

PROECOLOGICAL ENERGETIC SYSTEMS FOR FISHING CUTTERS

ph.d. eng. assoc. prof. Cezary Behrendt

Maritime University of Szczecin, Faculty of Maritime Engineering Institute of Marine Power Plants Operation, Waly Chrobrego 1/2,
70-500, Szczecin, Poland

c.behrendt@am.szczecin.pl

Abstract: *In view of the hazards to the environment resulting from operating fishing cutters, a proposal for energy saving and proecological energetic systems for these vessels is presented in this paper. It also demonstrates the significance of the proecological energetic systems, includes a review of the impact of fuel type, renewable energy sources and energy conversion methods on the degree of the hazards to the environment. The proposed solutions regarding the energetic systems refer to the fishing cutters of the length from 15 to 30 m. The solutions are divided into two groups according to currently available technologies and future technologies allowing for alternative energy sources to be applied.*

Keywords: FISHING CUTTERS, ENERGETIC SYSTEMS STRUCTURE, ECOLOGY

1. Introduction

The marine fishing industry constitute a major food supplier. This task is performed by fishing fleets belonging to the particular countries. The Polish fishing fleet operating at the Baltic Sea, in 2013, comprised of 142 of the fishing cutters the length of which equaled from 15 to 26 meters, while in 2004 there was 411 fishing cutters operated [3]. Such a considerable decrease results mainly from the catch limits, compensations granted to fishermen for vessels' scrapping and from the age of the operating fishing cutters, most of which is over 30 years old [2,3]. The energetic systems of the Polish fishing fleet, due to the old generations and the long operation periods of machines and devices, are characterized by high energy consumption and considerable environmental load [2]. Grants from the European Fisheries Fund allow for obtaining financing only for the replacement of engines for the main propulsion system with the engines of newer generation with less fuel consumption, which very frequently, does not provide an expected improvement of the operational properties of the propulsion system [2].

The reduction of the energy consumption of the energetic system may be obtained by a comprehensive approach to the issue by: a development of concepts and system design, the selection of energy saving and proecological machines and devices, drawing up and the implementation of energy management procedures.

When designing prospective energetic systems for the fishing cutters, an option of using alternative fuels and renewable energy sources should be considered, too.

Such an approach during a design process is furthermore in compliance with the sustainable development principle, strongly promoted in the European Union states, which consists in the integration of ecological, economical and social goals, the IMO requirements regarding the environmental protection and the Code of Conduct for Responsible Fisheries developed by FAO [5].

Aspiration to the sustainable development, in practice, requires:

- closing material cycle: raw materials – production processes – product use – waste and impurities – after utility raw materials,
- the reduction of energy consumption by increasing energy efficiency [7], the use of the renewable energy sources and the alternative fuels,
- quality promotion including, but not limited to, in terms of product durability, the minimization of waste and the environment protection.

This paper presents the developed conceptions of the energetic systems for the fishing cutters of the length up to 30m, divided into projects in which modern technologies were applied and prospective projects including future technologies.

2. Significance of proecological energetic systems

The most beneficial impact on the environment protection may be achieved when certain actions, involving mainly the improvement of the existing technologies and the development of new ones, are undertaken at a design stage. The proecological designing will, inter alia, contribute to the reduction of generated waste and impurities, the limitation of materials' and energy resources' consumption. Above all, a product, which in the particular case is a fishing cutter, should have higher energy efficiency and its operation should have the least effect on the environment.

The processes of generating mechanical energy, electricity and heat for the fishing cutters include the opportunities for actions directed at the improvement of energy and environmental indicators. The most significant are:

- further development of internal combustion engines, boilers, electric generators and auxiliary devices and control systems leading to the improvement of ship energetic system efficiency and the reduction of the burden on the environment,
- the wider use of alternative liquid and gas fuels, in particular hydrogen,
- the implementation of fuel cells in connection with hydrogen application
- the use of hybrid systems based on fuel cells and heat engines
- the use of energy from renewable sources,
- energy use rationalization.

