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INNOVATIVE TECHNOLOGY OF REACTIVE ENERGY COMPENSATION FOR IMPROVING SHIP'S EEDI

Global warming, caused mainly by greenhouse gas emissions, prompted the world community to sign the Kyoto Protocol in 1997. The regulation of greenhouse gas emissions and related economic activities have ceased to be the prerogative of national authorities and become the subject of international agreements. Due to the largest air pollutants from the world's oceans are ships, the International Maritime Organization (IMO) adopted in 2003 Resolution A.962 (23): "IMO Policy and Practice on Reducing Greenhouse Gas Emissions from Ships", and determined that it is possible to achieve significant reductions in greenhouse gas emissions from ships through the adoption of technical and operational measures. This suggests that ships need to be more energy efficient, operating conditions are well thought out, and a clear methodology for assessing ships in terms of greenhouse gas emissions. The estimated energy efficiency factor of the vessel is the Energy Efficiency Design Index (EEDI), which is calculated according to a formula developed by IMO with the possibility of improving it through innovative energy efficient technologies. Since the entry into force of the IMO resolution, mainly work is underway to improve the EEDI based on existing innovative technologies in various categories. Progress does not stand still, but the list of new innovative technologies for energy efficiency categories has not expanded.

The presented article is devoted to the development of innovative technology of category C, to improve the energy efficiency index of the ship structure. This technology can used on its own, as well as an additional tool to extend the capabilities of existing energy efficiency technologies. In addition, the innovative technology for reactive energy compensation allows improving the EEDI and environmental performance of already operating vessels, through their simple modernization during planned repairs.

Keywords. *Energy Efficiency Design Index (EEDI), innovative energy saving technologies, power factor correction.*

Introduction. The shipping industry has come under attention of the global community due to a lot of carbon emissions produced by the ships. Hazardous emissions going to increase more than 75% during the next 15 years. However, CO_2 emissions from shipping are possible significantly reduced with increasing the efficiency of a large number of the ships. With the aim to improve the environmental friendliness operations of the ships under continuously increasing costs of energy resources, underlie in requirements set by the International Maritime Organization (IMO) in Annex VI of the MARPOL Convention in relation to the design coefficient of energy efficiency. According to these requirements, most new vessels should be 10% more efficient from 2015, 20% more efficient from 2020 and 30% more efficient from 2025 [1].

The MARPOL Convention, in paragraph 4 of its Annex VI, introduces two mandatory mechanisms as an energy efficiency standard for marine ships. These are following regulatory mechanisms: an Energy Efficiency Design Index (*EEDI*) for new ships and a Ship Energy Efficiency Management Plan (*SEEMP*) for all ships.

EEDI is a coefficient indicating the vessel's energy efficiency and it is define as the ratio of carbon dioxide amount produced to the amount of carried cargo and the traveled miles. The calculations are produce for the specific operating conditions of the vessel. The goal of IMO is to make ship technologies more energy efficient by setting limits on this index. Thus, *EEDI* is a technical standard target applicable for new ships [2].

Shipbuilders able to select technologies that meet *EEDI* requirements for a specific ship design. A decline in the *EEDI* ratio over time will lead to more energy efficient ships.

Moreover, IMO has additionally introduced a voluntary energy efficiency operating indicator (*EEOI*) scheme. The main purpose of this coefficient is to use it as an effectiveness indicator of monitoring in shipping [1-3].

Publications analysis. For *EEDI* determination, the concepts of *achieved EEDI* and the *required EEDI* were introduce, and a formula was develop:

$$EEDI = \frac{\left(\prod_{j=1}^{M} f_f\right) \cdot \left(\sum_{i=1}^{nME} P_{ME(i)} \cdot SFC_{ME(i)} \cdot C_{FME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}\right)}{f_i \cdot f_c \cdot f_I \cdot Capacity \cdot V_{ref} \cdot f_W} + \\ + \frac{\left(\left(\prod_{j=1}^{M} j_i \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_i \cdot f_c \cdot f_I \cdot Capacity \cdot V_{ref} \cdot f_W}, \quad (1)$$

