MARINE PERSPECTIVE STATIC POWER SOURCES

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Traditionally, the main source of electricity on modern ships are generator units, among which diesel generators are the most widely used. In recent years, static sources and energy storage devices have been used on foreign and domestic ships.

Relatively low technical and operational characteristics of traditional storage batteries, such as specific capacity, charge-discharge current, as well as a small number of charge-discharge cycles, limited the scope of their application. Storage batteries are most widely used for emergency power supply of a ship and electric starter starting of thermal engines.

Increasing environmental standards and rising fuel prices determine the need and feasibility of searching for new types of electricity sources for ships and offshore facilities that can be used as the main ones, including for powering the ship's electric propulsion system.

The development of power electronics and the emergence of electrical materials with high specific characteristics in recent years have made it possible to create new generation static power sources, which are becoming widespread both on land-based facilities and on sea vessels, including those with electric propulsion [1].

The new generation of static power supply sources include: batteries on a new element base, supercapacitors, solar batteries, fuel cells.

Static power supply sources can be divided into two groups - generating and accumulative.

Generating static power supply sources include sources that produce electrical energy from other types of energy. Generating sources are capable of continuous operation in generator mode. Such static power supply sources include fuel cells and solar batteries. Accumulative static power supply sources include sources that are capable of accumulating electrical energy, absorbing it from sources of other types, with subsequent release. Such static power supply sources include batteries and supercapacitors.

The most promising for use on ships are batteries on a new element base and supercapacitors. Among the batteries on a new element base, lithium-ion (Li-Ion) batteries should be noted. These batteries have the highest specific stored energy per unit of mass. This type of battery allows you to create power sources with the smallest mass with the same capacity. Silver-zinc batteries (Ag-Zn) have the highest density of stored energy per unit of volume, which allows you to create energy sources with the smallest occupied volume with the same capacity.

For use on ships, the most promising type of storage batteries are lithium-ion batteries (Li-Ion), produced as individual elements. To achieve the required voltage and electrical capacity, battery groups are assembled in series and parallel [1].

A supercapacitor is an element with two electrodes, between which an electrolyte is located. Supercapacitors differ from storage batteries by significantly higher charge and discharge rates and a longer service life. Supercapacitors are capable of absorbing and releasing a large amount of electrical energy in a short period of time, so it is advisable to use them in a buffer mode. The operating temperature range of a supercapacitor is significantly wider than that of storage batteries. Supercapacitors, unlike storage batteries, are practically not used as the main source of electrical energy on a vessel due to the fact that they have significantly worse indicators for specific stored energy and density of stored energy. To increase the power, supercapacitor elements are combined into modules, modules - into systems.

Another type of static power supply sources of the new generation, solar batteries, is built on the principle of converting sunlight energy into electrical energy. Solar batteries are produced in the form of individual solar cells connected into solar modules. The peculiarity of generating static power supply sources is that they produce electrical energy directly from chemical or light energy. By now, a large number of different fuel cells have been developed, which can be classified according to various features: by reagents and methods of their use, ionic conductors (electrolytes), catalysts and operating temperatures.

Currently, the following types of fuel cells are being most actively developed:

– with a proton exchange membrane – solid polymer;

– solid oxide;

– based on carbonate melts.

Fuel cells differ from batteries in that they require a constant supply of fuel and oxidizer to maintain the chemical reaction to generate electricity. Fuel cells have the following advantages over rotating heat engines: low noise level; no harmful emissions; no moving parts; easy maintenance.

The amount of generated electric power is determined only by the available fuel and oxidizer reserves and can significantly exceed the similar parameter of storage batteries. Fuel cell maintenance is relatively simple and does not require large expenses. A traditional marine generator unit consists of a drive heat engine and an electric machine operating in generator mode. The generator rotates at a constant speed, as a result of which it generates electric power with a nominal value of the electric current frequency. The voltage is maintained constant using the generator excitation system, which changes the current in the excitation winding. The functional diagram of a traditional generator unit is shown in Fig. 1a.

