THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XI – SHIPBUILDING. ISSN 1221-4620
2016

PHOTOVOLTAIC TECHNOLOGY. THE FUTURE SOLUTION FOR SHIPS

Nicoleta Ivan
Technical College "Paul Dimo" Galati,
1 Dec. 18 Street, No. 27, Galati, Romania,
E-mail: nicoleta_ivan17@yahoo.com

Ionel Chirică
"Dunarea de Jos" University of Galati,
Domneasca Street, No. 47, 800008, Romania,
E-mail: ionel.chirica@ugal.ro

ABSTRACT

The energy sources onboard of ships has suffered many modifications in the last century, starting with sails up to marine diesel oil (MDO), which is the most used fuel for shipping. The consumption of MDO has been increasing since the shipping has been increasing. In the spite of the fact the ships produce the lowest emissions per tonne-kilometre, nowadays shipping policy is to find zero emission alternatives to the fossil fuels using. One of the best solutions is solar energy system (photovoltaic system) that now is currently used for small vessels. This new PV technology can be applied to large and medium-sized sea-going ships in special conditions. Research on the application of photovoltaic systems, which leads to significant energy savings and reduction of ships emission is presented in the paper.

Keywords: photovoltaic technology, solar cell, ship design, alternative energy.

1. INTRODUCTION

Emissions from the shipping industry have to be reconsidered in order to reduce air pollution. The International Convention MARPOL requires to be introduced measures, that have been applied in 2013, in order to minimise emissions. The general target is to reduce carbon dioxide emissions by 20% by 2020 and 50% by 2050 [1]. The achievement of these targets can be realised by using the cleaner fuel and new power solutions, that means including the use of renewable energies.

Renewable energy used for ships includes adopting solutions for main and/or auxiliary propulsion. In the last decade, some potential renewable energy options for ships have been used: wind (by using sails, fixed wings, rotors, or wind turbines), kites, photovoltaic (PV) systems, biofuels, hydrogen driven combustion, mobile wave energy converters etc [2]. These solutions are considered to be clean energy that can be integrated in the ship systems so for new buildings and by retrofitting existing ships.

The use of solar power solutions for ships leads to diminishing emissions and provides a clean source of renewable energy, resulting in the increase of operating costs.

The use of renewable energy in the shipping sector is of various kinds. One of them is a large amount of R&D for developing new project in this field.

Solar energy is the electromagnetic energy generated by nuclear fusion, which the sun transmits. The total energy transmitted by the sun is 420 trillion kWh. The electricity is produced from solar energy in several ways. The most popular ways use heating and photovoltaic (PV) panels. In the last decades, solar panels have been commonly used to capture solar energy. Depending on how solar energy is captured, converted and distributed, the solar power technologies are divided into two categories: passive and active.

Active technology uses thermal collectors and photovoltaic (PV) panels to capture energy. Passive technology uses: building orientation towards the sun, selecting materials with favorable thermal mass or light dispersing properties. For this type, the spaces are designed so that air circulates naturally.

Photovoltaic (PV) panels use the phenomenon of converting the light into electricity at the atomic level [3]. There are some materials with photoelectric properties, that means that under the action of sun beams they are able to absorb photons of light and to release electrons. Therefore, the electric current results by collecting electrons. The effect was firstly observed in 1839 by Edmund Becquerel.

However, the photovoltaic effect has been discovered in 1954, at Bell Telephone Company, when it was discovered that special materials as silicon can provide an electric charge when is exposed to sunlight.

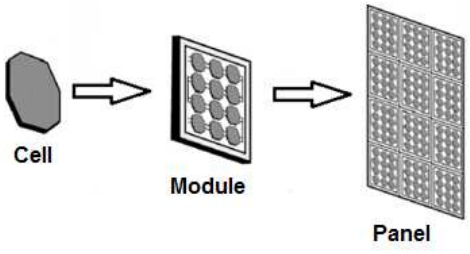

Fig.1. The structural compound of a PV panel

Solar cells (photovoltaic cells) consist of a thin layer made out of silicon or other semiconductor material. A special treatment is applied on this layer in order to form an electric field, positive on one face and negative on the other face. When the sunlight reaches the cell surface, electrons are released from atoms throughout the entire volume of the semiconductor material. These electrons are captured in the form of electrical current. By connecting a number of solar cells a photovoltaic module is obtained (see Fig. 1). These modules supply electricity as an ordinary 12-volt system. The current is influenced by how the light gets in the way.