where *SFC* – is the specific fuel consumption of the engine [g / kWh]. *CF* – is the dimensionless conversion factor between engine fuel consumption (g) and CO_2 emissions (g), determined by the carbon C content in a particular fuel [g CO_2 / g fuel]. $P_{ME(i)}$ – is the power indicator of the main engine (ME) equal to 75% of its nominal power minus the power consumed by the shaft generator (if any). P_{AE} – is the required power of auxiliary engines (DG) to provide electricity at the maximum load of the vessel. P_{PTI} – is the indicator equal to 75% of the nominal power consumed by each propeller motor, taking into account mechanical losses in it and excluding losses in the generator. P_{AEeff} – is the indicator of reduction of electrical energy due to the use of efficient technologies (use of waste heat recovery from the main engine). P_{eff} – is the indicator of the decrease in the main engine power due to the application of effective innovative technologies in the propulsion unit (PU) at 75% of the main engine power. *fi* – is the factor of the vessel's tonnage, meeting the requirements for limiting the vessel's tonnage, for example, the requirements that apply to ice-class ships. *fj* – is the corrective factor that takes into account the specific design of ship elements, for example, ice-class ships. *fw* – is the dimensionless coefficient that takes into account a decrease in speed at a certain unfavorable state of the sea, depending on the height and frequency of the wave, as well as on the wind speed. *feff* – is the coefficient of availability of each innovative technology. *Vref* – is the speed of the vessel measured in deep water taking into account the tonnage (DWT / GT depending on the type of vessel) in accordance with the above charter (knots). More details about the coefficients can be found in [3,4].

The *EEDI* calculation formula developed by IMO can represented in the separate blocks (products) form, consisting of a large number of coefficients are responsible for the energy efficiency of the vessel individual components. There are such units as main engine, ship's hull, ship's propeller, ship's generators and auxiliary machines. Certain coefficients in the formula take into account the availability and use of highly efficient technologies to improve the energy efficiency of a particular unit. The calculation the energy efficiency coefficients of different units are make individually, taking into account their characteristics. That’s why, all innovative energy efficient technologies are categorized into categories *A*, *B* and *C* depending on how they affect to the *EEDI* formula. In turn, innovative technologies for improving energy efficiency of categories *B* and *C* are divided into two subcategories: categories *B-1* and *B-2* and categories *C-1* and *C-2*, respectively.

Category *A* includes technologies that directly affect to the speed / power ratio of the vessel, that causes changes of combination between thrust and / or vessel speed. Such technologies, for example, at a constant vessel speed, lead to decrease the power of the power plant, and, opposite, at a constant power of the power plant, they lead to increase the speed of the vessel [22].

Category *B* uses technologies that reduce the power of the power plant at the same vessel speed V_{ref}, but do not generate electricity, and the saved energy is counted as P_{eff}. The technologies used in this category are divided into those that can be used at any time – technologies of category *B-1*, so the availability factor f_{eff} will be equal to 1. An example is the technology of air lubrication of the ship's hull. And technologies that can be used at full capacity only in limited conditions and periods – technologies of category *B-2* – the availability factor f_{eff} should be less than 1. For example, wind power [24].

Category *C* is a category for energy efficient power generation technologies. The saved energy is calculated as P_{AEeff} [6,7].

Similar to categories *B-1* and *B-2*, categories *C-1* and *C-2* are categories in which energy efficient technologies for electricity generation can be used at any time during operation, for example, waste heat recovery and technologies, which can be used only at full capacity under limited conditions, such as solar energy. For *C-1*, the availability factor f_{eff} should be considered as 1, and for *C-2* – f_{eff} should be less than 1 [16].

Waste heat recovery technologies increase the efficiency of using the energy generated by the combustion of fuel in the engine by recuperating thermal energy from exhaust gases, cooling water, etc., thereby generating electricity. There are two methods of generating electricity using heat recovery technologies: 1) a method of recovering thermal energy with a heat exchanger and driving a heat engine, which turn drives in electric generator; 2) a method of direct drive of electric generator using a power turbine of an internal combustion engine turbocharger. In addition, a waste heat recovery system can combines both of the above methods [6].

