each day the average EEOI index of Formula 1 is calculated, taking into account the correction factor for the relationship between greenhouse gas emissions (CO and CO2) and fuel consumption Cf = 3.151(Table I), corresponding to Light Fuel Oil (LFO), which is the only fuel used in navigation. The accepted mcargo = 47427 [mt], corresponding to the tonnage at nominal load. The studied period is from January 3, 2019 to February 4, 2019, which is characterized by approximately constant meteorological conditions and water temperature in the range of 27 ÷ 29◦C.

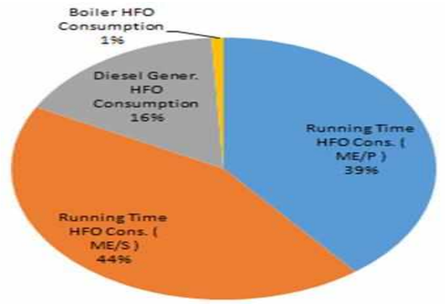
Figure 2. Effect of speed reduction on fuel consumption per mile traveled

Figure 1. Categorization of ships by speed

[3] Ivanova, G., Donev, I., Kostova, I., Study of the Influence of the Physical Environment on the Design and Operational Indices of Energy Efficiency EEDI and EEOI, 2020 12th Electrical Engineering Faculty Conference, "BulEF 2020", DOI: 10.1109/BulEF51036.2020.9326018, ISBN978-172819439-4

The report presents a study of the influence of various parameters of the physical environment on the design and operational indicators of energy efficiency EEDI and EEOI. The characteristic influences of the physical environment on energy and fuel consumption are examined. The obtained results allow for specific measures to be taken to improve the indicators and bring them into legal norms. The definitions of energy efficiency indices for the design of EEDI ships and energy efficiency in the operation of EEOI ships are governed by several IMO regulations. The required EEDI for all ships in summer loading conditions (the most severe sailing conditions due to lower water density) using 100% DWT. The exception is passenger ships, which are calculated using GT (gross tonnage).

The study presents an analysis of the energy balance of a class A1 passenger cruise ship during the Atlantic transition from Puerto Limon to Barcelona and Marseille. The main parameters of the ship are gross tonnage 47413 GRT, length 208 m., Passengers 1828 people and crew and support staff 620 people. The power supply is provided by 2 generators 2xMAN-B & W 9L40 / 54 (2x5994kW), 2xMAN-B & W 6L40/54 (2x3996kW) and emergency generator Detroit Allison 400 kW / 0.46 kV. The generators are powered by their own diesel engines and are not connected to the ship's main drive. The electricity consumers are divided into two main groups - consumers hotel part (premises, common parts and cabins), supplied by six three-winding substations 6.6 / 0.46 / 0.23 kV and main system consumers (consumers in the engine room). An analysis of the percentage of energy consumption for the first day in the waters of Puerto Limon is shown in Figure 1.



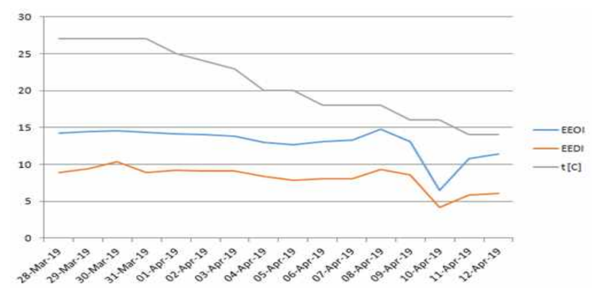


Fig 1. Energy mix of fuel consumption for Day 1 - Puerto Limon Fig.4. Change in EEDI, EEOI and t [C◦] of water

The graphical results of Fig. 4 , obtained on the basis of real data taken from the ship, show a decrease in the temperature of the sea water, which is a prerequisite for reducing energy costs, the most important being the reduction of fuel consumption for the movement of the ship. This is expected due to the increase in water density and the corresponding decrease in water displacement, which reduces the drag of the medium. Average fuel consumption decreases from 64 tHFO for a distance of 293 nm (Day 1 at t = 27°C) to 34t HFO for a distance of 190 nm (Day 15 at t = 14°C) Table III; Changes in sailing conditions do not significantly affect the consumption of electricity and the consumption of marine fuel for electricity generation. For the whole transition, electricity consumption represents 23% of the total energy mix. Characteristically, at low water temperatures, fuel consumption for electricity production has a significantly lower share. It varies from 37% for Day 1 to 16% for Day 16 or more than 2.5 times. Its percentage change is primarily due to the significant increase in fuel consumption for the main movement of the ship.

[4] Rachev, S., Ivanova, G., Achievement of Maximum Energy Efficiency through Vector Control of Induction Motor Electric Drive, IOP Conference Series: Materials Science and Engineering, 2021, 1032(1), DOI 10.1088/1757-899X/1032/1/012028, ISSN17578981

Electric motors are the predominant propulsion devices worldwide that consume electricity. For this reason, research aimed at minimizing their energy consumption is very relevant. The article refers to an applied energy-saving method - vector control of an asynchronous motor. In connection with this, a necessary condition for achieving maximum efficiency is the selection of the optimal value of the magnetizing current. If the magnetizing current is not properly controlled, the result can be higher power consumption from a frequency-controlled motor than from a direct-fed motor. In this case, certain electric drive parameters were analyzed.

The research is based on a mathematical model, representing a system of differential equations, which is transformed and solved with appropriate software. The aim is to seek minimal losses of electricity. The physical side of the subject is treated exclusively, without analyzing the economic benefits of introducing energy-saving measures.

Electromagnetic loads of alternating current electric machines (value of magnetic induction, current density, etc.), energy losses and heating are determined not by the active but by the apparent power, since the value of the magnetic flux in the motor depends on the total voltage , and not only of its active ingredient. IMs are suitable for DOL work. DOL devices are not controllable in the sense that they can only be turned on and off. Such devices put a strain on both the network and the machines and can be energy inefficient. Direct Torque Control (DTC) IM drives are a good solution for many applications.

The application of software simulations is useful to observe all quantities and to investigate the influence of various changing parameters. Simplifying assumptions are used: there is no asymmetry between the phase windings; the intermediate space between the moving and stationary parts of the engine is fixed; the rotor parameters are adjusted relative to the primary circuit. The non-linearity of the equations is due to the multiplication of independent variables or their functions. As is known, the differential equations of an AC machine contain variable coefficients. Direct coordinate transformation equations are applied to eliminate variable coefficients. The coordinate system used is orthogonal.

The research explored the energy saving potential of variable speed pump drive. The results of the conducted research are the obtaining of numerical values for the losses of electrical power in a specific IM for a pump unit under different modes of management. The simulation results can be validated by performing measurements on such pumping systems in operation. Speed regulation of inverter-fed IM pumping systems results in significant economic benefits due to reduced energy costs. In electromechanical energy conversion, a reduction in electrical power losses is observed when applying frequency / vector control.

[5] Ivanova, G., Gyurov, V., Analysis of the Energy Balance and Electric Consumption of Luxury Yacht for Charters, 2021 17th Conference on Electrical Machines, Drives and Power Systems, ELMA 2021 - Proceedings, 2021, DOI 10.1109/ELMA52514.2021.9503080, ISBN 978-166543582-6

Luxury charter yachts are a specific class of vessels that, due to the nature of their purpose, have a relatively high energy consumption for their gross tonnage compared to other passenger vessels. Their influence in the energy mix and environmental impact of passenger ships is often unjustifiably underestimated. In reality, the increased demands and claims of the owners regarding the luxury of the services offered, as well as the increased capacity for crew and passengers, lead to a significant increase in the size of the vessel and the installed users and, accordingly, capacities at the design level. The object of the present study is a luxury yacht for charter trips with a tonnage of 1560 GT and a length of 70.5 m., a crew of 19 people and 20 passengers, which is a vessel belonging to the class of small passenger ships. The normative requirements of the International Maritime Organization (IMO) include this type of vessels for ships, which are required to take measures to improve energy efficiency and reduce greenhouse emissions, in this case the aim is to reduce CO_2 emissions by 41% until 2025. This determines the need to carry out analyzes and research on establishing energy consumption and identifying measures to reduce it.

Determining the operational analysis of a ship's electricity consumption is very challenging, as it depends only on unpredictable models. The balance of the electric load is built for a group of users in order to identify the heavier groups of users. For each operating mode, electricity consumers are subdivided into continuous, periodic and sporadic operating. The statistical data for their work are respectively 70 ÷ 100% (17 ÷ 24 hours), 15 ÷ 70% (3.5 ÷ 17 hours) and less than 15% of the total duration of the considered daily regime. Studies conducted on different ships show that for the main modes – at sea and anchor, this process has a stationary ergodic nature and is well approximated by a normal law of distribution, the density of which is [1]:

$$f(P) = \frac{1}{\sigma (2\pi)^{0.5}} e^{-\frac{(P_i - P_{AVG})^2}{2\sigma^2}} \quad (1)$$

where: Pi is the current value of the load [kW]; PAVG - average load value [kW]; σ - standard deviation of the load. The results show that the highest consumption for Group 1 is in the "maneuvering" mode, as determined by the presence of a steering device with PW = 190 kW. This mode has the shortest duration. In sailing mode the consumption of Group 1 is PW = 47.39 kW and is three times higher than in standby mode (PW = 15.81 kW).