Certain abovementioned actions require a comment. The use of energy from the renewable sources is strongly promoted in the European Union member states. Not all onshore technologies, using renewable energy sources, may be efficiently applied at ships. One of the physical properties of the renewable energy is its low density when compared with the conventional energy. For instance, solar radiation is characterized by a density <math><1,33 \text{ kW/m}^2</math>, wind by a density <math><3 \text{ kW/m}^2</math>, while e.g. coal combustion in a boiler is a value of 500 kW/m^2 [4,6,12]. This property of the renewable energy causes that it is hard to use it at ships, in particular at small vessels, where the space is limited. Nonetheless, in case of bigger cutters it is worth to consider to use photovoltaic panels installed at the roof of the superstructure. Return to sail supporting main propulsion system may also be intentional. The actions aiming at using the energy from the renewable sources refer also to biofuels.

Hydrogen, the wider use of which is also postulated in shipbuilding, is a perfect fuel in terms of the environment since water is a product of the combustion process. In nature, hydrogen in a free form occurs in a small amount as it combines easily with other chemical elements. Its resources are considered to be an infinite supply as it is a water component and together with it circulate in a closed cycle in the nature. However, in order to

produce hydrogen, energy is necessary. That causes that at the current conventional fuel price level hydrogen is less attractive. Nowadays the most of hydrogen is obtained from the decomposition of hydrogen-rich compounds, including hydrocarbon fossil fuels, which also involves CO₂ emission. If hydrogen is intended to replace hydrocarbon fuels then its production should be related with the use of the renewable energy. Only with such a production method hydrogen is a clean fuel.

Figure 1 presents a scheme showing how fuel type selection or the renewable energy sources and the solutions regarding the propulsion in an energetic system for a fishing cutter affect the environment load.

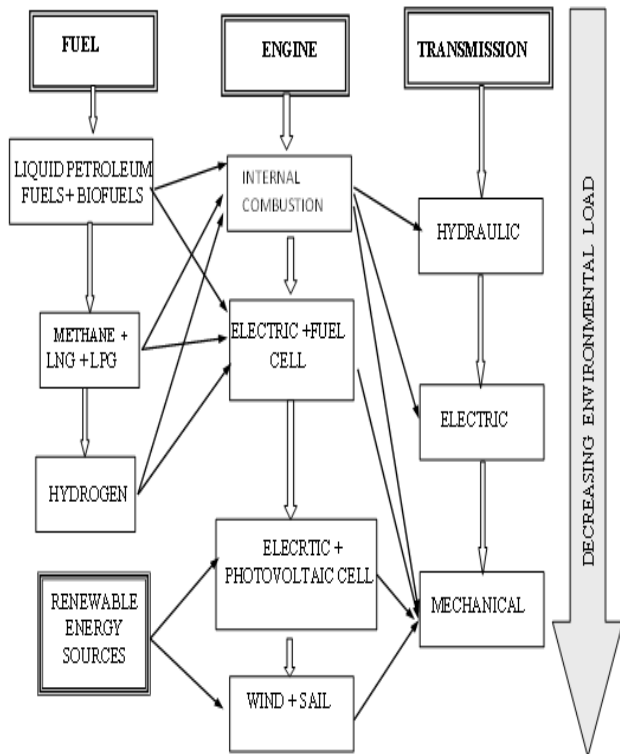


Fig.1. Impact of energy source and propulsion system configuration on environmental load

Figure 1 contains liquid and gas fuels which may be used at the ships. The renewable energy sources, as an alternative to the fuels, are included given the fact that their use has the minimum impact on the environment. In that case they are solar energy and wind energy. The proposal to install wind engine as the least burdensome environment may be also debatable, because in effect its impact on the environment is comparable with a photovoltaic cell supplying an electric motor.

Summing up, using the components listed in figure 1 leads to the development of a propulsion system that is more environmental friendly and energy saving, and thereby the entire energetic system for a fishing cutter.

3. Proposed energetic system

Complex energetic systems are at the fishing cutters in question. They consist of more technological devices of the higher total energy demand. Therefore, a proper solution regarding the energetic system is of particular relevance. In that group of the energetic systems many opportunities providing high efficiency occur. The selection of an appropriate energetic system will depend on the specific balances of mechanical energy, electricity and heat.