Problems and purposes formulation. As can we see from the literary sources analyze, a lot of attention is paid by manufacturing companies and scientific institutes in the field of shipbuilding to improving the energy efficiency of ships through technical improvements and increasing the efficiency of units, hulls and systems of ships. Technologies are being developed and implemented for the treatment of exhaust gases, their utilization and additional power take-out [4,15,20]. Energy efficient and, as a rule, expensive electric drives are design, maintenance and repair of which require large financial costs during operation. At the same time, unfortunately, not enough attention is paid to the quality of electricity, throughput of the ship's network and its improvement. There is not a single technology that is aimed to improving the listed parameters in the *C* category [21]. In addition, innovative technologies of *C* category are limited in use, or cannot be applied at all in partial or maneuvering modes of the vessel. For example, the utilization of waste gas heat cannot be used when the vessel is in the port, in the roadstead, or when maneuvering, because the amount required heat for producing the electricity is varies with the load, or is completely absent. Therefore, generating electricity is not possible. At the same time, it is possible to compensate the reactive energy in any ship operating modes.

When the ship's power plant is calculate, the power factor of electrical equipment is taken into account at its rated operation (load). Therefore, the estimated cos (φ) is within 0.75~0.9, which meets the requirements of regulatory documents and classification societies. However, the calculations do not take into account the modes of partial loads. In mentioned modes, asynchronous motors, such as the prevailing electric motors in marine drives, operate with a reduced power factor, which in turn decrease the overall power factor of the power plant [8].

The examples of marine electric drives operating with low cos (φ) are drives of steering gears, hydraulic mooring winches, electric drives for hatch cover opening hydraulics, thrusters, compressors of centralized air conditioning systems, electro-hydraulic cargo cranes, ballast pumps, and power transformers for refrigerated containers and ship consumers etc. Where are partial load modes of electric drives come from. To answer this question, it is necessary to study the features of

ship's operation, into account the seasonality of cargo turnover, seasons, weather zones and technical equipment.

The hydraulic steering gear uses pressurized hydraulic oil to shift the steer. Pumps are used for pressure rise, driven by asynchronous electric motors. For the overwhelming time, the oil circulates through the system without any works. Consequently, the electric motor is not fully loaded, and therefore its cos (φ) is in the range of 0.5~0.7. Electro-hydraulic cranes work according to a similar scenario. As a rule, on cranes, one electric motor drives 3 hydraulic pumps that lift the hook, boom and turn the tower. Due to these actions must be performed simultaneously, and then the power of the electric motor is selected accordingly to full load. However, as practice shows, the use for three simultaneous actions is not always necessary. And it is worth considering the fact that when lowering a load or an empty hook, the load on the electric motor is not rated. All these circumstances reduce the power factor of the drives and the power plant as a whole.

A separate issue is to consider the factors that reduce the cos (φ) on container ships with a high-voltage power plant. As a rule, these are modern container ships of large displacement and a large number of refrigerator containers. The container is powered with 440 voltage, which is significantly lower than the voltage generated by the power plant. For these purposes, step-down transformers are used. When the vessel is partially loaded with refrigerator containers, the transformers remain unloaded and the overall power factor of the power plant decreases.

Research. Innovative technologies for waste heat recovery and converting it into electricity are aimed to reduce the electricity generation with auxiliary engines. This leads to decrease the amount of consumed fuel and the emission of pollutants into the atmosphere.

An alternative way to improve the ships energy efficiency of *C* Category is the increasing the power factor for power supply system by compensating for reactive energy. Increasing the energy efficiency is possible due to artificially created conditions for increase the maximum active load of ship generators.

A visual representation of reactive power compensation, explained by an example of a simple AC circuit with reactive elements, shown in Fig. 1. Suppose that before compensation, the consumer had active power *P*, respectively, current *I*a (OB segment in Fig. 1.b)) and reactive power from inductive load Q_1 with the corresponding current I_L (BA segment). The total power S_1 corresponds to the vector I_{load} (segment OA). Power factor before compensation is cos (φ_1). The compensation vector diagram is shown in Fig. 1.b).