Group 3 Winches								
№	***Consumer***	***P_{INST} [kW]***	***Sea going***		***Harbour + Archor***		***Maneuring***	
			K_S	**P_W [kW]**	**K_S**	**P_W [kW]**	**K_S**	**P_W [kW]**
1	Hydraulic power unit	40	0	0	0.1	4	0.2	8
2	Anchor windlass 1	14.8	0	0	0.2	2.96	0.2	2.96
3	Anchor windlass 2	14.8	0	0	0.2	2.96	0.2	2.96
4	Telescopic mast	4	0.4	1.6	0.4	1.6	0.4	1.6
5	MCA Deck Crane	8.96	0.2	1.79	0.2	1.79	0.2	1.79
Total		**82.56**	**-**	**3.39**	**-**	**9.31**	**-**	**17.31**

[6] Gyurov, V., Ivanova, G., Increasing the Efficiency of Power Transformers in Marine Power Systems of Cruise Ships, 13th Electrical Engineering Faculty Conference "BulEF 2021", 1-4 , DOI 10.1109/ BulEF53491.2021.9690820, ISBN 978-166544192-6

The report presents a study of the energy consumption regimes in the energy system of a passenger ship, class 1A1. The study shows voltage regulation of power transformers depending on the connection scheme - single or parallel. As a result, graphs are displayed, which can determine the optimal operating areas of power transformers depending on the active loads and the ability to increase their efficiency. The electricity consumers of the ship in question are also divided into two main groups - consumers hotel part (premises, common parts and cabins), supplied by six threewinding substations 6.6 / 0.46 / 0.23 kV and main system consumers (consumers in the engine room), which are powered by the two power transformers TRBHT and TRTHT, the subject of this study. The parameters of the transformers are as follows:

TRBHT – Alstom 1000 kVA, Dyn 11, 60Hz, 6600/450/225 V, ΔP_0=2,2 kW, ΔP_K=11,2 kW

TRTHT – Alstom 1229 kVA, Dyn 11, 60Hz, 6600/450/225 V, ΔP_0=2,5 kW, ΔP_K=13,2 kW

Fig.2 and Fig.3 show load schedules for full [kVA], active P [kW], reactive Q [kVAr], strain D [kVA] and pulsating N [kVA] powers and for power factor PF for a typical 24- time period.

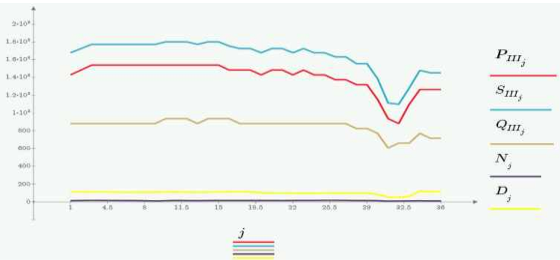


Fig. 2. Components of electricity consumption for a 24 hour period

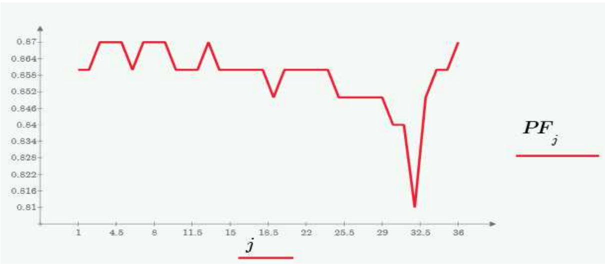


Fig. 3. Change of the power factor for a 24 hour period

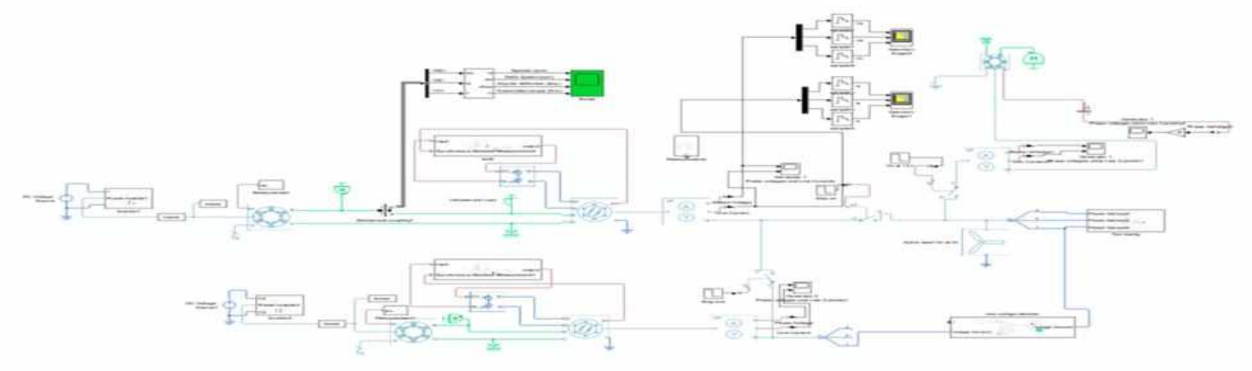
The index j shows the number of the measurement, in this case it is at a 30-minute interval. The power losses in power transformers of a cruise ship are studied, and traditional methods for estimation with coefficient are shown. of load β, as well as the application of the methodology cosφ-P plan [1], adapted to the studied object and the possible regime states of the transformers - separate, joint and parallel operation. The power losses in the load function are determined by formula (1).

$$\Delta P_{1(2)} = \Delta Po_{1(2)} + \beta^2 \cdot \Delta Pk_{1(2)} \qquad (1)$$

where: 1 - transformer TRBHT, 2 - transformer TRTHT. The study (Fig. 2) shows that for the whole period the power factor (in this case we can talk about the equality between PF and cosφ due to the low values of N and D) is below 0.9, and the average value is cosφ = 0.852. The presented study shows a way to improve energy efficiency by more precisely controlling the optimal operating range of power transformers and regulating the power factor. Qualitative and quantitative estimates have been obtained regarding the possible effect of reducing power and energy losses. For the specific case, a saving of 0.5% is equal in absolute values to a saving of electricity of 77 MWh per year when driving without passengers and light weather conditions (small number of course adjustments).

[7] Yodanov, Y., Milev, G., Gyurov, V., Duganov, M., Ivanova, G., Simulation of Methods for Diagnosis of the Mechanical Disturbances in the Operation of Ships Synchronous Generators, 13th Electrical Engineering Faculty Conference "BulEF 2021", DOI 10.1109/BulEF53491.2021.9690821, ISBN 978-166544192-6

The article presents an analysis based on simulation studies of the parallel operation of synchronous generators with torque fluctuations. These fluctuations are caused by mechanical disturbances of motor-generator sets, such as damaged bearings, eccentricity, etc. As a result of the negative impact of torque changes, fluctuations in the electrical parameters of synchronous generators occur. Based on the performed simulation, recommendations have been developed to quickly recognize such problems before their likely effect on the entire system. Stator Current Spectral Analysis (MCSA) is a widely used and standardized method (ISO 20958-2013) for the diagnosis of electrical equipment with asynchronous electric motors (AD). For the purposes of this study, a modified simulation model of a teaching bench implemented in Matlab Simulink was used.



The simulation is of a group of synchronous generators operating in "island mode of operation". It consists of two SG driven by AM with frequency control. The load on the generators can be provided in two ways; through a block with a characteristic active inductive load and by including AM in different modes. A standard block simulating rotor unbalance of a SG and a module that matches the AM rotor coupling with SG is used. Excitation is provided by an AC1C1 module according to the IEEE 421.5-2016 standard. The model allows additional weight to be placed at different positions about the axis of rotation for research. The spectra in Figs 2 and 3 were obtained using GCSA.

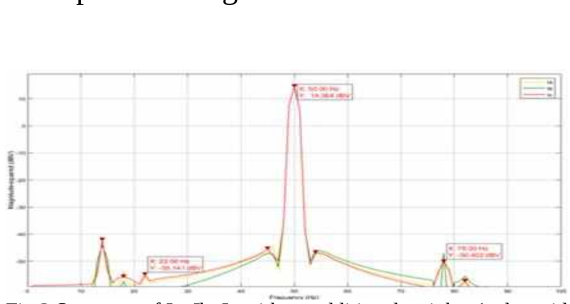


Fig.2 Spectrum of Ia, Ib, Ic without additional weights (only residual imbalance)

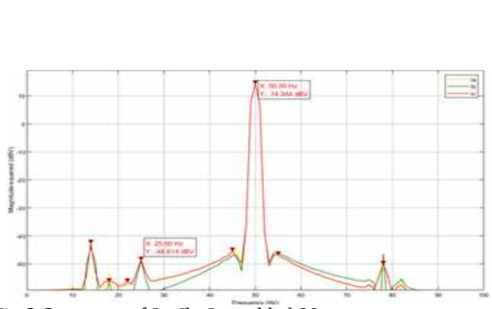


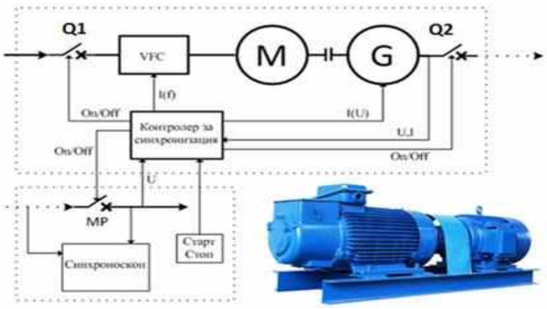
Fig.3 Spectrum of Ia, Ib, Ic - added 90 g

After adding 90g. at a radius of 70 mm. Fig.3 in the spectrum of the stator current, a peak with a frequency of 25 Hz and with an amplitude of -44 dB is observed, which is approximately 10 dB higher compared to the initial state.

[8] Milev, G., Gyurov, V., Ivanova, G., Duganov, M., Tzvetanov, B., Modelling and Simulation of Ships Electric Power Station with Self-excited Brushless Synchronous Generators, 13th Electrical Engineering Faculty Conference "BulEF 2021", DOI 10.1109/BulEF53491.2021.9690790,ISBN 978-166544192-6

The paper focuses exclusively on the development stages of a ship electric power station with self-excited brushless synchronous generators. Altogether, the research efforts were directed on making two motor-generator sets, emulating diesel-based power systems, integrated in a labora-tory environment where real ship gensets are not possible to be used. A simulation of such a system was undertaken via MATLAB Simulink, thus, allowing for the parameters of the actual machines to be used by connecting the generators in parallel. Undoubtedly, the availability of effective physical and simulation models enables more accurate calibration and creates a far more flexible research environment.

Simulation involves the actual parameters of electrical machines in the range of 6.3 kVA- for generators and 5.5 kW, 2.2 kW- for AC induction motors. The schematic diagram of an engine-generator group in laboratory conditions is shown in Figure 1. In the physical laboratory model, soft starting and speed control of induction motors driving synchronous generators will be performed by a frequency converter, allowing a wide range of supply frequency control.



