Simulation and Design of Solar Power System for Ocean Buoy

Jingxin Chen¹, Yang Li², Xuen Zhang³ and Yaofei Ma⁴
Beihang University, No.37 Xueyuan Road, Haidian District, Beijing, China.
¹buaa1203cjx@126.com; ²buaa12031206@126.com; ³13240315291@163.com;
⁴mayaofeibuaa@163.com

Abstract. Promoting maritime power and improving the ability of planning ocean is considered to be an important issue of nation security and development in China, also a pivotal to implement ‘The Belt and Road’ strategy. As an automatic observation station on the sea, ocean buoys play a vital part in this strategy. The majority of ocean buoys, powered by accumulator, work far away from the shore. Thus, solar photovoltaic system is a valid supply power for ocean buoys, which can greatly improve the battery life and make ocean buoys more economical. This essay contraposes the problem of continuous power supply for ocean buoys working on the sea and design a solar photovoltaic system for ocean buoys that works on the South China Sea providing power of 1kW and voltage of 36V and also a protection of 72 hours supply on extreme occasions. In the end, there will be some expansion about other cities on their solar energy resources and solar photovoltaic system parameters.

1. Introduction
It is our responsibility and opportunity to vigorously carry out "The Intelligent Ocean" project to help implement the national maritime strategy and further enhance the informatization level of the marine industry. Offshore ocean buoys are a very important part of the ocean exploration. It is an automatic observation station that floats for a long time on the sea.

In other countries, research and development on ocean buoy began in the late 1940s and early 1950s. Ocean buoy was firstly applied to marine surveys in the 1960s. In the 1970s, ocean buoy entered a practical phase and the technology became more and more mature. Later on, there were more and more types of ocean buoys and fields of application became more and more comprehensive. Because of the continuous development of technologies such as micro-processing technology and satellite communication technology, the working capability of ocean buoy is getting stronger and more stable. At present, ocean buoy technology develops quickly in the United States, Japan, France, the Soviet Union, the Netherlands, Australia, Canada etc. In the middle of 1960s, China began to research and develop ocean buoys. Since the 1990s, the actual application of ocean buoys in our country has officially started. After promoted by the "Seventh Five-Year" national project, ocean buoy technology has been maturing and improving, which is gradually catching up with the United States, Japan and other countries that have an earlier and faster development in ocean buoys.

In general, ocean buoys are located offshore from land and cannot be interconnected with the public power grid on land. To power the ocean buoys and reduce the number of batteries used, a suitable power supply system is required. Solar power system (photovoltaic power generation system) is a good choice due to abundant solar energy and easy collection. Using solar energy to charging batteries, the number of replacement batteries can be greatly reduced, thereby cost reduced.
Optimizing the angle of the solar panel slope can further allow the system to accept as much solar radiation as possible. In July 2015, Baidu Cloud Computing (Yangquan) Centre’s solar photovoltaic power generation project was successfully connected to the grid. This is the first application of solar photovoltaic technology in domestic data centers [1].

2. Design of ocean buoy’s solar power system configuration scheme

2.1. Design principle
In the design and configuration of solar power system, it is necessary to meet the demand of the load under the conditions of safety. Improving reliability and reducing cost are also important. For a stand-alone solar power system, the design principle is to meet the load’s demand under different solar irradiances in different seasons. Because the solar radiation in winter is relatively weak [2], system designed should at least meet the load’s demand in winter.

2.2. Structure of solar power system and functions of each part
In this project, solar power system consists of the following four main parts:
- Photovoltaic cell array (solar panel)
- Storage Battery pack
- Photovoltaic controller
- Inverter

Structure of this system is shown in figure 1.

The functions of each part are as follows:
- **Photovoltaic cell array (solar panel)**[3]. Photovoltaic cell array consists of photovoltaic batteries in series and parallel, which is often seen in everyday life of solar panels. This is a very important core part of solar power system, ensuring that solar energy is converted into electrical energy. Electrical energy can be stored in storage battery pack. It can also be directly used to charge the buoy.
- **Photovoltaic Controller**. Photovoltaic controller is located in the unidirectional current channel between the photovoltaic cell array and the inverter, and it is bi-directionally connected with the storage battery pack to control the working status of the system, that is,
  a) The ocean buoy uses electrical energy from photovoltaic cell array.
  b) The ocean buoy uses electrical energy from storage battery pack.
  c) Provide over-charge protection and over-discharge protection for storage battery pack.
When the temperature difference between day and night in a large area, the controller can also provide temperature compensation. In addition, the PV controller also has many other features, such as the choice of light control switch or time switch, the system provides with electronic short circuit protection, overload protection or unique anti-reverse protection.

- **Storage battery pack.** As the name implies, this part can store electrical energy, in case that there is less or no solar energy in winter, at rainy days or at night, when photovoltaic cell array cannot produce electricity.
- **Inverter.** It can change DC power into AC power.