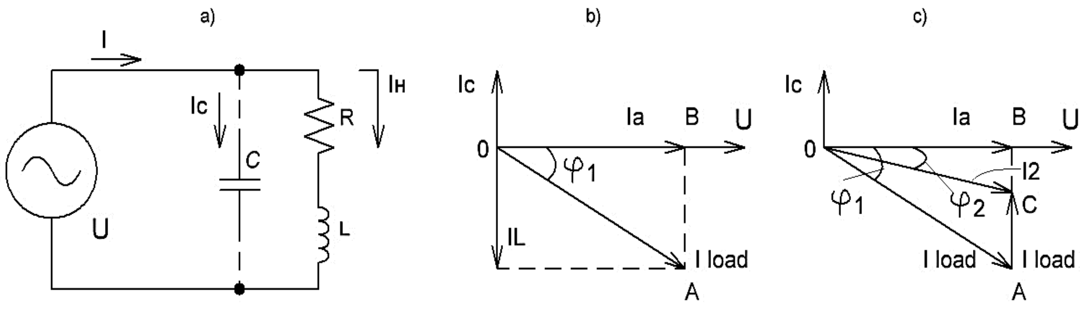

Fig. 1. Capacitive reactive energy compensation

After connecting a capacitor with power Q_c (current I_c) in parallel with the load, the total reactive power of the consumer will be Q_1-Q_c.

The phase angle will decrease from φ_1 to φ_2 and the power factor will increase from cos (φ_1) to cos (φ_2). The total power consumption for the same active power consumption *P* (current I_a) will decrease from S_1 (current I_{load}) to S_2 (current I_2), (OC segment). Consequently, it is possible to increase the network throughput at active power with the same wire cross-section due to compensation.

With changing the capacitance value of the compensating capacitors, it is possible to compensate the reactive current on the active-inductive load of consumers fully [9-10, 12]. Fig. 2 shows how the total current consumption can be reduced and the full load power factor increased to one.

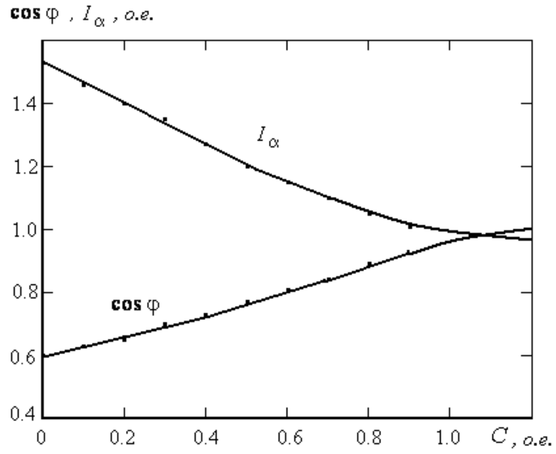

Fig 2. The total current and power factor dependence from the capacity of the compensating capacitors.

As mentioned above, incomplete loading of electric drives, as well as maneuvering modes of the ship, when an additional generator is required, regardless of the power consumption, significantly reduce the overall power factor of the power plant.

Generators are protected by maximum current, not by maximum power. When the power factor drops to 0.5, the generator can produce about 50-60% of active power, which can be converted into mechanical work. The rest of the generator load will be reactive power, which does not perform work, but is aimed to electromagnetic fields creation, supply wires, windings of electric motors and generators heating. Therefore, an additional generator has to be started to provide the required active power. This leads to additional energy costs and deterioration of the ship's environmental friendliness.