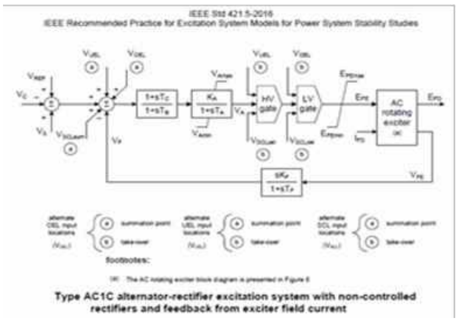


Fig. 1. Schematic diagram of an engine-generator group in laboratory conditions. Fig. 3. Excitation system conforming to IEEE 421.5 - type A1C1 st.

The excitation system of the synchronous generator is built in line with the IEEE 421.5 - 2016 standard type A1C1as depicted in Figure 3. Figure 2 shows the block diagram of the simulation model in Sim Power System (Matlab).

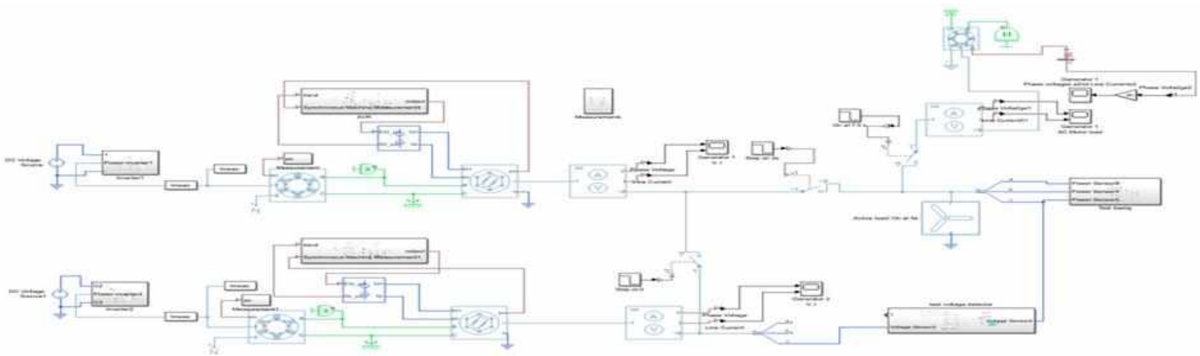


Fig. 2. Simulation model block diagram in Sim Power System environment.

The paper is designed to give a sharper focus on the simulation and analysis of the operation of a ship electric power station, directing the research efforts into the development of a laboratory-based physical model consisting of two induction motors with the following parameters: rated power P=5.5[kW]; rated voltage UN=400 [V]; rated current I=11.2[A]; rated speed n=1500[rpm], two synchronous generators with the following characteristics: total power S=6.3[kVA]; rated power P=5[kW]; rated speed n=1500 [rpm]; rated current I=9[A].

[9] Ivanova, G., Gyurov, V., Duganov, M., Rachev, S., Simulation Study of Power Consumption Modes of Hybrid SAVe Cube Ship Electrical Power Systems, 14th Electrical Engineering Faculty Conference "BulEF 2022", DOI 10.1109/BulEF56479.2022.10020200, ISBN 978-166549026-9

The report presents a simulation study of a hybrid SAVe CUBE marine power system that is parameterized with an existing ships architecture. Hybrid marine power systems are a new technical solution that raises new questions about power quality, electromagnetic compatibility and estimation of power and power losses. Their main purpose is to limit the spread of higher current and voltage harmonics, but the implementation of additional units is related to the use of advanced methods for analyzing electricity consumption. The results of the study can be useful for specialists in the field of operation of ship electrical power systems.

The implementation of hybrid energy systems initiates a transition from AC to DC to AC power system. One of the advantages of using a direct current network in the design and construction of new ships over an alternating current network is that it reduces the overall weight of the ship and results in an increase in cargo space. All control functions are made similar to those of a traditional air conditioning system. Control functions can be performed locally from the front of the SAVe CUBE panel for the specific component or set to be controlled remotely by PMS, production management, etc. The consumed electricity E_{Cons} can be determined by Equation (1).

$$E_{Cons} = E_{Gen} \cdot \eta = \frac{FC}{SFC} \quad (1) \qquad\qquad I_{LOAD} = \frac{P_{REF}}{V_{DC}} \quad (2)$$

where: EGen - generated electricity [kWh], η - total efficiency of the engine-generator group [kWh]; SFC - specific marine fuel consumption for marine power plants [t_{Fuel} / kW]., FC_{fuel} consumption. The main load in the ship's power system are the thrusters, which are connected to DC/AC inverters. To determine the load the required current is obtained by dividing the power reference P_{REF} by the actual DC link voltage as shown in Equation (2).

The simulation includes the study of different loading regimes. Figure 3 shows the variation of the torque and speed of Motor 1. The variation of the current during the start-up process and the load of Digatel 1 is shown in Figure 4. At the same load conditions, the graphs are very close to those obtained with an all-AC network. Figure 4 shows the unloading of Engine 1 when Generator 2 is switched on in parallel with Generator 1.

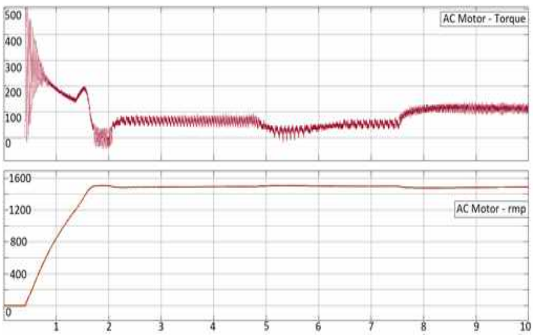


Fig. 3. Torque M[Nm] and speed n[rpm] of Motor 1

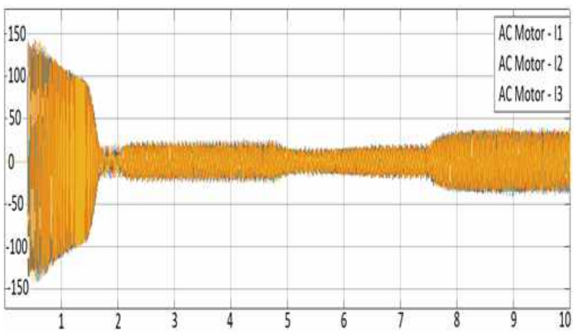


Fig. 4. Current load I of Motor 1

[10] Gyurov, V., Ivanova, G., Duganov, M., Rachev, S., Comparative Analysis of Reliability Indicators in Conventional and Hybrid SAVe cube Ship Electrical Power Systems, 14th Electrical Engineering Faculty Conference "BulEF2022", DOI 10.1109/BulEF56479.2022.10021201,ISBN 978-166549026-9

The hybrid SAVe CUBE devices are one of the most prospective topologies in marine power systems. The use of the AC-DC-AC architecture concept is related to limiting the spread of higher voltage and current harmonics in the ship's power supply system caused by the powerful electronic converters. This is associated with an increased number of elements, which also changes the overall reliability indicators. The report presents a comparative analysis of reliability indicators in conventional and hybrid marine power systems. The results can be used as quantitative criteria for evaluating the probability of failures, the overall reliability of the system, defining the repair cycle periods, which will facilitate the operational maintenance of ships electrical power systems.

SAVe CUBE is an integration of switchboard and large frequency converters. Its advantages over traditional power systems are compact size, the possibility of applications with variable and fixed speed generators, and fewer power conversion stages. The main difference compared to the traditional power system is internal common DC distribution. As well as the use of AC/DC and DC/AC converters between the DC switchboard and generators, large electric motors and the low-power AC network on board the ship.

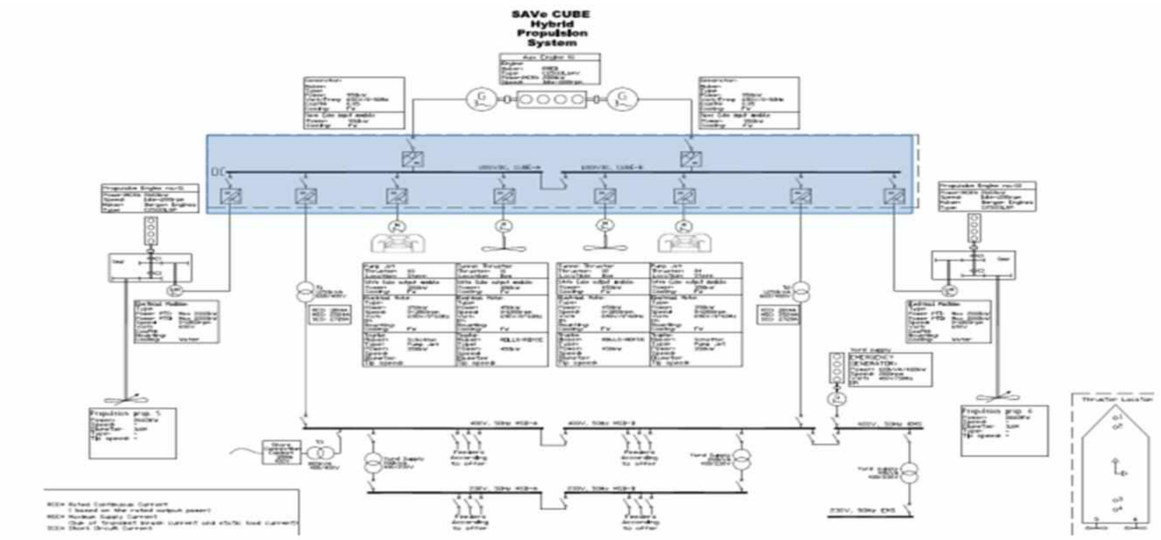


Fig. 5. Electrical diagram of an AC-DC-AC hybrid ship with all-electric propulsion

The scheme of the investigated AC-DC-AC hybrid ship power system architecture (SAV-e Cube) is shown in Figure 5. The scheme is applicable to various types of ships – passenger, specialized, etc., and due to its advantages related to the quality of electrical energy, energy efficiency and electromagnetic compatibility, it is expected that this type of architecture will have an increasingly wide application. The scheme and its modifications are characteristic of cruise ships. Calculations have been performed regarding the reliability assessment of the scheme for the different voltage levels as well as regarding the electric drive. Since the circuit is symmetrical with respect to the individual voltage levels due to the need to provide backup power and duplication of important equipment, only one half of the circuit will be considered in the calculations and in its entirety will be considered as parallel circuits for the different levels.

