POLISH MARITIME RESEARCH Special Issue 2018 S2 (98) 2018 Vol. 25; pp. 176-181
10.2478/pomr-2018-0090

APPLICATION OF SOLAR PHOTOVOLTAIC POWER GENERATION SYSTEM IN MARITIME VESSELS AND DEVELOPMENT OF MARITIME TOURISM

Yaqi Shi[1]
Wei Luo, M.S.[2]
[1] Wuhan Technical College of Communications, Wuhan 430074, Hubei, China
[2] Hubei Urban Construction Vocational and Technological College, Wuhan 430074, Hubei, China

ABSTRACT

The use of new energy generation technologies such as solar energy and electric propulsion technologies to form integrated power propulsion technology for ships has become one of the most concerned green technologies on ships. Based on the introduction of the principles and usage patterns of solar photovoltaic systems, the application characteristics of solar photovoltaic systems and their components in ships are analyzed. The important characteristics of the marine power grid based on solar photovoltaic systems are explored and summarized, providing a basis for future system design and application. Photovoltaic solar cells are made using semiconductor effects that convert solar radiation directly into electrical energy. Several such battery devices are packaged into photovoltaic solar cell modules, and several components are combined into a certain power photovoltaic array according to actual needs, and are matched with devices such as energy storage, measurement, and control to form a photovoltaic power generation system. This article refers to the basic principle and composition of the land-use solar photovoltaic system, and analyzes the difference between the operational mode and the land use of the large-scale ocean-going ship solar photovoltaic system. Specific analysis of large-scale ocean-going ship solar photovoltaic system complete set of technical route, for the construction of marine solar photovoltaic system to provide design ideas.

Keywords: Solar photovoltaic system; Ship; Photovoltaic control system

INTRODUCTION

As the core part of the system, solar panels function to directly convert solar energy into direct-current form of electrical energy, and generally only output energy during the day when there is sunlight. According to the needs of the load, the system generally uses lead-acid batteries as the energy storage link. When the power generation is greater than the load, the solar battery charges the battery through the charger. When the power generation is insufficient, the solar battery and the battery simultaneously supply power to the load. Currently used grid-connected photovoltaic power generation systems have two structural forms. The battery-storage energy link is called schedulable grid-connected photovoltaic power generation system; the non-battery link is called grid-connected photovoltaic power generation system. For large-scale ocean-going vessels, a comprehensive analysis of the energy utilization optimization, program feasibility, system reliability, and economic efficiency, etc., the feasible photovoltaic energy utilization mode is the grid connection mode and off-grid mode [1,2,3]. Considering that a ship is a limited space body, the links among them, equipment and systems are very relevant, and the design process can refer to the design of land-use photovoltaic systems. But at the same time, we must also fully consider the differences between the land-use and marine-use PV systems. As a maritime mobile platform, large-scale ocean-going vessels must be equipped with any equipment to ensure the safety of vessels [4,5].

Building a solar photovoltaic system on a large-scale ocean-going vessel involves not only the ship power system, but also aspects such as the hull structure, safe operation of the ship, and economical analysis. Therefore, the installation and use of photovoltaic systems on large ocean-going vessels needs to be completed in stages according to actual conditions. Due to the differences in the structure, functions and applicable routes of different ship types, when a large-scale ocean-going ship is to build a high-power solar photovoltaic system, it is not possible to arbitrarily select a ship as a loading platform [6,7,8]. We must consider the arrangement of photovoltaic solar arrays in large areas, the level of safety protection, and the solar radiation resources of shipping lines. We can only select the target ship type through evaluation and analysis. When solar panels are installed on ships, they must meet safety regulations, maximize area, and aesthetic principles. At the same time, the stability, maneuverability and aerodynamic characteristics of the ship should not be excessively affected. It is necessary to evaluate whether the installation of solar arrays is reasonable by calculating the stability of ships and local strength. Analyze the photovoltaic cell conversion efficiency, anti-corrosion problems, and vibration impacts and safety guarantees when solar panels are used in marine environments, and verify the reliability of marine solar photovoltaic systems designed and installed. The application of solar photovoltaic technology in ships has been developed in recent years, and in particular, there have been preliminary successful application cases in small vessels and yachts on rivers [9,10,11]. However, in the area of ocean-going vessels, the application of solar photovoltaic technology is not yet mature, and many countries are committed to the development and improvement of this technology.