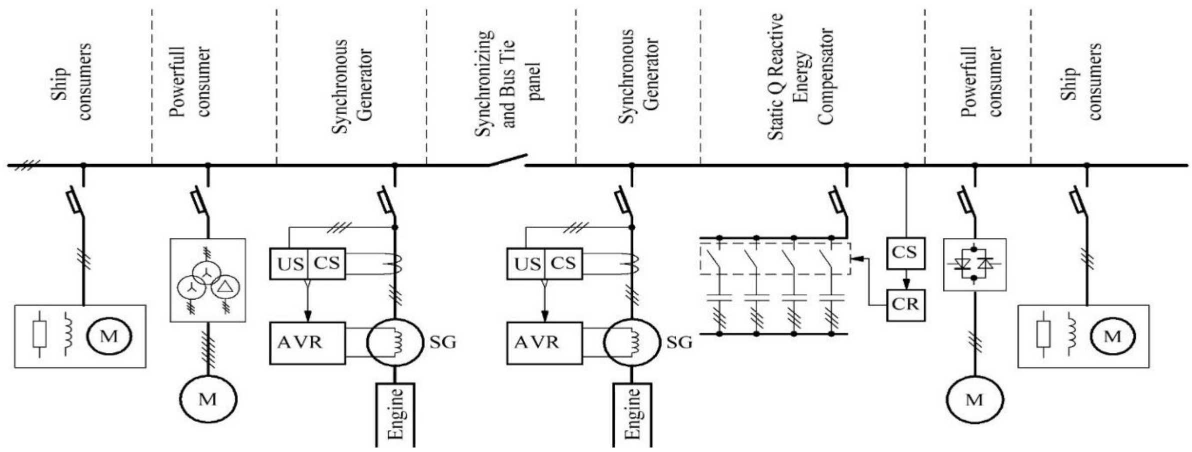

Fig. 3. Ship's power system with a capacitor's reactive energy compensator

Fig. 3 shows a vessel power system with a capacitor's reactive energy compensator (RECD). This arrangement of the power plant allows increasing the power factor at any time, even in maneuvering and cargo modes. In this case, the required reactive energy is generated by the compensator, and practically does not affect the generator. The power factor cos (φ) of a ship power

plant can be maintained equal to one or close to one. More details on the compensation of reactive energy in ship power systems can be found in [9,11].

The ship's electrical power plant of *CAP SUN ARTEMISSIO* consists of 5 generators HSJ7 917-10P type. The prime engines type is *HUYNDAI HIMSEN* 9H32 / 40. Alternator voltage *U* is 6.6

kV, alternator current I is 539.9 A, full power S is 6171.43 kVA, active power P is 4320 kW and power factor cos (φ) is 0.7. Fig. 4 shows the specification of these generators.

SPECIFICATION	
TYPE	HSJ7 917-10P
OUTPUT CAPACITY	6171.43 KVA
RATING	CONTINUOUS
PHASES,WIRE,CONN	3 Φ, 3 W, Y (DAMPER WINDING)
VOLTAGE	AC 6600 V
CURRENT	539.9 A
FREQUENCY	60 Hz
POLES	10 P
SPEED	720 RPM
POWER FACTOR	0.7 LAGGING
GD² / J	4220.0 Kg.m² / 1055.0 Kg.m²
ROTOR WEIGHT	8258 Kg
TOTAL WEIGHT	22.5 ton
CHARACTERISTICS	

Fig. 4. Specification of synchronous alternator type *HSJ*7 917-10P

As seen from the presented specification, the alternator parameters were determined experimentally with an inductive load and a power factor cos (φ) is 0.7.

If the power factor drops to 0.5, the maximum power that the generator can take over is 3082.3 kW. Which is 71% of full power. It would seem that the power reserve is 29% - 1251.41 kW, and the generator is already delivering the maximum current. *CAP SUN ARTEMISSIO* is capable of transporting 2,100 reefer containers. The rated power of each container is 6.5 kW. At the same time, it is possible to load 863 containers into the hold, and 1237 containers on the deck. Taking into account the loading factor and the nature of the cargo, the number of simultaneously operating containers is 837 on the deck and 863 in the hold, respectively. The total load of refrigerated containers is (837 + 863)·6.5 = 11050 kW. Refrigeration containers power supplies is carried out by step-down transformers, the primary winding of which is connected to the 6.6 kV main switchboard, and the secondary one supplies one of the distribution boards for ref. containers. The total number of transformers is 42. Of these, 26 transformers with a capacity of 630 kVA, 6 pcs. - 670 kVA, 5 units - 550 kVA, 4 units. - 500 kVA and 1 pc. – 750 kVA. In addition, two step-down transformers, each 4500 kVA, also power the 440 V low-voltage main switchboard.

As seen from the load analyze table, Table 1, in running mode with a full load of refrigerated containers, the power consumption is 13,900.4 kW. For cover this load, 4 generators from 5 are in service. That, with the condition of the permissible generator load factor is:

$$P_{\text{net}} = P_{Gen} \cdot k_3 \cdot m \quad (2)$$

$$P_{\text{net}} = 4320 \cdot 0.85 \cdot 4 = 14688 \text{ кВт},$$

where P_{net} is the total power of the network, P_{Gen} is the power of 1 generator with cos (φ) = 0.7, k_3 is the coefficient of permissible load of alternator (0.8~0.9)·P_{nom}, m is the number of operating generators. However, if we raise the cos (φ) to a value of 0.92~0.98, then the total load that the generators can take on will be: 21772.8 kW.

