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INCREASE OF OPERATING EFFICIENCY OF SHIP ELECTRICAL GENERATING PLANT WITH SHAFT GENERATOR

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Energy efficiency is one of the most important issues for research in shipping and shipbuilding. Shipowners suffer from high energy costs and make efforts to reduce fuel consumption by investing in new vessels and upgrading existing vessels. It is necessary to take into account that a previous analysis of system performance which will lead to successful application and guaranteed economy is required for the implementation of any technological solution [1].

One solution is to use a shaft generator driven by a propeller shaft and serving to supply ship consumers with uninterrupted power supply. Depending on the type of vessel and the power plant, various configurations of ship power plants are used. The use of a generator for supplying of receivers with power when the vessel is underway makes it possible to reduce the number of operating generating sets of the electric power plant and the number of operating hours, significantly reducing herewith the operating costs on fuels and lubricants of individual actuating mechanisms [2,3].

There are three main types of generators:

1. GCR (gear constant ratio) consists of a flexible coupling, a step-up gear and an alternator.
2. RCF (RENK constant frequency) consists of a flexible coupling, a step-up gear, a torsion rigid toothed coupling, a constant frequency gear and an alternator.
3. CFE (constant frequency electrical) consists of a low-speed alternator with electrical instrumentation.

The GCR system is the simplest and cheapest of all, and it includes a standard synchronous alternator and a simple gear. Its simplicity is attractive, and many ship owners use it to produce all the electrical energy at a constant electrical frequency during the voyage. Due to the fact that the frequency of rotation of the propeller changes (rough sea, altering of the current, speed, depth, course of the vessel, etc.), the frequency of the electrical network will change. In this regard, the synchronization of the shaft generator with the ship's power plant is problematic in terms of reliability, so the shaft generator is used to supply low-level receivers independent of the main network of a ship.

The second and third types of shaft generators include various frequency control systems that allow them to produce electrical energy with a constant electric frequency at a variable engine speed [4,5].

The RCF system generates electrical energy with a constant electric frequency over a wide range of propeller speed. The rotor speed of the shaft generator is controlled by an epicyclic gearbox with a hydrostatic motor, which guarantees a constant speed over a certain range of propeller speed. However, the efficiency of this solution is very low, that leads to higher fuel consumption, so the gain obtained by the generator from the main engine is lost on the transmission.

The CFE system generates electrical energy with a constant electric frequency over a wide range of engine speeds. The shaft generator can be used in combination with fixed-pitch propellers and continuous operation in parallel with the generator sets. A frequency converter is used to provide for a fixed network frequency and voltage level. The pulse width modulation of the transducer allows power on ships to be supplied without a synchronous condenser and thus simplifies the installation process and further maintenance.

The CFE shaft generator system is suitable for ships with a fixed pitch propeller. The overall efficiency of the slow-speed CFE type varies from 89% up to 91%.

Figure 1 presents an approximate generation of electrical energy from shaft generators operating on ships with a pitch changing mechanism.

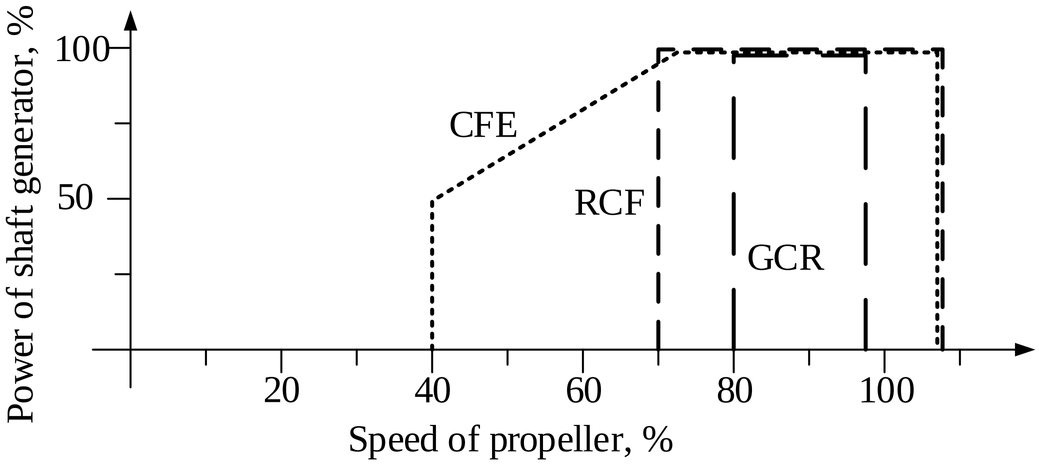

Figure 1. An approximate generation of electrical energy by shaft generators.

The block diagram of the PTO / CFE shaft generator is represented in Fig. 2. The circuit operates as follows.