By connecting a number of modules, a network (panel) can be created and electricity in direct current (DC) can be produced. As is usual for electric systems, the panels can be connected in series or in parallel, to produce the required current.

The electrical power *Ep*, in [Wh] per day, of a photovoltaic panel may be calculated according to the equation:

$$Ep = Wp \cdot Tss \cdot Tcf \quad (1)$$

In equation (1) *Tcf* is temperature correction factor, *Tss* is average number of peak sunlight hours per day, *Wp* is the power for each solar panel in [Wh].

The use of photovoltaic systems on ships is nowadays restricted to pleasure boats, or for the propulsion of solar boats for races. Due to the actual technology, the photovoltaic system is still recommendable to be used as a supplementary electric power system in order to diminish the diesel engine generator system.

Depending on the ship dimensions, according to [3] if a photovoltaic system is introduced within the ship electric system, the diesel engine power could be reduced by 20%. As a result NOx and SOx emissions are expected to be reduced by 25% and 17% respectively.

In this paper, a brief introduction to the use of photovoltaic generating system aimed to supplement electric power system is presented. The photovoltaic system is going to be practical, and its environmental friendly characteristics have to be analyzed according to a comparison of the present and future NOx and SOx emission for the proposed system.

2. PV TECHNOLOGY APPLIED IN SHIPBUILDING

The installation of photovoltaic (PV) plants to mainland became usual in the last decade. Special considerations have to be taken when this type of energy system is used onboard of ships. The most important difference between the mainland and ships PV applications is given by the environ-

mental conditions. During ship navigation, the photovoltaic systems are loaded to huge winds, high humidity and salt environment.

Due to the various ship routes the solar panels cannot fully exploit the sun radiation. Using mechanical moving systems the photovoltaic system can be more efficient.

The European Committee for Electro Technical Standardization (CENELEC) [4] has developed an IP Code (ingression protection rating) for measuring the electronic circuit protection levels [5, 6, 7].

The problems occurring due to the installation of the photovoltaic plants onboard of the ship are mainly:

- corrosion problems: all metal surfaces have to be galvanized or covered by special coatings and using special encapsulation materials;
- the systems do not have to disturb the cargo and human transfer on ship board. Thus, adequate installation areas have to be used;
- shading is other problem because, onboard of the ship, the open deck spaces are not very large. The shades cannot be exactly predicted because the ship orientation is changed almost continuously during navigation. To solve this problem, the special circuits and small-scale solar systems are preferable to be used onboard of ships [7].

The most important problem to install a photovoltaic system onboard of a ship is given by the very little deck space for placing up photovoltaic array on the deck. For example, in the case of a tanker, on the deck there are many pipelines.

Since the trend of photovoltaic energy sources on land hqs been increasing over the last decade in the shipping industry the trend is very slow.

In the Fig. 2, the schematic solar system is shown. The components of the system are: the solar panel aimed to produce the electric charge; charge controller (named also solar regulator) is designated to regulate the electric charge flowing into the battery and also to prevent the overcharging; batteries are used to store the electrical energy created by the solar panels; the inverter is aimed to convert DC into AC.

According to the calculus of the chosen photovoltaic system, in the scheme the battery and inverter capacities have to be used.