According to calculations, by increasing the cos (φ) of the network to a value of 0.98, it is possible, for a specific case, to take out of operation one diesel generator. Regarding to the passport data of the drive diesel engine, its daily fuel consumption is 16.495 tons of heavy fuel. Sea passage from the ports of China to the ports in Mediterranean Sea of Europe takes from 17 to 27 days, depending on the set speed, weather conditions, currents and the technical condition of the vessel. From the above, it follows that fuel savings can range from 280.415 to 445.365 tons. According to IAA "Sea News" bunkering in the port of Rotterdam with *VLSFO* 0.5% low-sulfur fuel will cost $ 527 per ton, in the port of Singapore – $ 646 per ton, in the port of Piraeus – $ 622 per ton. It is easy to calculate that for the passage from ports of China to ports of Europe, the ship can save from $ 147,800 to $ 288,000.

Table 1

CAP SAN ARTEMISSIO load analyze table fragment

ELECTRIC LOAD ANALYSIS
SUMMARY SHEET — ***(FOR HULL NOS. 2521-26)*** — page 1

CLASSIFICATION	NORMAL SEA GOING	AT PORT IN/OUT WITHOUT THRUSTER	AT PORT IN/OUT WITH THRUSTER	AT LOAD/ UNLOAD	AT HARBOR	AT EMERGENCY BLACK OUT	AT EMERGENCY FIRE
REEFER CONTAINER LOAD	11,050.0	11,050.0	11,050.0	11,050.0			
PREFERENTIAL LOAD	12,638.6	13,118.2	17,534.4	12,825.6	583.5		
TOTAL LOAD (WITH REEFER CONTAINER)	13,900.4	14,734.6	18,653.2	13,762.1		129.5	148.1
(WITHOUT REEFER CONTAINER)	1,899.0	2,733.1	6,651.7	1,760.7	1,228.5		
(AFTER PREFERENTIAL)	1,261.8	1,616.4	1,118.7	936.5			
NO. OF GENERATOR (W/ REF CONTAINER)	4 x D/G	5 x D/G	5 x D/G	4 x D/G		1 x E/G	1 x E/G
(WITHOUT REEFER CONTAINER)	1 x D/G	1 x D/G	2 x D/G	1 x D/G	1 x D/G		
(AFTER PREFERENTIAL)	1 x D/G	1 x D/G	1 x D/G	1 x D/G			

Reefer container on deck (FEU)	1237	837			6.50	1.00	1.00	5440.5	5440.5	5440.5		PT2
Reefer container in hold (FEU)	863	863			6.50	1.00	1.00	5609.5	5609.5	5609.5		PT2

In addition to fuel save, stopping the one of generators can reduce NOx emissions, thereby improving the ship's operating index and, consequently, the ship's environmental friendliness. For a specific vessel, based on the data on tests of a drive diesel engine, Figure 6, we calculate how much NOx emissions were reduced. The engine operating time for the passage from the ports of China to the ports of the Mediterranean Sea of Europe is with 17 days of passage is 24 – 17 = 408 h and with 27 days of passage: 24 – 27 = 648 h.. Taking into account the maximum load of the generator 0.85, and the drive diesel 0.75, the amount of emissions was reduced by P_{gen} k_3. NOx Chrab = 4320 0.85 · 9.26 · 408 = 13873109.76 (g) ~14 tons, and for 27 days of transition – 4320 · 0.85 · 9.26 · 648 = 22033762.56 (g) ~22 tons.

