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HYBRID ENERGY SYSTEM FOR A CLASSIC SHIP POWER PLANT

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Abstract

The article presents a brief overview of hybrid energy systems used on ships. The area of their application is outlined. The benefits of using such systems are also indicated. Then, the classic ship power plant is defined. The most important part of the article is a proposal how to modify a classic engine room by using a hybrid energy system. The idea is: to accumulate a part of electricity in areas where it is allowed to burn fuel with high sulfur content (cheaper). Then, use the accumulated energy in areas where it is allowed to burn only fuel with low sulfur content (more expensive). The implementation of such an idea requires the use of a battery pack on the ship. At the end of the article, the initial estimation of savings on fuel costs is made.

Key words: *energy, hybrid system, ship, power plant*

1. Introduction

Stricter requirements for the prevention of air pollution from ships, set out in Annex VI to the MARPOL Convention [1], led to the use of new devices and technical solutions on ships. Exhaust Gas Recirculation systems (EGR) and Selective Catalytic Reduction (SCR) reactors appeared to reduce NO_x emissions. Lowering the permissible sulfur content in the fuel caused the need to burn low-sulfur fuel or to install scrubbers to remove SO_x from the exhaust gas. The obligation to reduce CO_2 emissions became the cause of more attention paid to the generation and management of energy on the ship. It is obvious that reducing fuel consumption will reduce the emission of harmful gases into the atmosphere. It will also help to reduce operating costs. One of the many ways to reduce fuel consumption and better management of energy - is the use of hybrid drive systems. Especially, for ships with a variable power demand in different operating conditions. Perhaps, hybrid energy systems will be used on typical cargo vessels in the future.

2. Overview of Hybrid Propulsion Systems

Nowadays, hybrid propulsion systems we can find on special purpose ships. Such vessels are: Offshore Support Vessels (OSV), Anchor Handling Tug Supply vessels (AHTS), warships, coastguard vessels, research vessels, fishing vessels, construction support vessels, shuttle ferries.

In the hybrid propulsion system, the power for propulsion can be delivered in different ways. Mechanical power and electrical power together, only the mechanical power or only the electrical power. The mechanical power is delivered to the propeller by diesel engines. The electrical power is delivered to the propeller by electrical engines. The sources of the electricity can be gen sets or batteries.

Large international corporations develop their own solutions of hybrid systems. Below, briefly, the selected solutions of MAN Diesel & Turbo, Rolls-Royce and Wartsila are described.

According to the MAN proposal, hybrid propulsion systems can be differentiated between two configurations: CODLAD (Combined Diesel-Electric and Diesel Engine) - where the diesel engines and the electrical engines work in parallel on the propeller in case of the need for additional power; CODLOD (Combined Diesel-Electric or Diesel Engine) - where the diesel engines or only the electrical engines are used in slow speed mode.

Five work modes are listed. PTO - the main engine provides not only the power for ship propulsion, it also supplies the electric power needed for the ship's consumers. PTI - together with the main engine the electric machine works as an auxiliary motor, which delivers support to the propeller. PTO/PTH - In case of the main engine is not operating the electric machine in the emergency case is used as a motor, which delivers the power for the propeller. Hybrid mode (PTO/PTI) - the electric machine is used as alternator as well as propulsion motor, this is the way for flexible use of the main engine and the gen-sets. Electric Shaft - in case of a twin propeller application there is a possibility of driving both propellers with the power of one main engine supplying one shaft machine (PTO) and run the other shaft machine as "take-in-device (PTI)". All the details are available in [2].

Rolls-Royce offers the following solutions: SAVe-Line - a traditional diesel-electric propulsion system; SAVe-Cube - additional battery power is available for slow speed transits in harbor or for peak power load smoothing; SAVe-Step - similar to previous system, but there are transformers to step down the voltage because the system uses high voltage on the main switchboard and generators and low voltage on the consumers and distribution; SAVe-Combi - systems contains: the main engine, two gen-sets, one hybrid shaft generator (PTP/PTI), battery, shore connection. The last one system can operate in a wide variety of modes. For instance: parallel mode for excess power (main engine, shaft generator, gen-set); transit mode for optimum efficiency (main engine, shaft generator); boost mode for maximum speed (main engine, shaft generator working as the electric motor, two gen sets); diesel-electric mode for efficient lower speeds (two gen sets, shaft generator working as the electric motor); shore connection mode - for lower fuel consumption (only the shore power). All the information is given in [3]. The scheme of the SAVe-Combi system is shown in Fig.1.