Резюмета по показател Г.7 - научни публикации в издания, които са реферирани и индексирани в световноизвестни бази данни с научна информация

[1] Ivanova, G., Specifics in Determining the Operational Energy Efficiency Index EEOI According to the Requirements of the International Maritime Organization IMO for the Period 2020-2025, 12th Electrical Engineering Faculty Conference, BulEF 2020, DOI: 10.1109/ BulEF 51036.2020. 9326011, ISBN-978-172819439-4

The International Maritime Organization (IMO) has developed a series of measures to monitor emissions in an effort to minimize the harmful environmental impact of ships. In this regard, two indicators for energy efficiency assessment are standardized – Energy Efficiency Design Index (EEDI) и Energy Efficiency Operational Indicator (EEOI). The energy efficiency index is mandatory for all ships with a gross tonnage (GT) of more than 400 GT built after 1 January 2013. For all other ships with a gross tonnage of more than 400 GT, the preparation and implementation of a ship's energy efficiency management plan (SEEMP) shall take effect. The Energy Efficiency Index and SEEMP are expected to reduce annual carbon dioxide emissions from 703 to 1,325 million tonnes in 2050. For the first time in the history of a certain economic sector, mandatory measures for the global reduction of greenhouse gas emissions into the atmosphere are introduced. By circular 1/684 of the Marine Environment Protection Committee (MEPC) in 2009 rules for use by ships of the Energy Performance Index (EEOI) were adopted.

The definition used takes into account the environmental impact of ships on the basis of fuel consumed, its environmental impact and the cargo or number of passengers transported over a given distance. Thus, it is not possible to determine the exact energy and environmental impact of electricity consumers. As the purpose of the monitoring of energy efficiency indicators is to provide an opportunity to assess the current situation and identify measures to improve it, from the point of view of electricity consumers it is appropriate to detail the definition of EEOI, which does not change the physical its essence.

The considered energy efficiency efficiency index EEOI is applied in the operation of ships. The EEDI (Energy Efficiency Design Index) is used in the process of ship design and construction. Its definition is based on Regulation 2.23 and Regulation 20 of MARPOL, Annex VI. According to the regulations, the required EEDI is determined and the EEDI.

Defining the influence of electricity consumers and the increase in power losses on the EEDI indicator is done in a similar way [4]. The overall goal set by the IMO is to reduce the indicators to 30% in the period 2020-2025. The proposed detailed definitions of the EEOI and EEDI indicators allow a quantitative assessment of the impact of electricity consumers, and the expected effect on the improvement of the overall indicators through the implementation of system enhancers can reach 10% and more. The latter is a significant part of the IMO's goals for improving energy efficiency and reducing global environmental impact. The study presents an approach to broaden the definition of the energy efficiency indicator in the operation of EEOI ships. Through the proposed method it is possible to obtain a quantitative assessment of the impact of electricity consumers on the EEOI indicator. The methodology includes taking into account the action of reactive loads, asymmetric and nonlinear consumers in the ship's electric power system, by including reactive power Q, pulsating power N and deformation power D.

[2] Ivanova, G., Donev, I., Experimental Study of the Operational Energy Efficiency Index EEOI in Passenger Ships, 12th Electrical Engineering Faculty Conference “BulEF 2020”, DOI: 10.1109/ BulEF51036.2020. 9326063, ISBN978-172819439-4

The report presents experimental studies of a passenger ship to determine the operational energy efficiency index EEOI. As a result of the conducted research, experimental dependences for realized index and performed comparative analysis in relation to the normative requirements were established.

The regular monitoring and control of the EEOI is an integral part of the SEEMP for ships in service and the relevant calculation documentation is subject to monitoring by the IMO. The EEOI provides an accurate figure for each trip. The value of the EEOI depends on the measurement of the load or the transport work performed, e.g. tonnes of CO_2 / (tonnes / nautical miles), tonnes of CO_2 / (TEU / nautical miles) or tonnes of CO_2 / (man / nautical miles) for passenger ships. The IMO has adopted the EEOI as a tool aimed at supporting the process of limiting and reducing CO_2 emissions from ships in operation. The EEOI is calculated according to the following formula, in which a lower EEOI value means a more energy efficient ship. The definition of EEOI is shown in Formula 1, and the average value for a given course, including the general situation of using different fuels and carrying different volumes of cargo, is shown in Formula 2.

$$EEOI = \frac{FC \cdot C_F}{m_{c\arg o} \cdot D} \quad (1) \qquad AverageEEOI = \frac{\sum_i \sum_j FC_{i,j} C_{Fj}}{\sum_i m_{c\arg o_i} \cdot D} \quad (2)$$

where: C_F, j - environmental impact factor of the j-th type of fuel [tCO_2 / tFuel]; mcargo mass of the transported cargo [t] or number of passengers [pcs.]; D – distance traveled in nautical miles to perform the specified work [n.m.].

The average specific cost for the production of 1MWh from marine power plants is 0.24 tHFO (tons of heavy marine fuel). For the weekly study period, the consumption of HFO = 83.46 [tFuel], corresponding to produced and consumed 20MWh. The results of the study show that the percentage of electricity consumers varies from 38 to 55% of total marine fuel consumption. The small share is typical for the days with longer duration of navigation on the high seas. In terms of the route, the shortest sailing time is the fourth day, which is due to the longer stay in the port of Civitavecchia (Rome), due to planned excursions to land tourists.

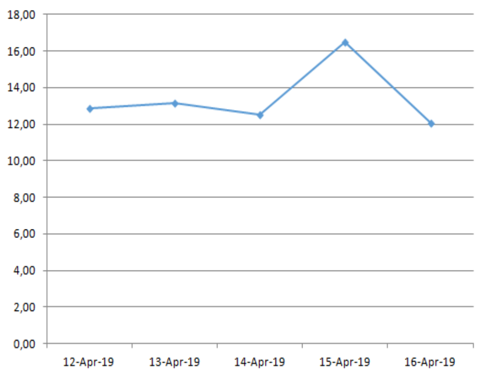


Figure 4. Change in EEOI for each day of the period

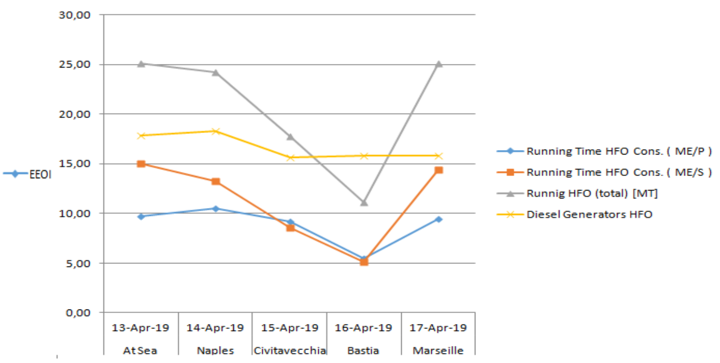


Figure 5. Change in HFO consumption for each day of the study period

[3] Ivanova, G., Analysis of the Specifics in Calculating the Index of Existing Marine Energy Efficiency EEXI in Force since 2023, 2021 13th Electrical Engineering Faculty Conference, DOI10.1109/BulEF53491.2021.9690805, ISBN 978-166544192-6

The report presents an analysis of the energy efficiency existing ships index (EEXI), which entered into force in June 2021 and will apply to all vessels over 400 GT under Annex VI of MARPOL of 2023. Guidelines for calculating the EEXI on overall energy efficiency are presented. With the help of the proposed guidelines, it is possible to identify specific measures to improve energy efficiency by electricity consumers. This means that by definition the newly built ships delivered in 2023, and after this year, will already meet EEXI. Accordingly, ships will be classified into five different efficiency classes (A, B, C, D, E) and thus the associated CO_2 reduction targets will even become stricter from year to year. The definition of the EEXI index for a ship is determined only by the design data of the ship as shown in Formula 1:

$$EEXI = \frac{CF \times SFC \times P_{EM}}{f_i \times f_c \times f_l \times Capacity \times V_{REF}} \quad (1)$$

where: P_{ME} - power of main engines [kW]; SFC – specific fuel consumption for the kth user [tFuel / kW]; EEXI Speed (Vref) - speed of the ship at 75% MCR, corresponding to the capacity; Capacity (Deadweight for container vessels, 70% of deadweight). The V_{ref} speed for ships falling within the EEDI requirement shall be derived from an approved speed-power curve as defined in the 2014 Energy Efficiency Design Index (EEDI) certification guidelines. However, different reduction factors are applied to different types of vessels to meet the new EEXI requirements, which are shown in Table 1.

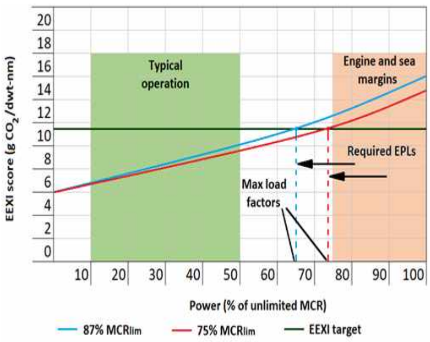


Fig.5. EEXI score by main engine power and evaluation point

№	*Ship type*	*Size*	*Reduc.factor*
1	*Bulk carrier*	*≥200000DWT*	*15*
2	*Tanker*	*≤200000DWT*	*20*
3	*General cargo ship*	*DWT≥15000*	*30*
4	*Ro - Ro passenger ship*	*DWT ≥1000*	*5*
5	*Cruise passenger ship having non-conven. propulsion*	*DWT ≥85000*	*30*

Table I. Reduction factors for different types of ships

The blue curve represents the EEXI,when evaluated at 87% MCRlim, and the red line represents the same at 75% MCR_{lim}. The ship's assigned EEXI target of 11.5 g CO2 /deadweight tonne nautical mile is also shown as a horizontal green line. As indicated, the 87% MCRlim evaluation condition would require a larger (+8%) EPL than the 75% MCR_{lim} condition. Each ship's EEXI target is calculated using the EEDI reference line, and its EEXI reduction factor from Table 1, which is determined by ship type and capacity (dwt).