For instance, the systems with two engines for the main propulsion system may be considered. Such a system, presented in figure 2, is characterized by the high power availability of the wide range of variable operational conditions. An open issue is a power share of each engine i.e. whether to adopt two identical engines or of diversified power. Such solutions also increase

propulsion system redundancy. An alternative to the above may be, presented in figure 3, an energetic system occupying less space in the engine room with the use of a shaft generator, which may work also as an electric motor supplied by an auxiliary power generator set. Due to that an auxiliary or emergency propulsion system is provided. Such system's efficiency is slightly lower comparing to a system with two internal combustion engines driving the propeller by a mechanical gear. The final selection may be determined by an engine room size and operational issues. The said systems also include a boiler for heat generation. It should be also mentioned about recommended waste energy use contained mainly in the engine cooling water.

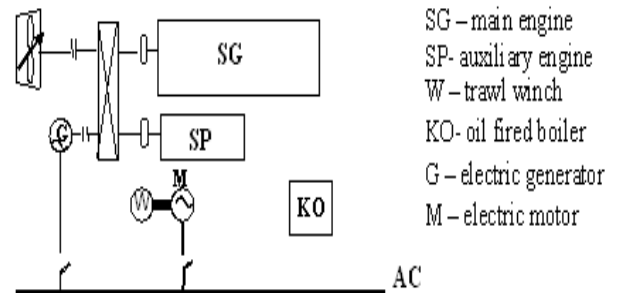


Fig.2. Energetic system scheme for a fishing cutter with two internal combustion engines

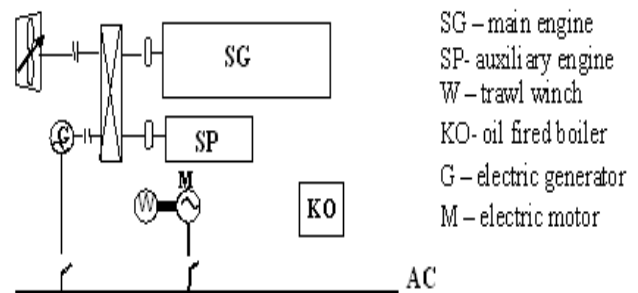


Fig.3. Energetic system scheme for a fishing cutter with internal combustion engine and shaft generator operating as engine

Particularly recommended solution regarding the energetic system is a system corresponding to a concept of all electric ships [1]. The proposed solution of such a system is presented in figure 4.

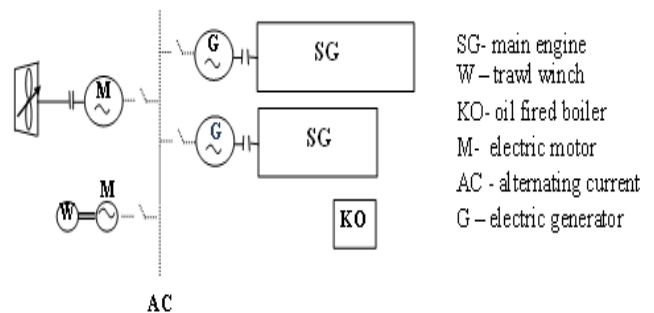


Fig.4. All electric ship energetic system scheme

As presented in the figures 2-4 it is possible to use hydraulic drive for winches instead of the suggested electric propulsion, however, the electric system is subsequently less effective.

4. Prospective energetic systems

It is essential that the decreasing resources of petroleum were taken into consideration upon developing solutions regarding prospective energetic systems for the fishing cutters and basing their work on unconventional fuels. In the short term it will also be possible to use natural gas since its resources are bigger than petroleum. Whereas, in the long term, only unconventional fuels as biofuels or hydrogen are remaining. Temporarily, it may also be intentional to use hybrid propulsion systems based on the

conventional energetic systems in relation with the unconventional energetic systems.

The use of hydrogen as the fuel is usually associated with storage problems due to its specific volume which results in the fact that its supplies require a large volume. In case of the fishing cutters with very limited autonomy usually to 72 hours, the issue virtually does not exist. The use of hydrogen as the fuel is possible not only in piston internal combustion engines but also in fuel cells constituting an electricity source.