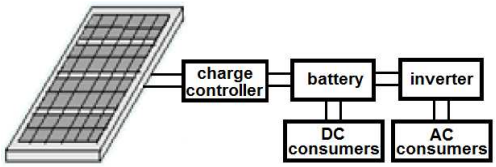

Fig.2. The schematic PV system

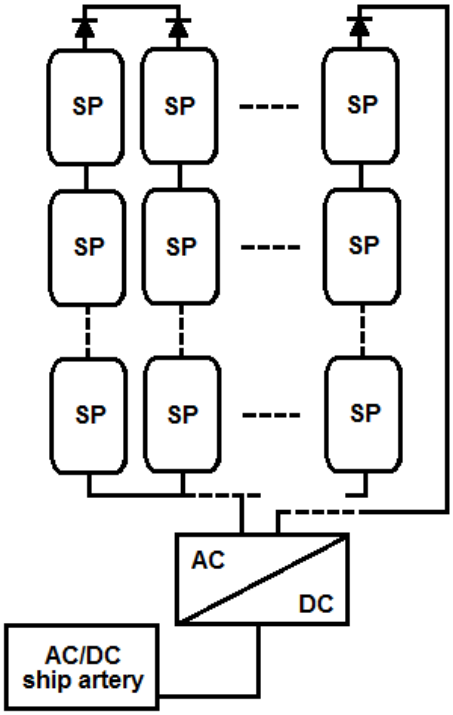

Fig.3. The Centralized technology

The power of a PV system depends on the number of the panels. All panels can be interconnected in parallel and in series (depending on current or voltage to be obtained). Four main technologies to interconnect panels and converters, on shipboard are used [8]:

1 Centralized technology, applied to solar systems with a big output power. A single

converter is used, for the group of panels connected in parallel (one panel is denoted with SP in Fig. 3).

2 String technology. Each group of panels has a converter, giving many advantages since the installed power capacity decreases (see Fig. 4).

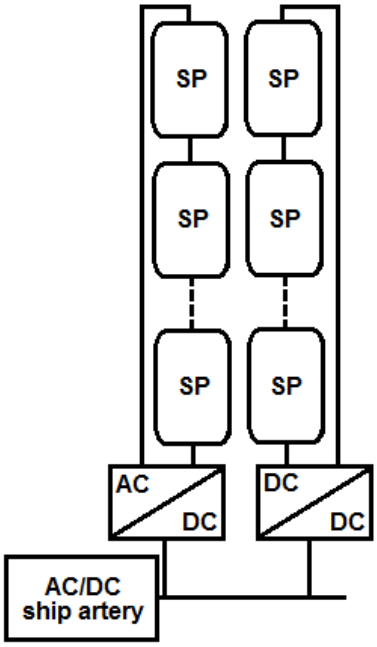

Fig.4. The String technology

3 Multistring technology which is an updated string technology. The power management is the same like in the case of the centralized technology. This technology assumes that many groups of panels with their own converters are used in parallel connections to a single central converter (see Fig.5).

4 MIC technology (module-integrated converter). The MIC is used for one phase applications. The output tension is of the 300 V (without using a transformer) (see Fig. 6). For ship applications, MIC technology may reach the output voltages of 400 V (DC or AC).

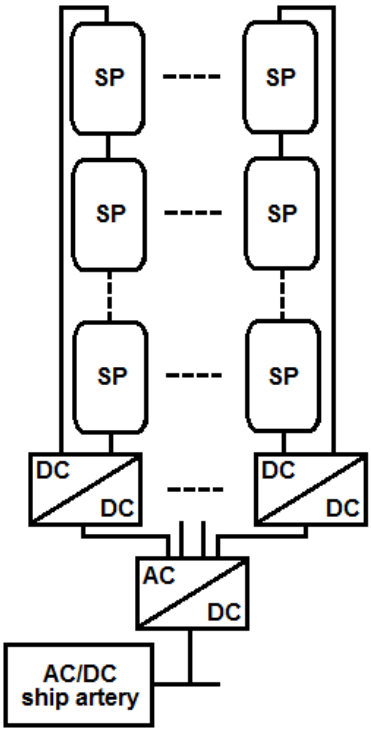

Fig.5. The Multistring technology

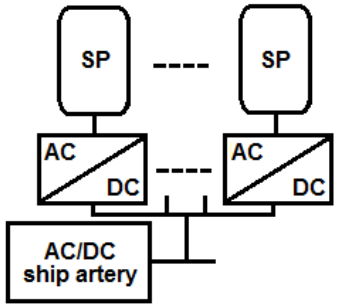

Fig.6. The MIC technology

A small number of small and pleasure ships having auxiliary PV panels has been built all over the world.