[4]Ivanova, G., Ways to Increase the Efficiency of a Ship Cooling System, 2021 13th Electrical Engineering Faculty Conference “BulEF 2021, DOI 10.1109/BulEF53491.2021.9690809, ISBN978-166544192-6

The report presents an analysis of the electricity balance on board large passenger ships needed to control the air conditioning system for heating, cooling and ventilation. Its calculation is carried out in terms of fuel oil consumption and CO2 emissions. A way to determine the impact of the cooling system on the overall energy efficiency is presented. Modern marine air conditioning systems are the largest consumers of electricity on board and represent 30% of the electricity consumed. Large cruise ships have autonomous well-balanced systems in which changes in each system can cause problems with other systems. During the voyage of a cruise ship type 1A1 on its route was considered and analyzed in detail the effectiveness of HVAC, an idea was found for its improvement and optimization of modes and operation. The calculations in this study are based on actual estimates of the consumption of the cooling system on board the vessel.Fig.1 shows the power consumption of the various consumers of a cruise ship. HVAC systems (heating, ventilation and air conditioning) use one third of the energy used on board the ship. Therefore, optimizing the operating modes of the ventilation system and finding the right solutions is an important element for saving energy. When passenger ships stay in port, the HVAC system even becomes a major en consumer.

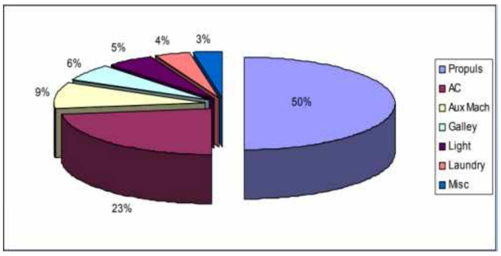


Fig. 1. Energy mix of class 1A1 passenger ship

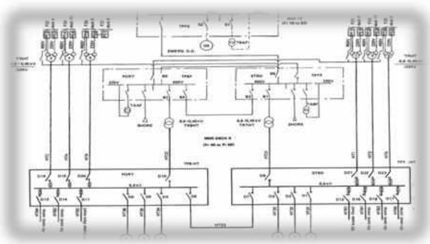


Fig. 2. One-line diagram of a class 1A1 ship with 5 pcs. HVAC systems

Figure 2 shows the energy system of the ship type 1A1 passenger, equipped with two four main engines with a nominal power of 1800 Kw. The power supply is provided by 6 Wartsila VASA 2200 kW / 6.6 kV generators and an Detroit Allison 400 kW / 0.46 kV emergency generator. Consumers hotel part (premises, common parts and cabins), supplied by six three substations 6.6 / 0.46 / 0.23 kV. The ship is equipped with five asynchronous motors for the air conditioning system for all rooms: passengers and crew cabin. One of the five HVAC systems of the ship, with a power of 165 kW, was studied, and the energy consumption and its dynamics were analyzed.

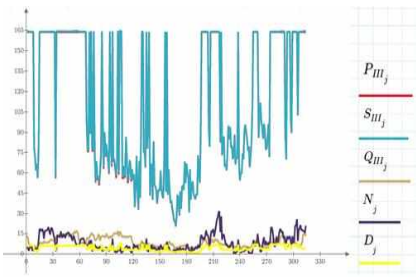


Fig. 3. Change of S [kVA], P [kW], Q [kVAr], D [kVA] and N [kVA] for 24 hours

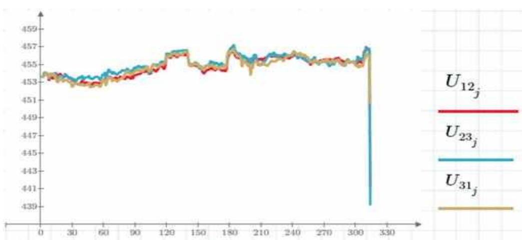


Figure 6. Voltage change U [V]

Figure 3 shows the dynamics of power in different modes of operation of the ship and different meteorological conditions. Data from several cruises were used for a detailed analysis of the voltage change. They took place in March in the Caribbean. Their main characteristics are presented in Figure 6.

[5] Ivanova, G., Study of Parallel Operation of Ship Generators with Different Power, 2021 13th Electrical Engineering Faculty Conference "BulEF 2021", DOI 10.1109/BulEF53491.2021.9690839, ISBN 978-166544192-6

The report presents an analysis of the parallel operation of ship generators of different type and power. An installed system on board a luxury passenger ship and power management are considered. A way to determine the impact of the electricity system on the overall energy efficiency is presented. The studied passenger ship is 76.60 m long and is designed to sail around the world in extreme weather conditions between -20 ° C and + 50 ° C, and has a maximum speed of 15 knots and a cruising speed of 11 knots. The power supply is supplied by six generators, four with an electric power of 800KW (1000KVA) and two of 400kW (500KVA). These generators are separated in the main switchboard MS1 on both sides of the main bus switch, usually closed (Bureau Veritas rules, this bus connection is only open in an emergency ″ in case of failure of one section of the switchboard BV part C). Figure 1 shows a single-line diagram of a multi-purpose research vessel.

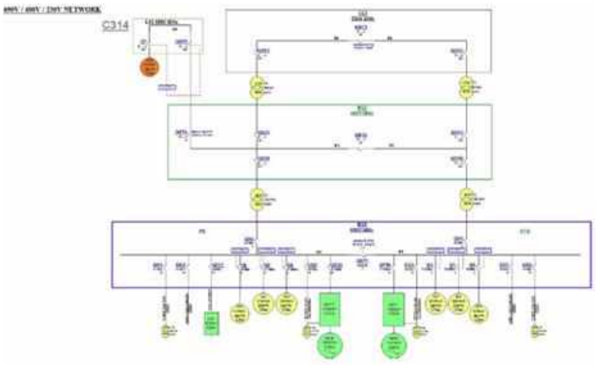


Fig. 1 Single - line diagram of a multifunctional research vessel

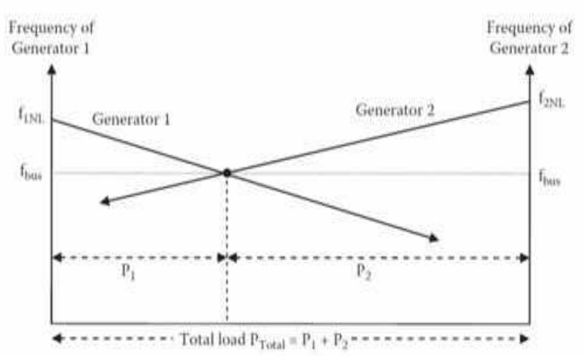


Fig. 2. Principle of load distribution during synchronization

The principles of load distribution during synchronization (at operating point fbus) are shown in Figure 2. The total installed capacity of such ships is determined by the equation 1:

$$P_{RG} = P_{RSG}\frac{N_{COM}}{N_{COM}-1} \quad (1)$$

$$\Delta P_{tran,gi(K,Nf)} = \frac{H_i.P_{r,gi(k)}}{\sum_{i=1}^{k-Nf} H_i.P_{r,gi}}\Delta P_{tran(k,Nf)} \quad (2)$$

Where: P_{RG} is the installed generating power; P_{RST} is the power required to generate energy; and N_{COM} is the number of subsystems separated. Each generator brings a certain power proportional to its inertia. Assuming that the generators remain in sync, the equation 2 can be used to calculate the load step of each generator. The simulation study includes adequate models of internal combustion diesel engines, generators and electric loads. The graphs visualize the peaks in power, currents and voltages at the described switching, as well as the subsequent transients for process establishment. All of them do not pose a threat to the sustainability of the ship's energy system. In this case, the system considered is modelled in the MATLAB/PSB-Simulink environment, as shown in Fig 3.

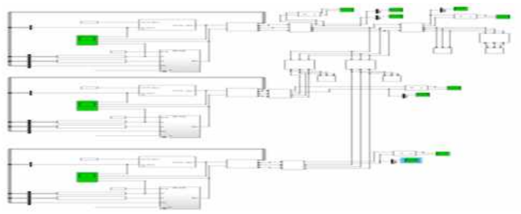


Fig. 3. General structure of the simulation model with three diesel generator sets and two powerful loads

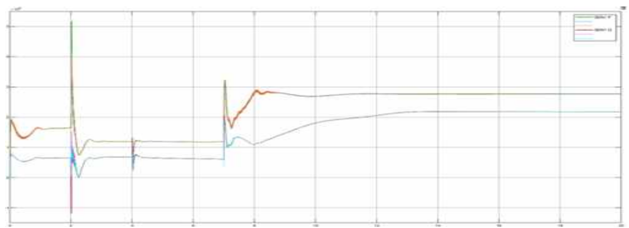


Figure 7 Change of active power P [W] (orange color) and Q [Var] (blue color) for one phase of Generator 2 - 1000 kV

Резюмета по показател Г.8 - научни публикации в нереферирани списания с научно рецензиране или в редактирани колективни томове

[1] Ivanova, G., V. Gyurov, R. Kirov, “Rationalization and optimization of energy processes in ship power systems by applying a complex multifactorial approach”, Scientific journal Mechanics Transport Communications, volume 16, issue 3/2, 2018, article no. 1728, ISSN 2367-6620

In the operation of ships, maritime organizations introduce rules and standards, most often created on the basis of criteria that are insufficiently scientifically substantiated. The introduction of innovative technologies with expanded use of electronization and computerization in ship electrical power systems, creates prerequisites for the deterioration of indicators of the quality of electrical energy, electromagnetic compatibility (EMC) and electrical energy efficiency (EEEF). This necessitates the formulation of modern arrangements, concepts and approaches, with the aim of rationalizing and optimizing the various energy processes in ship electrical power systems. The application of a complex expert approach is expressed in the understanding that, in addition to creating highly effective and practically applicable regulatory requirements, it is necessary for maritime organizations to carry out their activities by implementing progressive design solutions using high levels of automation and computerization of engineering work.

The proposed system for expert assessment of the quality of electricity and power supply uses the existing regulatory framework. It replaces the not so well-defined coefficient of relative significance (weight) with a reserve percentage when meeting the requirements. A sufficient number of levels of discretization of the assessment is provided - 27. The strengths and weaknesses in terms of quality of electricity supplied and quality of service are easily visible.