For small vessels such as fishing cutters, low-temperature fuel cells may be particularly useful, especially PEMFC (Proton Exchange Membrane Fuel Cell) deemed as the most prospective [9,11]. They are characterized by low work temperature not exceeding 100°C, high density of generated current, short, measured in seconds, start-up period and the possibility of fast load changes. The efficiency of such systems is at the level of around 40%-50% and is higher than the efficiency of internal combustion engines of low power installed on the fishing cutters. The difference is even more noticeable in the partial loads on which internal combustion engines operate less economically than on the nominal load. However, the efficiency of the cells in that case is considerably higher. Such cells are promised to be used extensively in the automotive industry. Apart from the undoubted advantages presented above quite long durability should also be mentioned for this type of cells as well as the lack of competition for them in the ecology field.

The energetic system based on the fuel cell comprises of, except the cell as an electricity source, an inverter converting direct current generated in the cell into alternating current, batteries and electric motors.

One of the advantages of the fuel cells is that water is a byproduct of the reaction of so called hydrogen cold combustion in the cell and therefore due to that there is no need to ensure water supplies. Such a solution eliminates the necessity to dedicate separate room for technical water tanks and reduces the vessel weight. There is also an opportunity to use waste heat from the cell cooling system.

Nevertheless, it appears to be the most realistic in the near future to use the cells as emergency electricity source or to supply the propulsion system during sailing at low speed in ports or at water areas covered by restrictive regulations on exhaust gases toxic components or noise emission. The fuel cells may be also a very good alternative for diesel engine generator sets. Their use in that case comes down to produce electricity only in a limited period e.g. during maneuvers or stay at a port. They may also be used as a local energy source for individual receivers at a vessel.

The energetic system for the fishing cutter with the fuel cell as an auxiliary power source is presented in figure 5 below. While figure 6 shows the energetic system entirely based on the fuel cell, which shall be treated as the furthest prospect for execution.

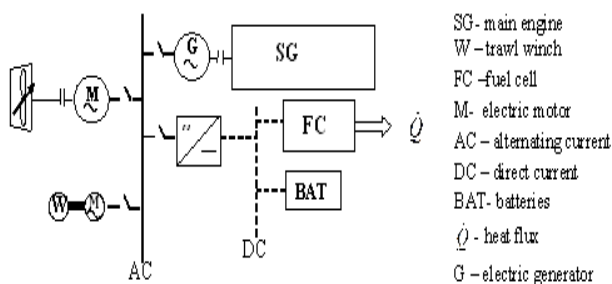


Fig.5. Energetic system scheme for fishing cutter with fuel cell as auxiliary power source

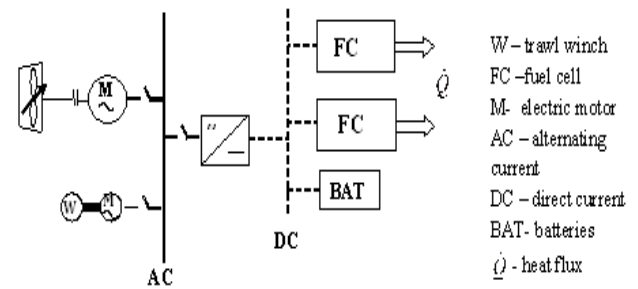


Fig.6. Energetic system scheme entirely based on fuel cell

Although costs regarding the energetic system solutions based on the fuel cells are still significantly higher than the cost of the energetic system solutions with internal combustion engines, their development potential should be borne in mind. Further price reduction should be expected upon cell volume production is commenced for vehicles.

Another prospective energetic system that may be applied, in particular at small fishing vessels using passive fishing gear, may be the hybrid system [4], which apart from an internal combustion engine, comprises also of the electric motor, supplied by batteries charged from the photovoltaic cell or from the shore.

Figure 7 presents a scheme of the energetic system with a photovoltaic panel.