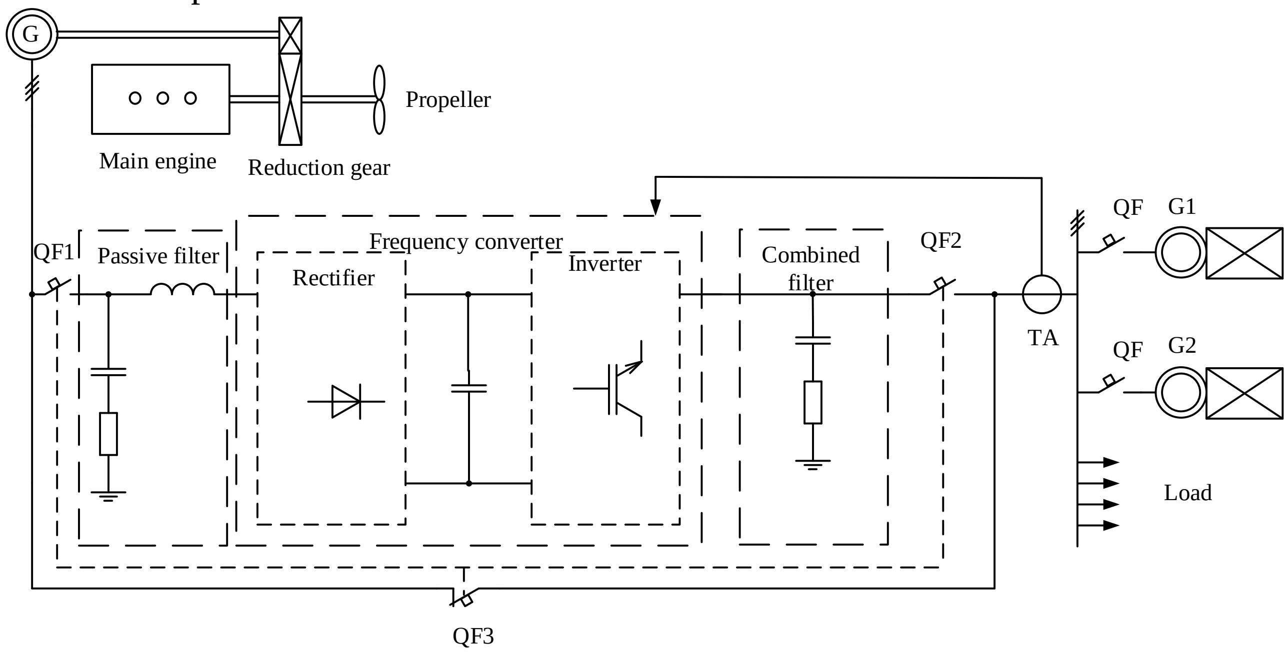

Figure 2 – Shaft generator

The main engine operates for controllable pitch propeller with minimal deviations from the rated speed. The shaft generator is connected to the line of shafting through the gear, and takes off some power from the main engine. The electric power is transferred from the shaft generator via the QF1 circuit-breaker to a frequency converter, which consists of 3 parts - rectifier, DC filter and inverter based on IGBT transistors. The current transformer TA deenergizes on each phase of the main switchboard and transfers its value to the frequency converter control system, which generates the voltage of the required value and frequency by feeding pulses to the IGBT transistors.

The voltage from the output of the frequency converter enters the main switchboard, through the circuit-breaker QF2, from which it is distributed to various consumers through feeders. A simple passive filter is to protect the generator from high frequencies on the side of the frequency converter. A combined filter is used to protect against high frequencies.

In the event that the speed of the main engine is stable, and the voltage and frequency at the shaft generator clamps correspond to the values on the bus bars of the main switchboard, then QF1 and QF2 are turned off and QF3 is turned on.

Power, taken off by the shaft generator from the main engine:

$$P = \frac{K_1 \cdot K_2}{\eta_1 \cdot \eta_2} \cdot P_{SG} \quad (1)$$

where K_1=1,1…1,3 – coefficient taking into account power losses due to equipment aging; K_2 – power reserve coefficient; η_1 – efficiency coefficient of shaft generator; η_2 – efficiency coefficient of gear; P_{SG} – rated power of shaft generator, kW.

In percentage terms:

$$p = \frac{P}{P_{ME}} \cdot 100\% \quad (2)$$

In the event that the amount of taken off power does not exceed 15%, the use of a shaft generator will not significantly affect the running properties of the main propulsion plant and the taking off of excessive power from the main engine will increase the overall energy efficiency of the entire complex as a whole.

Conclusion

It is advantageous to use shaft generators in some cases, allowing taking off some power from the main engine to increase the efficiency of the use of fuels and lubricants. It will allow to reduce the number of operating generating sets, to increase the load of the electric power plant, reduce fuel consumption and increase the their operation life. The use of a frequency converter with a shaft generator allows using it even with a wide deviation of the frequency of the main engine from the nominal value.

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