For different ship types, the increase in power losses caused by lower power quality (ΔP_Q) will have a different impact on the total energy consumption. A different ratio of the components in the formula (7) shows the reasons for the deterioration of the quality of electrical energy and technical solutions that can be applied to improve it. Using this definition, the reduction of electrical energy consumption through the application of technical solutions to improve the quality of electrical energy is comparable to the use of renewable energy sources.

In practice, in many cases it will be most effective to apply both methods simultaneously. The influence of the individual components in formula (6) – asymmetry, nonlinearity and reactive power are determined by the formulas:

$$\Delta P_Q = \frac{Q^2}{P^2}.100[\%] \quad (8) \qquad \Delta P_N = \frac{N^2}{P^2}.100[\%] \quad (9) \qquad \Delta P_D = \frac{D^2}{P^2}.100[\%] \quad (10)$$

The ratio between (8), (9) and (10) shows what technical solutions can be effectively applied:

•If (8) has the largest value, the use of compensation systems with capacitor banks is effective;

• If (9) and (10) have significant values, then the use of passive filter-compensating systems is effective;

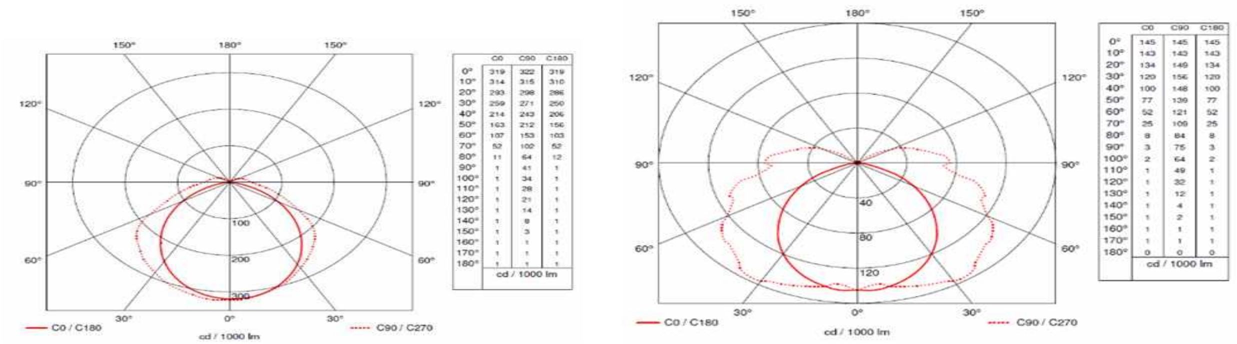
• If all three components have significant values, the use of active filters is effective.

From a practical point of view, it is important to determine the economy of primary energy carriers (fuels) caused by improving the quality of electrical energy through specialized technical means. Thus, the technical-economic efficiency can be evaluated.

[2] Gyurov, V., Panchev Hr., Ivanova G. “Peculiarities in designing the reconstruction of the lighting system of the engine room of a container ship in accordance with IACS No. 143/2013 ”, IX Scientific Conference "EF2017", TU-Sofia, Vol. 68, Book 1, Pages 163-170, ISSN 1311-0829

The report examines the design specifications that are subject to the various standardization requirements for workplace lighting and for specialized marine lighting systems. The study is based on technical characteristics of a real object - a container ship put into operation in 2004 with SAMSUNG basic electrical equipment. Significant in terms of technical complexity, degree of significance, risk factor for accidents and saturation with engineering equipment - ship's engine room. An approach to retrofit lighting with LED-based light sources is introduced, supported by a number of operational constraints - simplicity of implementation, repairability, uniformity and independence of supplies. Particular attention is paid to the application of IACS Recommendations No. 143/2013 on "Recommendations on human factors for the structural design of lighting, ventilation, vibration, noise, access and egress devices" for vessels intended to comply with the Convention on the Safety of Ships STCW in combination with specialized Relux design software. The need to conduct such a study in order to deepen the knowledge in the field is determined by the introduction of a mandatory subject for specialists from the "Electrical equipment of ships" department, according to the requirements of IMO 7.08 Electro-technical Officer.

For lighting systems in ships, the normative requirements specified in IACS No. 132/2013, developed by the International Association of Classification Societies, are valid. The illuminators used are LLNN 2X36W with conventional ballast, protection class IP55, mounted on metal perforated shelves. The light distribution of the luminaires is shown in Figure 2 (left).



	C0	C90	C180
0°	319	322	319
10°	314	315	310
20°	293	298	286
30°	259	271	250
40°	214	243	206
50°	163	212	156
60°	107	153	103
70°	52	102	52
80°	11	64	12
90°	1	41	1
100°	1	34	1
110°	1	28	1
120°	1	21	1
130°	1	14	1
140°	1	8	1
150°	1	3	1
160°	1	1	1
170°	1	1	1
180°	1	1	1
	cd / 1000 lm		

	C0	C90	C180
0°	145	145	145
10°	143	143	143
20°	134	149	134
30°	120	156	120
40°	100	148	100
50°	77	139	77
60°	52	121	52
70°	25	109	25
80°	8	84	8
90°	3	75	3
100°	2	64	2
110°	1	49	1
120°	1	32	1
130°	1	12	1
140°	1	4	1
150°	1	2	1
160°	1	1	1
170°	1	1	1
180°	0	0	0
	cd / 1000 lm		

Фигура 2. Светлоразпределение на осветител 2x36W T8 при работа с ЛЛНН (ляво) и при замяната на лампите с LED T8 2x22W (дясно)

The annual usability of engine room lighting is approximately 8,250 hours (continuous mode). The consumed electrical energy is respectively: Option 1: 58063.5 kWh; Option 2: 35706 kWh. The presented study shows the specifics in the design and reconstruction of the lighting system of a ship's engine room. A variant approach was used to justify the effectiveness of the solution. The specifics of evaluating the technical-economic efficiency-analysis against primary energy carrier are affected. Quantitative evaluations have been obtained proving the high efficiency of the implementation of LED light sources in ship lighting systems. This measure is one of the most widespread in practice, and the present study shows a thorough justification for the ways of designing a complex interior environment with modern software applications, which achieve an objective assessment of the effectiveness of the design solution.

[3] Proikov, M., G. Georgiev, Hr. Panchev, G. Ivanova, V. Gyurov, Study of indicators, parameters and characteristic features in the operation of the electricity supply system of "Elkabel" AD, Burgas, magazine "Mechanics, transport, communications", issue 16, volume 3/2, pages 68-74, 2018, article №1725, ISSN 1312-3823

The site's power supply system consists of a hydroelectric plant and 16 workshop substations. with an installed capacity of more than 7 MW, with the main users being AD with frequency control, DC motors, fans, pumps, etc. A study was conducted through objective measurements on the energy indicators and the indicators of the quality of electrical energy during two working weeks during a continuous 24-hour mode of operation of the company. The results of the research show the existence of certain deviations of some indicators from the normative ones. This provides an opportunity to improve the operating modes and increase the electrical efficiency of the studied object. An overload of the capacitor banks in terms of current was established due to the occurrence of voltage resonance. The resonant frequencies at reduced and normal load of power transformers (PT) have been determined. To prevent resonance phenomena, it is necessary to introduce automatic power management of the capacitor banks using a regulator operating according to the "direction and magnitude of reactive power" criterion. This provides an opportunity to increase the number of compensating power steps and perform finer adjustment. In addition, this approach allows adjusting the adjustment time depending on the dynamics of the cargo schedule. Switching processes are eased by using specialized contactors for capacitive load, suppressing inrush currents, which significantly improves the reliability of the system.

Measurements were made for two weeks on the quality indicators of EE (PQEE) carried out with a network analyzer "Hioki 3197" connected to the 20kV bus system in the substation of the enterprise through current and voltage measuring transformers. The harmonic components of I and U, THDI and THDU, unsymmetry of U and I, power factor, I and U, consumed active, reactive and total power are recorded. The company's energy department provided data on the annual consumption of active electrical energy, which is about 19 million kWh, and on the annual consumption of reactive electrical energy, which is about 9.4 million kVArh. The presence of reactive load compensation in the company's power supply system causes high values of the daily average $cos\varphi_{cp.}$ (Fig. 1). It varies widely, with values of the order of 0.84 indicating insufficient compensation power in individual units of the power supply system or inefficient KB management in individual units of the power supply system.

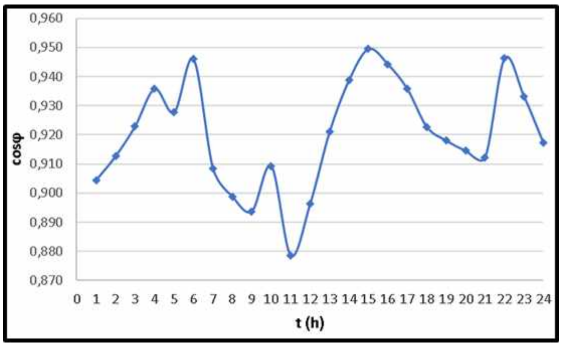


Figure 1

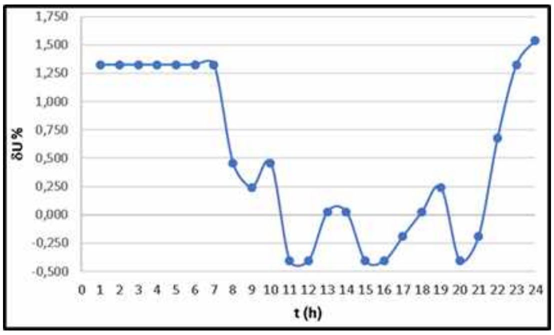


Figure.2

The deviation of the voltage δ of 20kV busbars, presented as average values in a 24-hour section, changes in the range (-1.273 ÷ 2.48)% (Fig. 2).

[4] Gyurov, V., Hr. Panchev, G. Ivanova, Realization of theoretical and experimental studies of light technical parameters of LED light sources for navigation ship lighting, IX Scientific Conference "EF2017", TU-Sofia Yearbook, Volume 68, Book 1, Pages 155-162, ISSN 1311-0829

Navigational lights are one of the main technical means to ensure the safety of navigation. Calculation of their location, mode of operation and light technical parameters are regulated by the STCW convention and IMO standards. The implementation of LED technology for light sources poses questions related to the optimal design and manufacture of this type of light sources. The report presents theoretical and experimental studies of the light technical parameters of LED based navigation lights for vessels. The results may be of interest to marine professionals, lighting engineers and LED lighting manufacturers on how to design specialist light sources.