3. Modelling and calculation mechanism

3.1. Solar radiation’s calculation model

At present, the calculation models of incline irradiation mainly include the following:

- Proposed by Liu and Jordan, improved by Klein[4][5], and based on that solar has the same characteristic in isometric isotropy, this algorithm considers the scattered radiation and the ground-reflection radiation in isometric isotropy. The method is relatively simple but not accurate enough, which only has relatively high accuracy in spring equinox and autumnal equinox.

- Klin Klein and Theilacker proposed the average lunar bf illumination method (KT) in 1981, the algorithm shows anisotropy of solar energy in different direction in the sky, which improves the accuracy but increases complexity. [6]

The most important mathematical model above is KT proposed by Klein and Theilacker. This method can calculate the irradiance of the array slant plane with different latitudes, different orientations and different inclinations. In addition, Klein further analysed the calculation results and proposed a new quaternary method to adjust the inclination change period, which can further increase the annual irradiance obtained on the array surface.

In order to improve the accuracy of solar radiation calculation, KT method will be applied.

4. Simulation

4.1. User Interface Introduction

Simulation system in this paper achieves the aims below:

- Solar radiation modelling based on sky anisotropy model (KT method)
- Configuration of system capacity
- Optimization based on bevel inclination

Use MATLAB Graphical User Interface (GUI), these parts will be presented with a selection of interfaces, the interface is saved as a .m file named chooseplease. Open it and click the corresponding button, you can achieve the corresponding model program running.

4.2. Solar radiation calculation simulation

Solar radiation modelling based on sky anisotropy model (KT method) is shown in figure 2 and figure 3.
4.3. Configuration of photovoltaic cell array and storage battery pack

Take Haikou City as an example.

In the simulation system, solar energy system’s capacity configuration is realized through programming, the results are as follows. 250W polysilicon photovoltaic module is adopted. Its parameters and configuration are shown in table 1.

Table 1. Configuration of photovoltaic cell array.

| Rated power (W) | Open circuit voltage (V) | Peak operating voltage (V) | Short circuit current (A) | Peak operating current (A) | Serial number | Parallel number | Total power (W) | Total Weight (kg) |
|----------------|--------------------------|----------------------------|--------------------------|----------------------------|---------------|----------------|-----------------|------------------|
| 250            | 37.4                     | 30.3                       | 8.7                      | 8.08                       | 2             | 31             | 15179.088       | 1080             |

Parameters and configuration of storage battery adopted is shown in table 2.

Table 2. Configuration of storage battery pack.

| Specification   | Standard voltage (V) | Nominal capacity (Ah) | Reference Dimensions (mm) | Reference weight (kg) | Serial number | Parallel number | Total Weight (kg) |
|-----------------|----------------------|-----------------------|---------------------------|-----------------------|---------------|----------------|-------------------|
| JGFM-1200       | 2                    | 1200                  | 780                       | 475                   | 18            | 3              | 4266              |

4.3.1. Photovoltaic controller and inverter. Parameters of photovoltaic controller adopted is shown in table 3.

Table 3. Photovoltaic controller.

| Specification   | Rated voltage | Rated current | Number of input of PV array |
|-----------------|---------------|---------------|-----------------------------|
| SD48300         | DC48          | 300           | 6                           |
Table 4. Inverter.

| Specification | Input rated voltage (V) | Input rated current (A) | Rated output power (kW) | Range of input voltage (V) | Inverter efficiency |
|---------------|-------------------------|-------------------------|-------------------------|---------------------------|---------------------|
| SN482KS      | DC48                    | 48                      | 1.6                     | 42~64                     | 86%                 |

4.4. Simulation optimization on inclination of photovoltaic cell array s’ bevel
Take Haikou City as an example.

The MATLAB program is further improved, so that the inclination bb in the program is changed from 0 to 90 in a certain step, and the results of each angle value are compared. The main method used to generate a graph to compare irradiation parameters is shown in figure 4 and figure 5.

How solar radiation in winter varies with inclination is shown in figure 4.

![Figure 4. Slope of solar radiation in winter varying with inclination.](image)

How solar radiation of the whole year varies with inclination is shown in figure 5.
Therefore, combine situations in both winter and the whole year and through the modelling and optimization of this system in MATLAB, the inclination angle of photovoltaic cell array is modified to $\beta = 22^\circ$ in Haikou City.

5. Conclusions
In this paper, the practical problem about marine buoys has been solved. The design of ocean buoy’s solar power system has been established through detailed calculation of solar radiation, modelling and configuration of photovoltaic modules and battery pack. This system can provide 1kW, 36V power for ocean buoys in South China Sea, and in extreme cases it can supply up to 72 hours of continuous power. The simulation system has been optimized and expanded to make the calculation more accurate. At the same time, the configuration of the solar power system can be realized in 28 other major cities nationwide.

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