This article through analysis, plans to establish a set of solar photovoltaic power generation system in the conventional ship, to provide some power support for the ship, to achieve the purpose of energy conservation and emission reduction. The basic working principle of solar photovoltaic power generation is that under the sunlight, the energy generated by the solar cell module is charged by the controller to the battery or directly to the load when the load demand is satisfied. If the sun is insufficient or at night, the battery supplies power to the DC load under the control of the controller. For the AC load, an inverter must be added to convert the DC power into AC power [12,13,14,15]. The most significant feature of grid-connected photovoltaic systems is the direct current generated by solar cell components. The use of new energy generation technologies such as solar energy and electric propulsion technologies to form integrated power propulsion technology for ships has become one of the most concerned green technologies on ships. For the application of solar photovoltaic system in ships, based on the introduction of the principle of solar photovoltaic systems and the use of models, the application characteristics of solar photovoltaic systems and their components in ships are analyzed. The important characteristics of the ship-based power grid based on solar photovoltaic systems are discussed and summarized, which provides a basis for future system design and application.

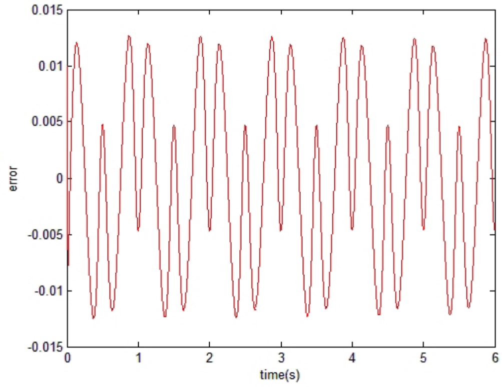

Fig. 1. The photovoltaic characteristics of solar photovoltaic arrays

PV SYSTEM INTRODUCTION

With the development of tourism and the development of tourism resources such as lakes and scenic spots, cruise ships, as a carrier of nature, have gradually become an entertainment way for people to travel and vacation. However, the problem of water, air and noise pollution caused by oil, water, and noise emitted from the cruise ship's power system has become increasingly serious, making the development of green ships more practical. Solar energy is a kind of renewable energy source, easy to get, and inexhaustible, inexhaustible, the application of solar energy on the cruise ship, its pollution problems will be solved. Therefore, there are more and more applications of solar photovoltaic systems on ships, and the application technology of solar energy has become one of the most important green technologies for ships. Because of the performance characteristics of the solar photovoltaic power supply system itself, it has its unique advantages and related constraints in its application.

Especially applied to the ship power grid, in order to obtain continuous, stable solar energy, and ultimately become an alternative energy source that can compete with conventional energy sources, it is necessary to solve the problem of energy storage. In other words, the solar energy in sunny days is stored to meet the needs of use at night or on rainy days. At the same time, efforts should be made to prevent hot spot, islanding, and grid stability. At present, these problems are the weakest links in the application of solar energy in ships, and have also become the key issues that we must consider in the design of marine solar applications in the future. The analysis made in this paper provides a design reference for solar photovoltaic systems in marine applications. The simulation results show that the model can correctly reflect the characteristics of the transformer ground fault, and protect the transformer in time. It has good quickness and stability. The differential protection model can provide an important basis for observation and analysis of transformer faults, and has a certain guiding role in the research and design of ship transformer protection devices in the future.

