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MODERNIZATION OF HYBRID ELECTRIC-POWER SYSTEM FOR COMBINED PROPULSION COMPLEXES

Abstract. *The development of the energy sector in the shipbuilding industry is crucial to sustainable energy development in general, and includes reviews and reforms of investment, the creation of the reliable source of electric power and the optimization of operating conditions by means of scientific and containing approaches in competitive requests.*

In the article the problem of modernization of ship electric power systems as elements of ship power plants combined (hybrid) propulsion systems in order to save fuel and service life of diesel generators are considered. For the first time addressed the prospects for the use of double-layer electrochemical capacitors (EDLC), as secondary, and accidental marine energy sources, with the possibility of partial compensation for the lack of power, as well as future promising areas of modeling, optimization and quality improvements in ship power systems in terms of their resistance to changing operating conditions.

Based on preliminary calculations determined by the estimated cost of such systems, identified regulatory issues that need to be addressed in the future.

According to some estimates, aspects such as the absence of effective methods of research, lack of time for rapid inspection of newly built vessels, the lack of means to accurately predict the use of alternative energy sources, depending on the speed of movement of the vessel and operating conditions, the estimated risk of non-objective assessments of energy efficiency and the absence of systemic technical conditions play the significant role in increasing the relevance of the alleged studies.

Keywords: *diesel generator, ship power system, hybrid, static source of energy*

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МОДЕРНИЗАЦИЯ ГИБРИДНЫХ ЭЛЕКТРОЭНЕРГЕТИЧЕСКИХ СИСТЕМ КОМБИНИРОВАННЫХ ПРОПУЛЬСИВНЫХ КОМПЛЕКСОВ

Аннотация. *Рассмотрена проблема модернизации судовых электроэнергетических систем, как элементов судовых энергетических установок комбинированных (гибридных) пропульсивных комплексов с целью экономии топлива и моторесурса дизель-генераторов. Впервые были рассмотрены перспективы использования двухслойных электрохимических конденсаторов (EDLC), как вторичных, так и аварийных судовых источников электроэнергии. На основе предварительных расчётов определена ориентировочная стоимость таких систем, определены нормативные проблемы, которые необходимо решить в дальнейших исследованиях.*

Ключевые слова: *дизель-генератор, судовая электроэнергетическая система, гибридный, статический источник энергии*

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МОДЕРНІЗАЦІЯ ГІБРИДНИХ ЕЛЕКТРО-ЕНЕРГЕТИЧНИХ СИСТЕМ КОМБІНОВАНИХ ПРОПУЛЬСИВНИХ КОМПЛЕКСІВ

Анотація *Розглянута проблема модернізації суднових електроенергетичних систем, як елементів суднових енергетичних установок комбінованих (гібридних) пропульсивних комплексів з метою економії палива та моторесурсу дизель-генераторів. Вперше було розглянуто перспективи використання двошарових електрохімічних конденсаторів (EDLC), як вторинних так і аварійних суднових джерел електричної енергії. На основі попередніх розрахунків визначена орієнтовна вартість таких систем, визначені нормативні проблеми, які необхідно вирішити у подальших дослідженнях.*

Ключові слова: *дизель-генератор, суднова електроенергетична система, гібридний, статичне джерело енергії*

Introduction. Tighter requirements on environmental protection, the future transition to the more expensive grade of fuel with low sulfur content, reducing harmful emissions, noise characteristics of vessels in certain areas of navigation are reduced, highlight certain are-marine diesel engines are excludes, causing the need alternative energy sources to find that meet the requirements of maritime and environmental legislation increased [1 – 3].

Exploring of alternative diesel and gas engines for ship power plants (SPP) combined propulsive complexes (CPC), which focuses on heat recovery systems, exhaust, leading to significant savings in annual operating costs, but did not solve environmental problems.

The use of heat recovery, which covers part of the electricity consumption, and devices to reduce harmful emissions into the atmosphere promising direction of building SPP CPC, but today is one that is losing relevance.

This fact forced to rethink critically the experience of using the ship electricity storage, solar and hydrogen energy sources, ensure the safety of their operation and improve their production technology and obtain approval of the leading classification societies [5 – 7]. An important feature, such as advanced battery systems, is the possibility of charged from the selection of heat recovery of marine cranes modes braking of shaft generator and from renewable energy sources, such as solar and hydrogen elements. So today, the design and construction of modern SPP CPC, we have to reckon with this fact.