The Wartsila Corporation installed hybrid battery system on offshore supply vessel the Viking Lady. The new system cut the fuel consumption by 15 %. The payback time is about for years. The nitrogen oxide (NO_x) emissions were down by 25 %. The Viking Lady was also the very first merchant ship that used a fuel cell in its propulsion system, generating some 330 kW [4]. In 2015 the car ferry "MF Folgefonn" was retrofitted into a full scale hybrid and plug-in hybrid ferry [5].

A very interesting concept is Wartsila's zero emission ferries. According to [6] the new ferries are designed to run entirely on batteries, or in a battery-engine hybrid configuration where the fuel options are LNG or bio-fuel. In plug-in operation, the fuel consumption is reduced by 100% compared to conventional installations, and all local emissions are completely eliminated. With the plug-in hybrid configuration, emissions are reduced by 50%.

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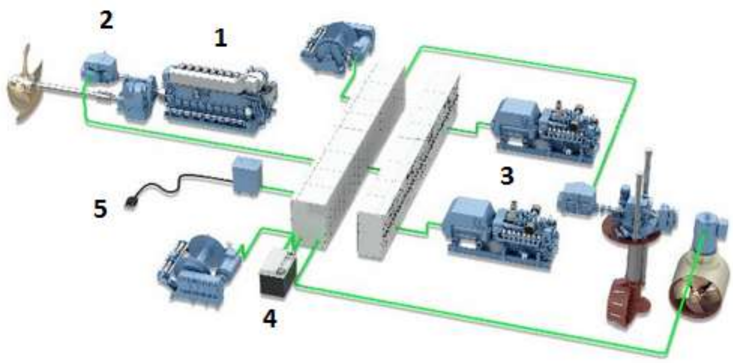

Fig.1. The SAVe - Combi propulsion system [3]
1 - main engine, 2 - shaft generator/motor, 3 - gen sets, 4 - battery, 5 - shore connection

3. Classic solution of ship power plant

All the above examples were targeted for special vessels with a very variable operation modes and equipped with diesel - electric propulsion system. The question is whether installing hybrid systems on typical cargo ships makes sense. For long periods of time, the power demand on such vessels is approximately constant. The propulsion is provided by the low-speed diesel engine. There is no reduction gear. The pitch of the propeller is fixed. Electricity is provided by generating sets. In some cases, the shaft generator is installed. This solution of ship power plant we can call the classic.

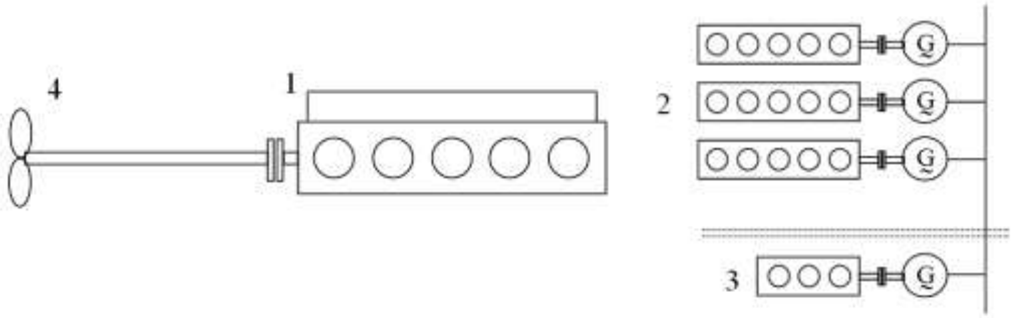

Fig.2. Classic solution of ship power plant
1 - main engine, 2 - gen sets, 3 - emergency gen set, 4 - fixed pitch propeller

4. The proposal of hybrid energy system for the classic ship power plant

In order to meet the requirements for reducing sulfur oxide emissions, the main engine and auxiliary engines must burn low-sulfur fuel in Sulphur Emission Control Areas or the vessel should be equipped with the scrubber.