Meteorological visibility is the best distance at which a black object of suitable size can be seen and recognized by day against the horizon or, in night observation, can be seen and recognized if the general illumination is raised to daytime levels. By definition, the relationship between meteorological visibility (V) and throughput is:

$$V = \frac{\ln 0.05}{\ln T_{м}} x d_{u}$$

Where: V is the weather visibility in nautical miles, Tm is the atmospheric transmittance (dimensionless) per nautical mile, d is the transmittance [dimensionless] per nautical mile.

In the case of light appearing as a point source, the light range D is defined as the maximum distance at which light can be seen, determined by the light intensity I of the light, the meteorological visibility V and the "required illuminance" (formerly known as the threshold) Et in the eye of the beholder. At this distance, the illuminance E in the eyes of the observer is reduced to the value Et:

$$I = (3.43 x 10^{6}) E_{t} D^{2} (0.05)^{-\frac{D}{V}}$$

Where: I is the light intensity, Et is the necessary illumination in the eye of the observer, D is the distance in nautical miles, V is the meteorological visibility in nautical miles. Prevailing visibility conditions vary from geographic area to area. Therefore, this should be taken into account when choosing a light. The choice should be based on a practical value of light range, not a nominal range.

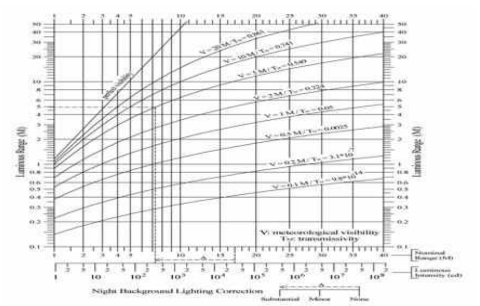


Fig. 1 illustrates the Luminescent range - at night

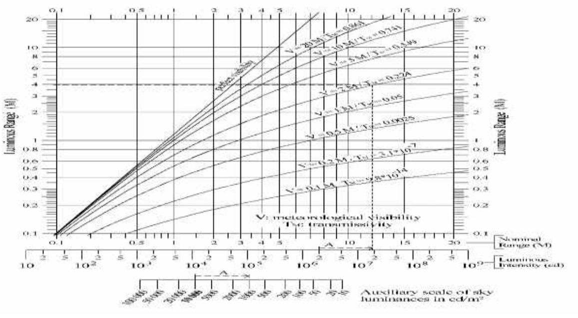


Fig. 2 illustrates Luminescent range - during the day

[5] Donev, I., G. Ivanova, V. Gyurov, R. Kirov, Research and analysis of energy efficiency in passenger ships, International Scientific Conference "Unitech 2018", Proceedings Volume I, pp.116-120, ISSN 1313-230X

To assess the energy efficiency in buildings, the indicators defined by standard EN 15232 "Energy performance of buildings - Impact of Building Automation, Controls and Building Management" can be used, which is also applicable to ship indoor spaces. The requirements for lighting systems regarding their energy efficiency are defined by standard EN 15193 "Energy performance of buildings - Energy requirements for lighting". The specific annual indicator LENI (Lighting Energy Numeric Indicator) is used as an indicator.

$$LENI = W_{ОСВ,ЕЛ} = \frac{W_L + W_P}{A}$$

where: A- total unfolded illuminated area of the premises [m2]; WL - energy consumed by the lighting system to provide the necessary light environment [kWh/year]; WP - parasitic energy related to the losses in the battery elements of emergency and evacuation lighting and the stand-by functions of the lighting control system [kWh/year]. Their calculation is carried out according to the following formulas:

$$W_L = \sum\left[\left(P_N.F_C\right).\begin{bmatrix} t_D.F_0.F_D + \\ + t_N.F_0 \end{bmatrix}\right]/1000 \quad (15) \qquad W_P = \sum\begin{bmatrix} P_{PC}.(t_Y - t_D - t_N) + \\ + P_{EM}.t_{EM} \end{bmatrix}/1000 \quad (16)$$

where: P_N - installed power [W]; P_{PC}- total parasitic power [W]; P_{EM} - total charging power evacuation and emergency lighting [W]; $t\gamma$ - annual time period 8760 hours; t_D - time period for operation of the illuminators in the bright part of the day [h]; t_N - time period for operation of the illuminators in the dark part of the day [h]; t_{EM} - time period for charging the emergency and evacuation lights [h]; F_C - factor depending on the use of the installed power, F_C=(1+MF)/2, F0 - factor depending on the presence (absence) of people, F_D - factor depending on the use of natural lighting.

Fig. 1. Specialized LED floodlight for marine application model FL40, IP67

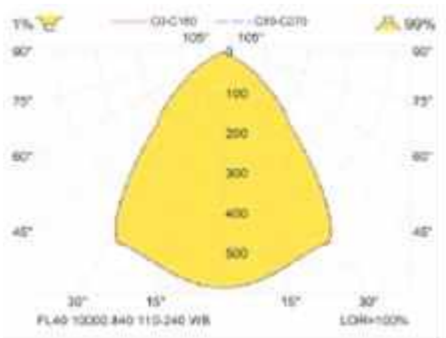


Fig. 2. Light distribution of an illuminator FL40

Figure 1 shows a view of an illuminator from the range of illuminators used, and Figure 2 shows its light distribution. During the reconstruction, the normative requirements defined in IACS No. 132/2013 - International Association of Classification Society were observed. The work presents an innovative complex approach to the assessment of the energy efficiency index EEDI, expanding its functional scope by taking into account the influence of the quality of electrical energy, optimizing the modes of HVAC systems, cooling and lighting systems. In this way, the consumption of the primary energy carrier - marine fuel - is more fully and adequately assessed.

[6] Parushev, P., D. Dimitrov, G. Ivanova, P. Deneva, S. Angelov, Control of the ventilation of cargo platforms of ferries with PLC, magazine "Mechanics, transport, communications", issue 16, volume 3/2 , pp. 68-74, 2018, article #1725, ISSN 1312-3823

The report presents an engineering solution for a ventilation control system on cargo platforms of Ro-Ro ships and ferries. With the development of water transport, the share of specialized ships for the transportation of cars and trucks gained a significant share. This is determined by the specifics of the production of new cars, distributed in certain geographical areas and providing the opportunity to saturate the global markets of certain brands of vehicles. For other destinations, the transport of TIR truck loads has proven to be profitable and thus transport corridors and specialized vessels have been established for this. The control system is implemented with a programmable logic controller. Fulfilling the requirements for industrial management, a reasoned choice of PLC modification was made. Possibilities for analyzing the states of the controllable parameters are provided. The types of input signals are defined. Controller inputs and outputs are allocated and initialized. The actions of the system elements are described by the verbal algorithm. The synthesized block diagram describing the control process and the observable control parameters is presented. The specific screen messages are defined.

In general, ventilation is a set of measures that maintain the cleanliness and mobility of the air. Fresh air enters the room or working area with a flow rate that is sufficient to satisfy the needs of people and the ongoing technological process. The main function of ventilation is to provide an air environment, in the place of residence, that does not contain harmful gases, vapors and dust with more than certain permissible concentrations. A schematic diagram of the movement of air flows is shown in Fig. 1, where the engineering solutions for two of the decks are given . During the operation of internal combustion engines, toxic substances dangerous to humans are emitted. Ventilation is required to remove the products of the combustion process and discharge them into the atmosphere.

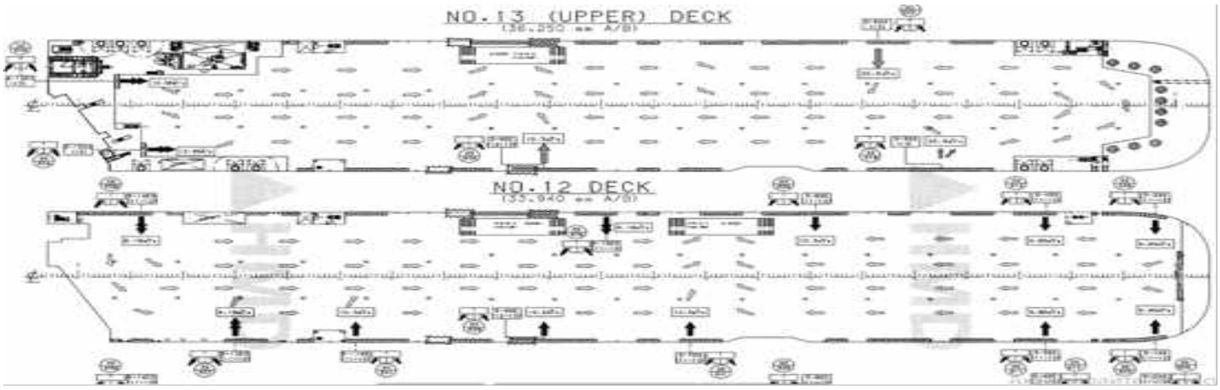


Fig.1 Movement of air current

The chosen Easy 512-DC-TC controller is suitable for programming to control two-speed electric motors, thanks to its built-in function blocks, which are part of the advanced functions of the "Easy" series controllers. In case of forced ventilation, suction ventilation is mandatory. The air intakes are evenly spaced throughout the space. The air is sucked 50% from the upper and 50% from the lower area of the deck (h from the floor 0.3m). For decks for more than 100 passenger cars or 50 buses, at least two suction fans with the same characteristics are provided. The presented software solution can be modified depending on the work volume of the decks, the type of sensors and the need for hierarchy of the system in terms of management and control levels of ship automation.

[7] Kirov, R., G. Ivanova, Analysis of lighting technical and electrical requirements and characteristics of ship lighting, XV National Conference with international participation, BulLight/Bulgaria light 2014. Sb. reports, pp. 262-264, ISSN 1314 – 0787

The ship is a floating city in constant motion. The development of shipping is related to the implementation of new and diverse technologies in all nodes and units of the ship's equipment, including the artificial lighting system. Maritime transport has an international nature, which is why lighting specialists are obliged to comply with a large number of rules and requirements, very often insufficiently well defined, but at the same time extremely strict and regulated by various authorities.