Table 2

NOx emission table for *HUYNDAI HIMSEN* 9H32 / 40 drive diesel engine on different loads

	Based on Parent engine						Based on calculation 1)		
Load (%)	NOx, actual (g/kWh)	Ha or Hsc(*) (g/kg)	Khd(**)	Ta (℃)	Tsc, actual (℃)	Tsc,ref (℃)	Tsc, max. (℃)	Khd(***)	NOx, max. (g/kWh)
100	8.39	2.13	0.881	13.1	53.0	53.0	55.0	0.885	8.43
75	9.26	2.05	0.881	13.6	52.0	52.0	55.0	0.888	9.32
50	9.68	2.04	0.882	14.2	51.0	51.0	55.0	0.891	9.77
25	10.29	2.08	0.886	15.6	49.0	49.0	55.0	0.899	10.43
10	13.53	2.12	0.889	16.8	48.0	48.0	55.0	0.905	13.74
D2 (g/kWh)						**9.55**			**9.64**

With complex reactive energy compensation, the availability factor feff is taken equal to 1, due to the possibility of using the compensation device at any time and under almost any conditions. RECD does not generate electricity on its own; therefore, it is not possible to calculate the amount of electricity produced, as is done to calculate the energy efficiency of an exhaust gas recovery system. However, if compensated the reactive load, it is possible to load up the alternator with an active one. And, at a certain moment, when the power factor of the network cos φ = 1, the active power P will be practically equal to the full S. Thus, more energy efficient use of generators will save either their power or the number of simultaneously operating generators to cover the current load. The saved power can be considered as an indicator of the reduction in electricity PAEeff due to the use of energy efficient technologies. Then the PAEeff coefficient should be calculated using the formula:

$$P_{AEeff} = P'_{AEeff} - P''_{AEeff} - \sum P_{loss}, \quad (3)$$

where P'_{AEeff} is the electricity produced by the generator with reactive component compensation, P''_{AEeff} is the electricity that the generator can generate without reactive component compensation, $\sum P_{loss}$ is the sum of mechanical losses in the generator, in the compensator and power lines.

Innovative technologies for reactive energy compensation using *RECD* should be classified as technologies of category *C*. However, according to the tasks being solved, they can meet the criteria of both categories *C-1* and *C-2*. Like waste heat recovery, reactive energy compensation can be applied throughout the ship's operating time. However, the technology of reactive energy compensation can be used in all modes of ship operation.

The technology of individual compensation for reactive energy match the criteria of category *C-2*. *RECD* used either during start-up or during operation of a consumer whose capacity is comparable with a power plant. As a rule, such consumers work during cargo operations or during ship maneuvering.

It should note that exhaust gas recovery and reactive energy compensation could apply simultaneously and independently of each other. The combined use of the two technologies will reduce the number and / or capacity of the installed auxiliary generator sets, which, in turn, will lead to a decrease in the consumption of expensive energy resources and the amount of emissions of polluting gases into the atmosphere.

Conclusions. Marine innovative energy efficient technologies are the complex of measures from different sectors designed to improve the *EEDI* and the environmental friendliness of ships. Therefore, they are divided into the corresponding categories *A*, *B* and *C*, since affect *EEDI* in

different ways. Existing *EEDI* improving technologies offer either mechanical ways to improve energy efficiency or directly generate electricity, and do not consider electrical and electrodynamic improvement. Today, the *C-1* category presents innovative technologies aimed at generating electricity by utilizing waste heat and are the only technologies available in it. However, they can be limited used in the port, during ship maneuvers and anchorage. The innovative reactive energy compensation technology is a technology that is successfully applicable for both *C-1* and *C-2* categories, depending on the goal. It is possible to increase the network throughput and active power with the same wire cross-section with reactive energy compensation. This technology is not aimed at generating electricity, it allows the power plants to be loaded with more active power, which make possible to use either a smaller number or less powerful diesel generators for covering the current load, which leads to significant savings in fuel burned and, as a result, greenhouse and poisonous emissions gases into the atmosphere.

Obviously, an innovative technology for reactive energy compensation has to be added in *C* category. The value of the availability factor f_{eff} should be taken equal to one if complex compensation is applied, and f_{eff} <1 if individual.

The development, validation and implementation of innovative energy efficiency technologies are complex processes that never end. They are develop as we gain experience. Therefore, all current guidance documents should be temporary and change as progress develops.

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Лісовенко Д. В., Дудко С. А.