Analysis of the literature and formulation of the problem. Operation the majority of ship power systems (SPS) as components of EMS, carried out the simultaneous operation of two or more diesel generators (DG), one disconnected and one emergency diesel generator (EDG). In normal mode, usually two workers DG loaded to 20 – 45 % of its rated capacity, while load any of these generators to the level of 80 % of the rated power is switched to parallel work–you network the third generator, the emergency diesel generator switched on for 30 seconds after the power failure. There are some SPS, where the normal mode of operation only one main DG and the other is on standby and ready for connection in parallel with the main generator. For most vehicles specified feature SPS operation due to security requirements, since the operation of the vessel necessarily required dynamic provision of electricity, which require Maritime Register of Ukraine, Russia, Japan and others [8 – 10].

as of shipping and ports, which the work of

The presence of such the significant (not less than 100 %) of the dynamic reserve of energy is the need of effective damping unpredictable peak loads in the SPS that can cause disabling and even major customers around the CPC. This requirement arises also because to run disconnected DG followed its synchronization with the ship's network is needed though short time (see. Table. 1), but this is the time during which the vessel blackouts can occur fatal accident [11 – 12].

Table. 1. The time from submission of the signal to automatically start receiving the time to load nominal value for the DG, prepared for rapid load acceptance

Power, kW	Time, s
To 100	10
From 100 to 500 including	20
From 500 to 1000 including	30
More than 1000	40

The peak load on SPS may arise due to the nature of ship operation, the specific type of process performed by ships (dynamic positioning oil rigs, hooks and trawls al.). The inclusion of powerful contingent of consumers, especially the narrow ship passage and weather conditions.

It should be noted that the generator sets, automatic launch system hardware, between expectations are in “hot standby”. This means that at least made permanent shirts heated engine (for power liquid–cooled). Power station with automatic start–up can take the load after few seconds (see. Table. 1), after power failure in the external network, it does not need extra time to warm up the engine. Also, no need to make manual switch in the fuse board – all necessary switching performed automatically and during DG carried automatic maintenance frequency output voltage and power engine speed. For particularly difficult conditions, special SPS DG can work in this mode when the engine is running continuously, but the generator load is not connected or minimum. In this mode, fuel consumption, though not very big, but is also available. Remember that when switching to emergency mode, guaranteed job batteries. Therefore, during normal operation SPS necessary to provide and charging batteries, in which also consumes fuel [13].

It is also clear that the total fuel consumption for the two partially loaded DG significantly higher than in other DG working under similar stress.

But for security fee shipping. However, in order to save fuel and at the expense of safety, often in the vessel's practice are cases of gross neglect safety rules when the ship is at one and the second included DG that, at best, is in the "hot standby".

So urgent task, which is aimed at solving the existing problems simultaneously improve navigation safety and efficiency of operation of ship electric power systems.

The purpose of the article. Proposed that the technical component of the traditional approach to building SPS suitable for use in many types of vessels.

Theoretical Part. The basic principle of the proposed modifications SPS concluded that in many cases the practical operation of vessels, the work of the main DG may be at loadings up to 80 % of the nominal value and the dynamic reserve of energy will be an additional source of static electricity [14].

This approach is known, but its technical implementation to date has been virtually impossible because of the lack of highly static energy, which is significantly higher than for its technical and operational characteristics classic batteries and variety of peak load and supply of electricity are provides.

It to use SPS extra battery, which is made up of electric double-layer capacitor (EDLC) is proposed [15].

There EDLC decision on the use of road transport and electric networks in some special purpose.

The device EDLC – static electrochemical, organic or inorganic electrolyte "covers" which is the electric double layer at the interface between the electrodes and the electrolyte. Functionally EDLC is the hybrid capacitor and chemical current sources and refers to the storage of electricity molecular types. Capacitors symmetrical double electric layer capacitors are different from the classical fact that the spatial separation of opposite charges, which create working electric field using polarized microscopic layer at the boundary surface between two media distribution.

Modern bipolar EDLC is sealed and the technological design based on activated carbon in bound water and an alkaline electrolyte and has a very high energy and powerful performance. Properties EDLC allow its effective use as charging pulse current source of operating voltage charge to several hundred volts and the number of charge-discharge cycles at least the million. Modern EDLC with high stored energy density and little leakage of charge. There EDLC batteries with specific energy stored more than 50 J/cm^3 (two orders of magnitude more specific energy of any classical capacitors) and specific average power of 10 kW/ kg. The latter figure is much higher than traditional power density of acidic or alkaline batteries and allows EDLC as damper sources in SPS.

For example, the company ELTON advanced technology of electrochemical capacitors "asymmetric" type developed and patented. This design negative electrode made of activated carbon materials (polarized electrode), and the positive electrode is unpolarized (faradic). The positive electrode made of nickel hydroxide as the electrolyte used an aqueous solution of alkali used in alkaline batteries and therefore has low price. This asymmetrical design has created and mass produces electrochemical capacitors with high specific capacity and energy, low internal resistance, weakly dependent on the temperature during operation and storage.