In the ship's rooms, the possibilities for creating the maximum impact of the light-colored interior during the short-term stay in them are significantly smaller than in the terrestrial light environment. The main reasons for this are the restrictive possibilities to achieve greater height in the premises, the limitations in the configuration and geometry of the premises and the small possibilities of using natural lighting. Ship lighting systems, despite the architectural limitations, make it possible to build all artificial lighting systems - general lighting system; emergency lighting system; local lighting system (local) and combined lighting system.

The schemes for building the ship's energy systems are very different. When using star/delta circuits for the power transformers, satisfactory operation is achieved even in the presence of case short circuit. Many ships use the star-delta system (440/220 V). There are single-wire (the second wire is the ship's metal hull with a potential of 24 V), two-wire, three-wire and four-wire (delta / star with isolated star center) power supply systems. Ship lighting is constantly developing, but its rapid development is expected in the coming years with the use of modern sources (LED) and optimized lighting for a specific purpose.

In the design practice, new adapted methods for calculating the light-color environment in ship's rooms and decks are yet to be created. With regard to the regulatory framework, criteria and principles for standardization are yet to be formulated, which take into account both the quantitative indicators and the characteristics related to the quality of ship lighting.

Ship lighting systems, despite the architectural limitations, make it possible to build all artificial lighting systems - general lighting system; emergency lighting system; local lighting system (local) and combined lighting system. And here there is the need to measure and calculate horizontal illuminance, vertical illuminance, integral light values, natural illuminance coefficients, light flux utilization coefficients, etc. In addition to norming on quantitative indicators, it is necessary to create scientifically based norms on qualitative indicators of ship lighting and to establish the relationship between them.

[8] Ivanova, G., Gyurov, V., Assessment of Energy Efficiency of a Motor Yacht Depending on Routes and Sailing Area, IOP Conference Series: Materials Science and Engineering, DOI 10.1088/1757-899X/1216/1/012004

The report presents an analysis of luxury charter yachts which are a specific class of vessels that, in order to meet the schedules and increased requirements of the owners regarding the luxury of the services offered, have relatively high energy consumption for their gross tonnage, compared to other passenger ships. The study focuses on the analysis of energy efficiency of luxury yachts by calculating the energy efficiency index (EEDI). This involves comparing different parameters that affect the value of the EEDI and can lead to energy savings. The report presents theoretical and experimental studies of the energy costs of a 70-meter luxury yacht for charter trips. With the use of the design data of the ship's electrical equipment at different operating modes, at different routes, under different conditions, dependences for analysis of the optimal modes of movement are obtained, which leads to the realization of maximum savings of electricity and primary energy. We will do an experimental study of the relationship between the optimal speed of a luxury motor yacht, the route, energy costs and EEOI (Energy Efficiency Indicator), which means "optimal yacht speed", which improves operational energy efficiency [1], [2], [3]. The yacht with traditional propulsion, with a length of 70.54 m, class LR X 100 A1 SSC, G6, XLMC, UMS is considered. Main engines: 2xCaterpillar 3516B (2x1825kW @ 1800 rpm), generators: 3 x 200Kw, max. speed 17Kn, total power 4894 hp. The capacity of the fuel oil tanks is 204,000 l.

The percentage of the different operating modes in relation to the total working period are shown in Figure 1. A characteristic feature of luxury yachts is the significantly longer period in port or at anchor compared to the periods of sailing. The maintenance costs of the main diesel engines and generator sets for the given yacht are shown in Figure 2. An essential feature is the significantly higher hourly usability of the generators compared to the main engines. This is determined by the longer stays in port. The hourly emissions for the different operating modes are then combined with the operating profile, thus relating to the annual operating hours of the set mode. In this way, the total annual CO2 emissions are quantified.

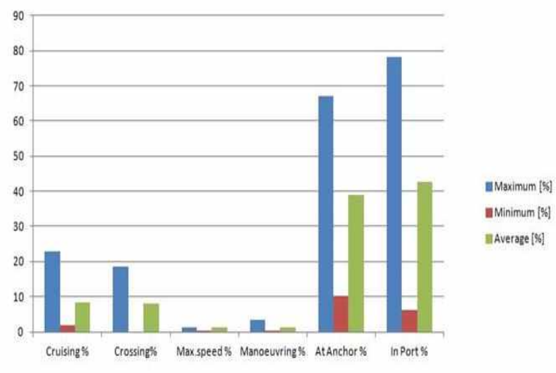


Fig. 1. Yacht operating modes based on maritime trafic

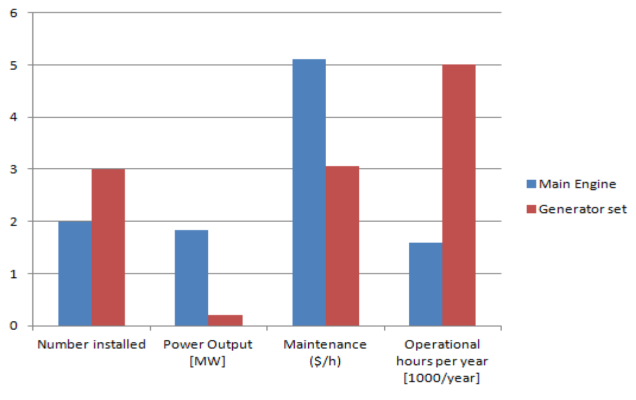


Fig.2. Maintenance costs of the main diesel engines and generator sets for the yacht

The report examines the specifics of energy consumption of luxury yachts for charter trips. The definitions for Energy Efficiency Design Index (EEDI) and their applicability for luxury yachts are considered. The results show quantitative dependences on the ratios between the different operating modes, energy consumption and maintenance costs. The significant difference between duration of regimes "sailing-harbour" shows the need for in-depth study of issues related to energy efficiency and environmental impact of yachts for various operating modes.

[9] Gyurov, V., Ivanova, G., Study on Technical Solutions for Shore Power Supply of Motor Yacht, IOP Conference Series: Materials Science and Engineering, DOI 10.1088/1757-899X/1216/1/012005

The report presents an analysis of modern technical solutions for shore power supply of a specific class of passenger ships - luxury yachts for charter trips. The design data of a motor yacht in its different operating modes are considered, as well as the energy mix related to the fuel consumption at shore supply of the yacht during its stay at the port. The use of modern technical systems for shore supply includes the application of specific frequency converters, through which compatibility between the different voltage standards and the frequency for different shore power supply systems is realized. The costs of onshore power, compared to those of marine fuel, can be calculated from the current prices of onshore electricity and the energy produced from its own generators. The analysis of the basic design data of the motor yacht and the assessment of the energy costs on board, fuel economy and emission reductions will provide a clear answer to the advantages of the power supply from the shore of the vessel. Modern luxury yachts reach lengths up to 90 m, tonnage up to 2500 GT, speed up to 20 kn and passengers and crew up to 50 people. These parameters place the yachts in the class of small passenger ships, but with increased requirements for the comfort of the environment. For this reason, it is necessary to use powerful propulsion systems in the range of 2-4 MW and machinary equipment with high energy consumption in the range of 0.5-1MW.

The basic standards for the on-board power supply system of yachts are: European – 400/230V 50Hz; USA – 460/265V, 240/120V 60Hz; China 380/22V 50Hz; Japan 220/110V 60Hz. This shows the existence of significant differences in voltage levels and frequencies for different countries. Another way of converting voltage and frequency for shore power involves the use of specialized galvanically isolated inverters (Figure 2). For this purpose, it is necessary to use an isolation transformer with sufficient power to transfer the necessary electricity. The advantage of the method is that due to the absence of electrical machines, greater energy efficiency and lower additional losses can be achieved.

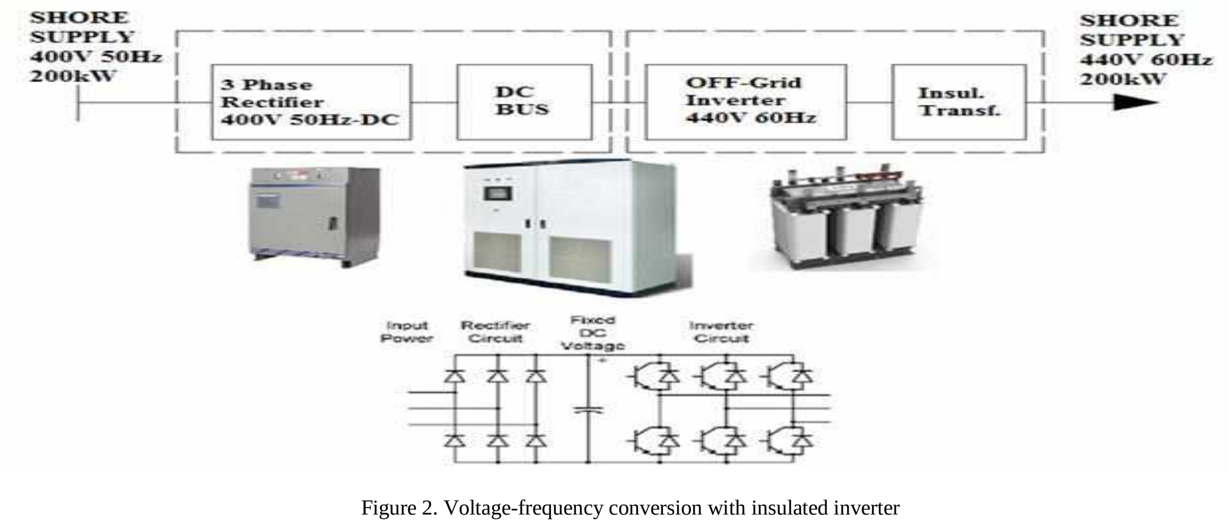


Figure 2. Voltage-frequency conversion with insulated inverter

This type of solution involves the use of a specialized multi-stage isolation transformer (Figure 3). The initial connection of the windings is carried out with current-limiting resistors, as the stages are determined manually or with the use of a programmable logic controller. This solution is widespread for yachts whose electrical equipment is not sensitive to changes in feed frequency. An analysis of a shore-type on-board electrical power system for a GT1560 super yacht is presented.