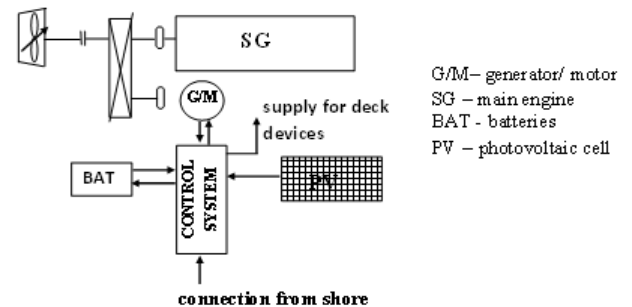


Fig.7. Scheme of hybrid system with photovoltaic cell

It is also possible to charge the batteries by the internal combustion engine when the electric machine operates as a generator. The propeller may be propelled by the internal combustion engine itself, by the electric motor itself or by both engines simultaneously. Sailing using only the electric motor, beyond the emission limitation of harmful exhaust gas components, has also an advantage that the energetic system does not emit noise.

Summary

The energetic system proposals for the fishing cutters presented in the paper are the concepts with regards to the modern and future technologies which may be applied in the shipbuilding, providing the reduction of energy consumption and impact degree on the environment. In order to select the solution for a specific vessel, the system efficiency should be determined, demand for mechanical energy, electricity and thermal energy should be specified on the grounds of an energy audit as well as machines and devices should be fitted.

The energies' demand is significantly affected by the hull resistance which depends on its shape, by catch type and the fishing gear related thereto. These issues are not presented in the paper as they have no decisive impact on the energetic system configuration. The employees of the Marine Engineering Faculty of the Maritime University of Szczecin have conducted research on marine energy issue for many years. An energy audit methodology has been developed [10], energy research has been carried out [2,3] as well as an energy audit of a number of the fishing cutters. The possibility to use LNG as the fuel has also been considered [8]. The research are implemented in close cooperation with fishermen, scientific and research institutions in

Poland and abroad and with the financial support from the European Union within the granted projects.

References

1. Ackermann G.: Electrical Systems—the Ship Propulsion of Tomorrow?, HANSA Maritime Journal, 8/2004,
2. Behrendt C. (redakcja): Raport z realizacji projektu nr 00017-61535-OR1600006/06 w ramach Sektorowego Programu Operacyjnego Rybołówstwo i Przetwórstwo Ryb 2004-06, działanie 4.6: Działania innowacyjne i inne pt. Opracowanie wytycznych do modernizacji jednostek rybackich w aspekcie zmniejszenia nakładów energetycznych i oddziaływania na środowisko, Szczecin, czerwiec 2008 r., str.1300,
3. Behrendt C.: Analysis of Fishing Cutter of the Polish Fishing Fleet and Structure of Their Power Systems, DEMaT'13 Conference, Rostock 2013, conference materials pp. 253 - 261,
4. Dymarski C.: System napędowy małej jednostki rybackiej, III Międzynarodowa Konferencja Naukowo-Techniczna Explo-Diesel & Gas Turbine '03, Gdańsk 2003,
5. Green Growth and Energy Use in Fisheries and Aquaculture, Organization for Economic Co-operation and Development, TAD/FI (2012),
6. Key Challenges to Promote the Energy Efficiency in Fisheries From a Research and Innovation Perspective, Report from workshop about energy efficiency organized by the European Fisheries Technology Platform, Madrid 2012,
7. Klyus O., Behrendt C., Rajewski P.: Reduction of Nitrogen Oxides Emission and Fuel Consumption in Fishing Cutter Engines, DEMaT'13 Conference, Rostock 2013, conference materials pp.293-300,
8. Rajewski P., Behrendt C.: Clean Shipping for Small Fishing Boats on Baltic Sea, DEMaT'13 Conference, Rostock 2013, conference materials pp.297-304,
9. Sattler G.: Brennstoffzellen Systeme für Maritime Anwendungen, 24 Duisburger Kolloquium, 2003,
10. Szczepanek M., Kamiński W.: Test Methodology Assumptions for Energy Test of Fishing Fleet Cutters, DEMaT'13 Conference, Rostock 2013, conference materials pp.263-270,
11. Zeńczak W.: Laboratory Testing of the Fuel Cells Applicability in Marine Power Systems, Marine Technology Transactions, vol.17/2006, pp.213-227,
12. Zeńczak W.: Koncepcja rozwiązania siłowni statku śródlądowego z ogniwem paliwowym, XXIII Sympozjum Siłowni Okrętowych, Gdynia 2002.