Moreover, such EDLC does not require maintenance, have a wide operating temperature range, store performance at extremely low (–50°C) temperatures, able to withstand without fracture and failure of heightened tension.

Super capacitors based elements 400–500 series has weight of 200 kg, 5 MJ energy and peak power of 200 kW. For comparison – 4 acid battery weight in 4×50 = 200 kg, with power consumption of 20 MJ, but peak power less than 40 kW. It is clear that acid batteries require special care, ventilation, etc., and is notable given greater peak power, which is necessary in the short–term loads in SPS.

One of the important issues – is the official definition of the place of use of ship power systems using EDLC. But it is not technical but organizational type and entirely dependent on experience (which is not) operation, the recognition of SPS Maritime Register, classification authorities, engineering companies.

One of the issues – is the cost of such complex SEES. It should be noted that the prices of electrochemical capacitor EDLC is constantly declining. Thus, in 1996, 1 F EDLC capacity cost $0,75 at the total cost of almost $284 for the 1,0 kJ of energy. Already in 2006, 1 F containers had to spend $0,01 and the 1 kJ of energy – $2,85. In 2014, 1 F EDLC capacity needed to spend only $0,0045 and 1 kJ of energy around $1,0. Obviously, in 18 years the share price fell by nearly 1 kJ 300 times, and 1 F capacity – 150 times, and this decline continue.

At first glance, these amounts are small, but you must remember that:

a) only few EDLC battery with sufficient and necessary additional electronic devices;

b) the voltage of one element EDLC small – about 2 V;

c) the sequential IM same identical elements in the EDLC battery, the total battery capacity C_Σ, F, is given by:

$$C_\Sigma = 1/C_1 + 1/C_2 + 1/C_3 + \ldots + 1/C_n ,$$

where $C_1 = C_2 = C_3 = \ldots = C_n$ – the capacity of individual elements of the same type EDLC, i.e. the total battery capacity of successive elements is significantly reduced;

d) work with EDLC as storage (buffer) capacitor power energy systems, they quickly lose up to half of the output voltage of the initial voltage, giving up to 75 % of stored energy.

That is, the necessary energy E, J, calculated from the known formula:

$$E = C_\Sigma \cdot U^2/2 ,$$

where U – working battery voltage must agree to four times higher.

Estimated value of energy:

$$E = 2 \cdot C_\Sigma \cdot U^2 ,$$

leading to the substantial increase in capacity have required batteries.

Depending on the time of $\Delta\tau$ in buffered mode and the required power (easier – and of current consumption I) is easy to calculate the required number of individual elements EDLC as follows:

$$C_\Sigma = (I \cdot \Delta\tau)/U .$$

As result of previous calculations can be seen that only cost EDLC battery can be tens of thousands of dollars.

Therefore, from the practical point of view, as an emergency (buffer) source used by SEES EDLC is quite possible, but needs to address for number of research tasks.

First, the task EDLC battery, which could have the capacity of several thousand farad.

Secondly, this task is the connection of individual elements in the EDLC battery with ensuring uniform distribution of voltage between the battery cells.

Thirdly, it is to stabilize the output DC voltage under load EDLC.

There is an extremely important task of converting direct current into three-phase alternating current with the ability to instantly sync with SPS.

In addition, the need to solve the problem of theoretical and economic assessment of the possibility of using EDLC in SPS, selecting parameters and calculating its basic characteristics, identifying variables EDLC, simulation of static energy and SPS with EDLC in static and dynamic modes, the theoretical justification and constructive solutions of electronic charge and voltage stabilization formation algorithms included in EDLC SPS, technological and structural study of the entire system and for number of others.

Conclusion. Thus, SEES offered must include the following elements:

– an electronic device providing charge (charging) battery EDLC of the ship's electrical network or from the shore network;

– EDLC battery, comprising individual elements (banks) EDLC [15], voltage distribution system, its own monitoring system [16], control and protection;

– an electronic device stabilize the output voltage based on the pulse converters, such chopper-booster types (power factor correction, booster converter) [17 – 18];

– controlled static generator (converter "voltage direct current – voltage three-phase"), for example – based on industrial frequency converters with ensuring its constant readiness to sync with SPS;

– microcontroller systems management [19] connecting the parallel operation of EDLC SPS using speed sensors voltage, frequency, current, if necessary – the temperature of the executive contactors;

– alarm system monitoring [16], diagnosis, protection of the system.

This material was fairly new solutions for the SPS and requires further research.

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