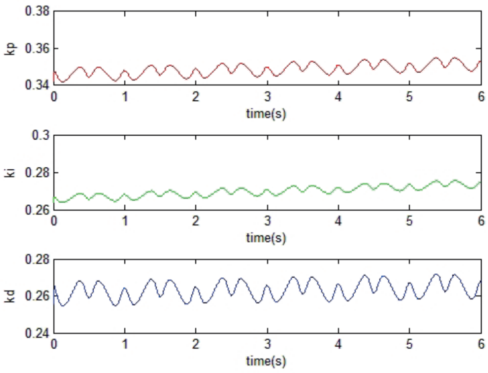

Fig. 2. Electricity boosting method program flow

OCEAN SHIP SOLAR PHOTOVOLTAIC SYSTEM OPERATION

The direct current generated by solar cells enters the battery first, and the characteristics of the battery affect the efficiency and characteristics of the system. The battery technology is very mature, but its capacity is affected by the amount of electricity at the end of the day and the duration of the sun (power generation time). Therefore, the battery watt-hour capacity and ampere-hour capacity are determined by the scheduled continuous sunshine-free time. The research on the reliability of photovoltaic systems in this paper is an important support to ensure the rational design, reliable operation, fault prevention and maintenance of photovoltaic power generation systems. After reviewing related application examples and domestic and foreign scholars' research on photovoltaic power generation system and reliability theory, a comprehensive analysis of the factors affecting the reliability of photovoltaic power generation systems was conducted. Summarized the evaluation of reliability indicators for photovoltaic power generation systems and proposed suggestions for improving the reliability of photovoltaic power generation systems. Photovoltaic power generation is based on the principle of photovoltaic effect, using solar cells to convert solar energy directly into electrical energy. Regardless of whether it is used independently or connected to the grid, the photovoltaic system is mainly composed of solar panels (components), controllers and inverters. The primary solution for photovoltaic applications is how to convert solar energy into electricity. Photovoltaic solar cells are made using semiconductor effects, which convert solar radiation directly into electrical energy. Several of these devices are packaged into photovoltaic solar cell modules, and then several components are combined into a certain power photovoltaic array according to actual needs, and are matched with energy storage, measurement, and control devices to form a photovoltaic power generation system.

The controller is a device that controls and manages the solar photovoltaic power generation system. "Because the controller can adopt a variety of technical implementation methods, the actual application of the controller to the controller is not consistent. Therefore, the functions performed by the controller are also different. The photovoltaic system operates under the control of the controller. The controller can use a variety of technical means to achieve its control function. More common logic control and computer control two ways. In harsh marine environment conditions, in addition to taking into account extreme weather issues such as hail, photovoltaic power generation system components in particular should consider the use of weather protection and salt spray protection devices in the marine climate environment. Although most glass covers for solar panels are made of toughened glass with high light transmittance, they are prone to a series of problems such as contamination in long-term environments with large temperature differences, large salt, and high humidity.

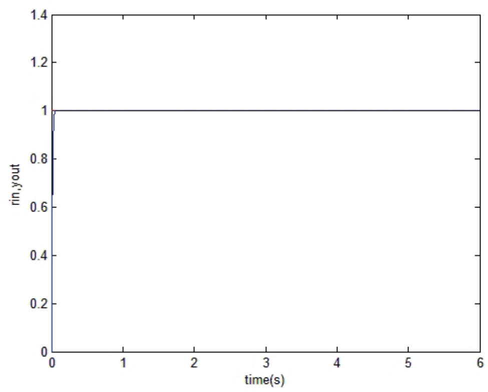

Fig. 3. Solar cell characteristics simulation model

To install and use solar photovoltaic systems on large-scale ocean-going vessels, in order to fully utilize the advantages of photovoltaic energy, it is necessary to conduct in-depth research on the power output characteristics of installed solar panels in the marine environment. In order to complete the optimal design of the photovoltaic system installation and power conversion control based on the characteristic parameters obtained in the specific environment. At present, solar photovoltaic technology has been applied on land on a large scale, and applications and innovations on ships have also been continuously improved. However, it can be seen from the existing solar ship cases that the application of PV technology to ships has fundamentally obvious constraints. Ships are a kind of transportation tools that work in marine complex environmental conditions. Its own power system is a network structure that is relatively independent and requires high reliability and stability.