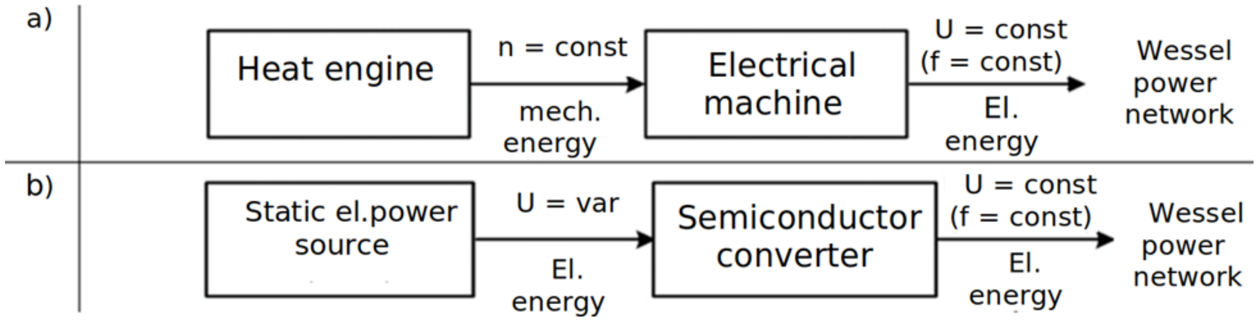

Figure 1 — Functional diagrams of ship power sources:
a – generator unit; b – valve static power supply

To convert and stabilize the output parameters of static power supply sources, a semiconductor converter (inverter, constant-to-direct current converter) is used, which converts direct current electricity into alternating or direct current electricity with stabilized (nominal) parameters.

Together, the static power supply source and the semiconductor converter make up a valve static power source. The functional diagram of the valve static power source is shown in Fig. 1b.

In the case of using a static power supply source capable of storing electricity, the semiconductor converter is made reversible, capable of charging a battery or capacitor.

Storage batteries on a new element base and supercapacitors can be used in two operating modes:

– buffer, in which the static source operates in parallel with the main ones, absorbing excess electricity or replenishing the lack of electricity in the ship's network;

– autonomous, in which the static source functions as the main and only source for powering general ship receivers and the ship's electric propulsion system.

The use of static power supply sources in the buffer mode allows for a significant reduction in fuel consumption in dynamic modes of operation of the ship's electric propulsion system, for example, on icebreakers and ice-going vessels when navigating in ice or in rough seas [2].

Solar panels and fuel cells can only operate in the electric power generation mode. Storage batteries, fuel cells and solar panels have limited maximum load currents. Supercapacitors can be used to provide starting currents for direct-on-line electric motors. Only storage batteries and supercapacitors operate in the buffer mode. When a storage battery and supercapacitor operate in the buffer mode, both charging and discharging can occur. In the buffer mode, when discharging a static power source, short-term operation is typical - power compensation at the time of a sharp change in load, for example, when operating lifting and transport machines, deck mechanisms, etc. The static power source can be charged briefly with a high current, which is typical for a supercapacitor, or continuously with a limited current (typical for storage batteries). For a supercapacitor, such a buffer mode of operation is the main one in most cases.

All types of static power sources can be used in parallel operation with generator units. The issues of synchronization and load distribution are solved using semiconductor converters and automatic control systems. Load distribution between parallel static power sources of different types may occur disproportionately to their power and will depend on the nominal capacity of the source. Currently, fuel cells and supercapacitors operate mainly in parallel mode with marine generator units or with other types of static power sources.

Storage batteries have limited charge and discharge currents. The magnitude of the charging current depends on the type of battery. In normal charging mode, limited charging currents ($0,2^0$ ... $0,5^0$ C) are typical for the battery. Charging the battery with a current higher than the nominal (1^0 C) is considered accelerated. In the accelerated charging mode of batteries, it is necessary to observe temperature conditions. Accelerated charging of the battery can negatively affect its service life. Supercapacitors have equally high efficiency during charging and discharging and have virtually no limitations on discharge/charge currents. The supercapacitor's charging rate depends on the current-limiting capacity of the semiconductor converter with which the supercapacitor is used [3].

The conducted studies have shown the feasibility of using new-generation static power sources, which include storage batteries on a new element base, supercapacitors, fuel cells and solar panels on modern ships as the main and auxiliary sources of electricity.

It has been established that in order to obtain the nominal parameters of electricity in the ship's network when powered by static sources, it is necessary to use semiconductor converters. The set of equipment, including a static power source and a semiconductor converter, forms a valve static power source.

The work shows that the operation of static power sources, depending on their type, is possible in autonomous and buffer mode, parallel operation mode with ship generator units, shore network or other static sources. In this case, only storage power sources (storage batteries and supercapacitors) can operate in buffer mode. All types of static power sources can be operated in autonomous mode and parallel operation mode.

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