Auriga Leader (Fig. 7) is the first large ship built with auxiliary power partially supplied by PV panels installed on ship open deck. The main dimensions of the car carrier built in 2008 and owned by Nippon Yusen, are: L=200m, B=32.26m, D=34.52m. The photovoltaic system, having 328 solar panels,

operated for a total of 2600 hours had generated electricity of 32300kWh. The PV system provides 40kW that means about l0% of the ship power while anchored in port. The solar power system is integrated into the ship main electrical system. The PV system is integrated into the ship main electrical system and is able to provide 0.05% of the ship propulsion power and 1% of the electricity used on the ship being used for pumps and ship lights. Due to this type of electricity, in one year the fuel is reduced by 13 tons and the CO2 emissions is on about 40 tons [1,9].

Fig.7. The solar panels placed on Auriga Leader open deck [1]

3. CONCLUSIONS

The paper revealed several issues related to using of PV systems onboard of the ship.

Various alternate energy sources offer a great advance against fossil fuels using. Solar energy systems are currently used for small vessels. This new PV technology can be applied to large and medium-sized sea-going ships. Research on the application of marine grid-connected photovoltaic systems will lead to significant energy savings and reduction of ships emission.

Photovoltaic technology can be considered a promising energy sources to be applied on ships. It represents an alternative to the conventional energy generators on board.

The costs of a PV system and of course availability of solar energy are the main problems that have to be taken into account when a solar energy is designed to be used onboard of the ship. By using the photovoltaic technology to supply some of the ship power requires a reducing of fuel consumption and implicitly the reducing of the ship emission are performed.

A PV solar system installed onboard of ship can affect the ship stability, especially when the position of storage batteries are not considered accurately.

The design of an electric system that provides full use of a photovoltaic system on ship, in general, can be applicable to any ship types. In the near future, due to the advances in the technology of materials and systems many experiments could be carried out to verify the effectiveness of the system on the field.

PV technology can be considered as a promising energy sources to be applied on ships. It represents an alternative to the conventional energy generators on board of ships.

Acknowledgements

The present paper has been developed with the support of Ship Design Group Galati.

REFERENCES

[1]. *International Renewable Energy Agency, Renewable Energy Options for Shipping*. Technology brief. 2015.

[2]. **Jörg Sommer**, 2013, "*Ship propulsion by renewable energies available at sea: Innovations for utilisation of wind and waves"*, MARIN Wageningen.

[3]. http://www.solarmango.com/dictionary/photovoltaics/

[4]. www.cencenelec.eu/Pages/default.aspx

[5]. **T. Katagi, Y. Fujii, E. Nishikawa, T. Hashimoto, K. Ishida**, "*Photovoltaic Generating System on Ships to Reduce Fossil Fuel Dependence"*, Bulletin of the M.E.S.J., Vol. 24, No.2, 70-75, 1994

[6]. "*IP-ingress protection ratings*" http://www.engineeringtoolbox.com/ip-ingress-protection-d_452.html.

[7]. "*IP code*" http://en.wikipedia.org/wiki/IP_Code

[8]. **I. Kobougias, E. Tatakis, J. Prousalidis**, *PV Systems Installed in Marine Vessels: Technologies and Specifications*, Hindawi-Advances in Power Electronics, V. 2013 (2013), Article ID 831560, 8 pages.

[9]. *NYK and Nippon Oil Corporation Joint Project Auriga Leader Completes Seven Months of Voyages Using Solar Power*, http://www.nyk.com/english/release/31/NE_090908.html

Paper received on December 9th, 2016