By comparing the implementation mode and operational characteristics of land-use solar photovoltaic conversion and utilization technologies, the current status and trends of solar-powered ships are analyzed. Based on the selection of the target ship type, the analysis of the power system and the assessment of economic performance, the research direction for the application of solar photovoltaic technology to large-scale ocean-going vessels as an auxiliary energy source is identified. Completed the overall framework design process for marine solar photovoltaic power generation systems. From the point of view of green shipping and sustainable development, solar photovoltaic conversion does not produce secondary pollution to the environment because it generates non-chemical reactions. The effective use of photovoltaic energy will correspondingly reduce the work load of the ship generator set, which will inevitably be accompanied by a reduction in the amount of fuel consumed by the ship, the greenhouse gas emissions of the ship and harmful gas emissions. The research and design of solar photovoltaic technology and its application in large-scale ocean-going vessels have been conducted from both technical feasibility and economic feasibility. Completely discusses the power matching method, the system optimization analysis process and the consideration of related issues, and provides detailed analysis ideas, calculation methods, and data references for the evaluation of the early implementation process of the project.

Tab. 1. Indications of echocardiography

Codon	Hexadecimal	Codon	Hexadecimal
CUU	100	AUU	200
CUC	101	AUC	201
CUA	102	AUA	202
CUG	103	AUG	203
CCU	110	ACU	210
CCC	111	ACC	211
CCA	112	ACA	212
CCG	113	ACG	213
CAU	120	AAU	220
CAC	121	AAC	221
CAA	122	AAA	222

The solar cell's power output characteristics change in the marine environment, especially under water fog erosion and hull vibration conditions. Considering the idea: the former is mainly aimed at analyzing the change of physical and chemical characteristics of the light-receiving material on the surface of the battery under water fog corrosion, and determining the influence of the material change on the solar light transmission; The latter mainly analyzes the influence of the vibration of the battery substrate on the reflection and transmission of sunlight on the light-receiving surface, the dynamic change of energy. Based on the simplification of the solar cell in the simulation process of this test system, in the next step of research, the changes in the power output at different temperatures and different radiation intensities must be incorporated into the influencing factors of the entire grid-connected system to be considered. Harmonic waves in the solar PV inverter pollution and impact on the ship's power grid, hazards of islanding effects and remote monitoring of the PV system of the ship. The third major objective is to give an assessment of the working status of the PV system and provide technical support to the crew.

OPTIMIZATION AND ANALYSIS OF OFFSHORE VESSEL PV SYSTEM

The research and design of solar photovoltaic systems for large-scale ocean-going vessels is a relatively large system project. It involves not only the ship power system, but also the structure of the hull, the safe operation of ships. Therefore, how to select the right target ship to carry out optimization design and evaluation analysis of the entire system is the first problem to be solved. When transplanting the PV system to the ship, it is necessary to consider that the arrangement and installation of solar panels are easily affected by the placement and safe work of the deck machinery equipment such as pipelines, passages and cranes on the deck of the ship. Therefore, it is necessary to select the target ship type in a targeted manner and make some explanations for the rationality of the installation method of the photovoltaic system. Currently, crystalline silicon high-efficiency solar cells and various types of thin-film solar cells are the focus of research and development of new global solar cells.

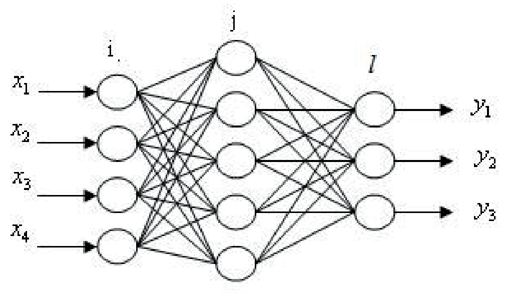

Fig. 4. Solar cell characteristics simplify simulation algorithm flow

The system can also act as a power regulator to stabilize the grid voltage! Harmonic components can be cancelled to improve power quality. In this system, the grid-connected inverter converts the DC power generated by the solar panel into AC power with the same frequency and phase as the grid voltage. When the main grid is powered off, the system automatically stops supplying power to the grid. When there is sunlight exposure and the AC power generated by the PV system exceeds the load, the excess will be sent to the grid.