Let's consider the third possibility. Maybe, we should accumulate a part of electricity in areas where it is allowed to burn fuel with high sulfur content (cheaper). Then, use the accumulated energy in areas where it is allowed to burn only fuel with low sulfur content (more expensive). This requires the use of batteries on a ship. The batteries would be charged by gen sets or a shaft generator. In the sea travel only one gen-set is working, so one of the two standby gen sets could be replaced by a battery pack. The proposal of hybrid/battery system for the classic power plant is shown in Fig.3.

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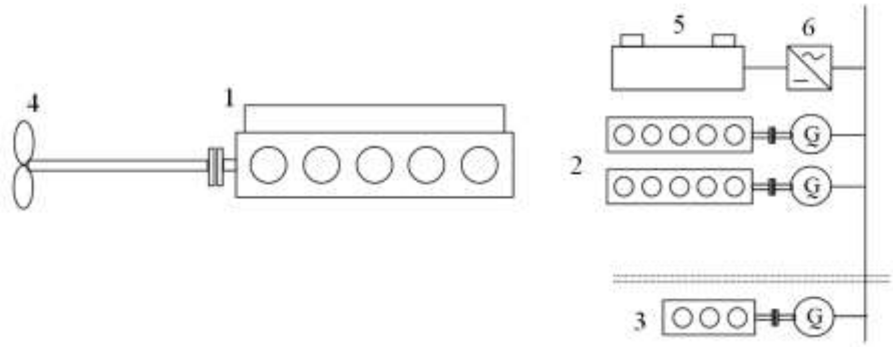

Fig.3. Hybrid/battery system for the classic ship power plant
1 - main engine, 2 - gen sets, 3 - emergency gen set, 4 - fixed pitch propeller, 5 - battery pack, 6 – inverter

5. Estimated savings on fuel costs

Let's consider the case of a ship on which the demand for electrical power is 1000 kW. One 20-tonne gen-set was replaced with battery pack of similar weight. Assuming a battery weight of 0.152 kWh/kg [6], we can obtain a battery capacity of 3000 kWh. The cost of battery charging in global area (HFO burning) is calculated in the Tab.1.

Tab.1. One time battery charging cost

Battery Capacity [kWh]	Charging Time [h]	Charging Power [kW]	Charging Efficiency [-]	Gen-set Efficiency [-]	Fuel Cal. Val. [kJ/kg]	Fuel Cons. [kg/h]	HFO Price [USD/t]	**Battery Charging Cost USD**
3000	10	300	0.95	0.42	39 000	69.4	320	**222**

Now let's check how much money we can save on fuel costs using the battery pack in the protected area instead the gen-set (only low-sulfur fuel allowed). The result is in the Tab.2.

Tab.2. Saving on fuel using batteries instead of gen-set for 2.9 hours in SECA

El. Power Demand [kW]	Inverter Efficie ncy [-]	Power from Battery [kW]	Battery Cap. [kWh]	Battery Operation Time [h]	Gen-set Efficie ncy [-]	Fuel Cal. Val. [kJ/h]	Fuel Cons. [kg/h]	LSF Price [USD/t]	**Saving on Fuel USD**
1000	0.95	1052.6	3000	2.9	0.42	42 000	204	550	**325**

In conclusion: we can save in our case 325 – 222 = 103 USD on one cycle: charging batteries in the global area and use them in Sulfur Emission Control Area.

6. Final remarks

As we can see, the use of hybrid systems on special ships can cut the fuel costs by 15% and more. The proposal described above shows the possibilities of savings also on cargo ships. These savings, however, are not significant. The estimated cost of a 3 000 kWh battery would be around 900 000 USD. However, the price of one gen-set should be deducted from the price of the battery pack. One sentence, taken from [4] can be a good summary of this article: "In the future all vessels will have batteries."

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