ІННОВАЦІЙНА ТЕХНОЛОГІЯ КОМПЕНСАЦІЇ РЕАКТИВНОЇ ЕНЕРГІЇ ДЛЯ ПІДВИЩЕННЯ EEDI СУДНА

Глобальне потепління, викликане по більшій мірі викидами в атмосферу парникових газів, спонукало світову спільноту до підписання у 1997 році Кіотського протоколу. Регулювання викидів парникових газів і пов'язана з ними економічна діяльність перестала бути прерогативою національних властей і стала об'єктом міжнародних угод. У зв'язку з тим, що найбільшими забруднювачами атмосфери з боку світового океану є морські судна, Міжнародна Морська Організація (ММО) прийняла в 2003 році резолюцію A.962 (23): "Політика і практика ММО щодо скорочень викидів парникових газів з морських суден", і визначила, що домогтися значних зменшень викидів парникових газів з морських суден можливо за рахунок прийняття технічних і експлуатаційних заходів. Це говорить про те, що судна повинні бути більш енергоефективними, експлуатаційні режими продуманими, а також необхідна чітка методологія їх оцінки з точки зору викиду парникових газів. Оціночним коефіцієнтом енергоефективності судна став конструктивний коефіцієнт *енергоефективності (EEDI), який розраховується відповідно до формули, розробленої ММО з можливістю його поліпшення за рахунок інноваційних енергоефективних технологій. З моменту вступу в силу резолюції ММО, головним чином ведуться роботи по поліпшенню EEDI на базі існуючих інноваційних технологій по різним категоріям. Прогрес не стоїть на місці, проте список нових інноваційних технологій для категорій енергоефективності не розширився.*

Представлена стаття присвячена розробці інноваційної технології категорії С, для поліпшення індексу енергоефективності конструкції судна. Цю технологію можна використовувати самостійно, а також в якості додаткового інструменту для розширення можливостей існуючих технологій енергоефективності. Крім того, інноваційна технологія з компенсації реактивної енергії дозволяє поліпшити EEDI і екологічні показники вже діючих суден, шляхом їх нескладної модернізації при плановому ремонті.

Ключові слова. *Енергоефективність (EEDI), інноваційні енергозберігаючі технології, корекція коефіцієнта потужності.*

Лисовенко Д. В., Дудко С. А.

ИННОВАЦИОННАЯ ТЕХНОЛОГИЯ КОМПЕНСАЦИИ РЕАКТИВНОЙ ЭНЕРГИИ ДЛЯ ПОВЫШЕНИЯ EEDI СУДНА

Глобальное потепление, вызванное по большей мере выбросами в атмосферу парниковых газов, побудило мировое сообщество к подписанию в 1997 году Киотского протокола. Регулирование выбросов парниковых газов и связанная с ними экономическая деятельность перестала быть прерогативой национальных властей и стала объектом международных соглашений. В связи с тем, что наибольшими загрязнителями атмосферы со стороны мирового океана являются морские суда, Международная Морская Организация (ММО) приняла в 2003 году резолюцию A.962(23): "Политика и практика ММО относительно сокращений выбросов парниковых газов с морских судов", и определила, что добиться значительных уменьшений выбросов парниковых газов с морских судов возможно за счет принятия технических и эксплуатационных мероприятий. Это говорит о том, что суда должны быть более энергоэффективными, эксплуатационные режимы продуманными, а также необходима четкая методология оценки судна с точки зрения выброса парниковых газов. Оценочным коэффициентом энергоэффективности судна стал конструктивный коэффициент энергоэффективности (EEDI), который рассчитывается согласно формуле, разработанной ММО с возможностью его улучшения за счет инновационных энергоэффективных технологий. С момента вступления в силу резолюции ММО, главным образом ведутся работы по улучшению EEDI на базе существующих инновационных технологий по разным категориям. Прогресс не стоит на месте, однако список новых инновационных технологий для категорий энергоэффективности не расширился.

Представленная статья посвящена разработке инновационной технологии категории С, для улучшения индекса энергоэффективности конструкции судна. Технологию компенсации реактивной энергии на судах можно использовать самостоятельно, а также в качестве дополнительного инструмента для расширения возможностей существующих технологий энергоэффективности. Кроме того, инновационная технология по компенсации реактивной энергии позволяет улучшить EEDI и экологические показатели уже действующих судов, путем их несложной модернизации при плановом ремонте.

Ключевые слова. *Энергоэффективность (EEDI), инновационные энергосберегающие технологии, коррекция коэффициента мощности.*