$$y(k) = \frac{a(k)y(k-1)}{1+y^2(k-1)} + u(k-1) \tag{1}$$

Comprehensive analysis, the application of solar energy should consider its instability, mutation and low confidence characteristics, so the use of the ship, the following two types of situations are recommended:

$$X_{in} = [e(k), e(k-1), e(k-2), 1]^T \tag{2}$$

$$\left.\begin{aligned}
&\frac{\partial E(k)}{\partial y(k+1)} = -(r(k+1)-y(k+1)) = -e(k+1)\\
&\frac{\partial u(k)}{\partial O_1^{(3)}} = e(k)-e(k-1)\\
&\frac{\partial u(k)}{\partial O_2^{(3)}} = e(k)\\
&\frac{\partial u(k)}{\partial O_3^{(3)}} = e(k)-2e(k-1)+e(k-2)\\
&\frac{\partial O_l^{(3)}}{\partial net_l^{(3)}} = g[net_l^{(3)}]\\
&\frac{\partial net_l^{(3)}}{\partial \omega_{jl}^{(3)}} = O_j^{(2)}(k)
\end{aligned}\right\} \tag{3}$$

As solar energy is affected by climate and light conditions, there is a fluctuation phenomenon in power generation. Therefore, when an off-grid PV system supplies power to a load, auxiliary energy storage batteries are usually provided:

$$\frac{\partial E(k)}{\partial net_l^3} = \frac{\partial E(k)}{\partial y(k+1)} * \frac{\partial y(k+1)}{\partial u(k)} * \frac{\partial u(k)}{\partial O_l^{(3)}} * \frac{\partial O_l^{(3)}}{\partial net_l^{(3)}} \tag{4}$$

The capacity of the battery shall be determined according to the requirements of the effective time and proportion in the photovoltaic power generation throughout the day, and at the same time, a certain number of days of self-sufficiency shall be taken into consideration, so that the photovoltaic power generation system can meet the load requirements of the entire day:

$$E(k) = \frac{1}{2}(r(k) - y(k))^2 \tag{5}$$

As the proportion of power generation capacity of photovoltaic power generation system increases, it will directly affect the voltage stability of the power grid:

$$X_{in} = [e(k), e(k-1), e(k-2), 1]^T \tag{6}$$

Inrush current caused by unsynchronized voltage phases caused when power is restored may cause tripping again or damage to photovoltaic system, load and power supply system:

$$\frac{\partial O_j^{(2)}}{\partial net_j^{(2)}(k)} = f'[net_j^{(2)}(k)] \tag{7}$$

The solar controller is an automatic control device for controlling the solar cell array to charge the battery and the battery to supply the solar inverter load in the solar power system:

$$\frac{\partial net_j^{(2)}}{\partial \omega_{ij}^{(2)}(k)} = O_i^{(1)}(k) \tag{8}$$

Considering the installation and orientation, occlusion issues should also be considered, such as crystalline silicon solar cells, where very little shielding will cause a large power loss; However, the effect of shielding on the thin film battery will be much smaller. In addition, the ventilation conditions are very important for the cooling of solar modules. As the temperature increases, the power generation will decrease; and the module temperature will also have a certain influence on the installation method.

CONCLUSIONS

With the development of tourism and the development of tourism resources such as lakes and scenic spots, cruise ships, as a carrier of nature, have gradually become an entertainment way for people to travel and vacation. However, the problem of water, air and noise pollution caused by oil, water, and noise emitted from the cruise ship's power system has become increasingly serious, making the development of green ships more practical. Solar energy is a kind of renewable energy source, easy to get, and inexhaustible, inexhaustible, the application of solar energy on the cruise ship, its pollution problems will be solved. Therefore, there are more and more applications of solar photovoltaic systems on ships, and the application technology of solar energy has become one of the most important green technologies for ships. The grid-connected photovoltaic power generation system directly connects the direct current generated by the solar module to the public power grid after the grid-connected inverter is converted into an alternating current that meets the requirements of the mains grid. The grid-connected photovoltaic power generation system has centralized large-scale grid-connected photovoltaic power stations, which are generally state-level power stations. The main feature is that the generated power can be directly transferred to the grid, and the grid can be uniformly deployed to supply power to users. However, this kind of power station has a large investment, a long construction period, and a large area, and it is difficult to develop. The decentralized small-scale grid-connected photovoltaic system, especially the photovoltaic building integrated power generation system, is the mainstream of grid-connected photovoltaic power generation due to its advantages of small investment, quick construction, small land occupation, and strong policy support.

BIBLIOGRAPHY

1. Sukamongkol Y., Chungpaibulpatana S., Ongsakul W.: *A simulation model for predicting the performance of a solar photovoltaic system with alternating current loads*. Renewable Energy, Vol. 27, no. 2, pp.237-258, 2002.

2. Kolhe M., Kolhe S., Joshi J C.: *Economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India*. Energy Economics, Vol. 24, no. 2, pp. 155-165, 2002.

3. Dubey S., Tiwari G N.: *Thermal modeling of a combined system of photovoltaic thermal (PV/T) solar water heater*. Solar Energy, Vol. 82, no. 7, pp. 602-612, 2008.

4. Kolhe M.: *Techno-Economic Optimum Sizing of a Stand-Alone Solar Photovoltaic System*. Transactions on Energy Conversion, Vol. 24, no. 2, pp. 511-519, 2009.

5. Kolhe M.: *Techno-Economic Optimum Sizing of a Stand-Alone Solar Photovoltaic System*. Transactions on Energy Conversion, Vol. 24, no. 2, pp. 511-519, 2009.

6. Quaschning V.: *Technical system comparison of photovoltaic and concentrating solar thermal power systems depending on annual global irradiation*. Solar Energy, Vol. 77, no. 2, pp. 171-178., 2004.

7. Kelly N A., Gibson T L.: *Improved photovoltaic energy output for cloudy conditions with a solar tracking system*. Solar Energy, Vol.83, no. 11, pp. 2092-2102, 2009.

8. Ravindra M., Moharil, Prakash S.: *Kulkarni. Reliability analysis of solar photovoltaic system using hourly mean solar radiation data*. Solar Energy, Vol. 84, no. 4, pp. 691-702, 2010.

9. Hoppmann J., Huenteler J., Girod B.: *Compulsive policy-making—the evolution of the German feed-in tariff system for solar photovoltaic power*. Research Policy, Vol. 43, no.8, pp. 1422-1441, 2014.

10. Mandal P., Madhira S T S., Haque A U.: *Forecasting Power Output of Solar Photovoltaic System Using Wavelet Transform and Artificial Intelligence Techniques*. Procedia Computer Science, Vol. 12, no. 1, pp. 332-337, 2012.

11. Mbewe D J., Card H C., Card D C.: *A model of silicon solar cells for concentrator photovoltaic and photovoltaic/thermal system design*. Solar Energy, Vol. 35, no. 3, pp. 247-258, 1985.

12. Ilango G S., Rao P S., Karthikeyan A.: *Single-stage sine-wave inverter for an autonomous operation of solar photovoltaic energy conversion system*. Renewable Energy, Vol. 35, no. 1, pp. 275-282, 2010.

13. Richards B S., Conibeer G J.: *A comparison of hydrogen storage technologies for solar-powered stand-alone power supplies: A photovoltaic system sizing approach*. International Journal of Hydrogen Energy, Vol. 32, no. 14, pp. 2712-2718, 2007.

14. Patterson M., Macia N F., Kannan A M.: *Hybrid Microgrid Model Based on Solar Photovoltaic Battery Fuel Cell System for Intermittent Load Applications*. Transactions on Energy Conversion, Vol. 30, no. 1, pp. 359-366, 2015.

15. Natarajan S K., Mallick T K.: *Numerical investigations of solar cell temperature for photovoltaic concentrator system with and without passive cooling arrangements*. International Journal of Thermal Sciences, Vol. 50, no. 12, pp. 2514-252, 2011.

CONTACT WITH THE AUTHOR

Yaqi Shi, B. S.
e-mail:13026183800@163.com

Department of Electronics and Information Technology
Wuhan Technical College of Communications
6 Baishazhou Road
Hongshan District
Wuhan Hubei
430065
CHINA