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Research on Application of a Three Dimensional Solar Power

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Abstract. Traditional transmission lines on-line monitoring device solar power supply usually adopts flat-panel structure, which has low energy use efficiency of solar power and easy to be destroyed by wind and rain. Therefore, a three-dimensional solar power is proposed in this paper. This structure includes the cube of solar power, hollow high transparency cylindrical shell, reflective films and bracket, and has carried on the hardware design. Then, the output power of three-dimensional and flat-panel structure solar power is discussed respectively under the condition of sunny, cloudy, overcast and rainy days. The results show that the efficiency of the three-dimensional solar power is higher. Finally, taking the South China power grid for transmission lines on-line monitoring device power consumption as an example, the application scheme of three-dimensional solar power supply in transmission lines on-line monitoring device is completed.

1. Introduction

Transmission lines inevitably go through harsh environments and complex environments, which can easily affect the operation status of transmission lines [1, 2]. Therefore, it is of great significance to obtain the status parameters of the line through the on-line monitoring device, and to evaluate the status of the line and fault warning [3, 4]. However, the power supply problems seriously restrict the application of on-line monitoring devices in transmission lines [5, 6].

At present, the power supply scheme of on-line monitoring devices for transmission lines mainly uses battery-coordinated solar power [7-9]. Among them, the solar power usually adopts a flat-panel structure. This structure has the following deficiencies: (1) Low efficiency, seriously affecting the output capacity of solar power, especially in the areas where solar energy is relatively scarce, the generated power is insufficient for transmission lines on-line monitoring devices [8, 9]; (2) larger, difficult to install. In addition, it is extremely vulnerable to the direct destruction of wind, rain and icing as well as adverse weather conditions, such as windy, rainy and overburden ice, affecting its reliability [6, 7].

Therefore, this paper proposes a three-dimensional solar power structure. Based on this structure, the theoretical design and hardware design are carried out. The experiments of three-dimensional and flat-panel are carried out under the conditions of sunny, cloudy, overcast and rainy days respectively. Finally, with the power consumption of the on-line monitoring device of transmission lines by China
Southern Power Grid, the application scheme of the three-dimensional solar power supply in the transmission lines on-line monitoring device is completed.

2. **Design and Characteristics of a Three-dimensional Solar Power**

2.1. **Design of a Three-dimensional Solar Power**

Figure 1 for the proposed three-dimensional solar power structure, the structure is mainly composed of the cube of solar power, reflective films, brace shaft and the fixed plate. Among them, the cube of solar power by the six 58 × 58 × 2 mm solar panels, can receive solar radiation in multiple directions, at the same time, the reflective films structure make the vertical direction of the sun's rays reflected to the cube solar power, thereby increasing solar power utilization efficiency of solar energy.

![Figure 1. Structure of tridimensional solar power.](image1)

In order to prevent the direct destruction of the solar power by wind and rain, and at the same time in order to facilitate the installation of solar power, thus design the shell and bracket. Among them, the shell is made of high strength acrylic material hollow high transparency cylinder, which has the functions of wind resistance and rain resistance, and its light transmittance up to 94%, the bracket made of aluminum, hinges and L type connectors, Figure 2 is a three-dimensional structure with a protective solar power supply and its site installation diagram.

![Figure 2. Framework of three dimensional solar power and its site installation diagram.](image2)

2.2. **Characteristics of a Three-dimensional Solar Power**

Compared with the flat-panel solar power, the three-dimensional solar power has the following characteristics: (1) The cube-structured solar power supply can receive light in all directions and increase the utilization efficiency of solar energy; (2) The reflective films structure reflects the light in
the vertical direction to the solar panel to increase the utilization efficiency of the solar energy and further increases the output power of the power supply. (3) The high transparency shell prevents the direct destruction of solar power supply device by wind and rain.

3. Experiments and data analysis

3.1. Experimental Design

In order to compare the power generation of the three-dimensional and flat-panel solar power supplies, a comparative experiment is designed as shown in FIG. 3. Figure 3 (1) capacitor C is used to store electric energy. Diode D is used to prevent the electric energy stored in the capacitor from flowing backwards. The multimeter is used to measure the voltage across the load. The rated power of the monocrystalline silicon solar cell is 220 mW and the rated voltage is 2V, the size is 58 mm * 58 mm. The energy processing module in FIG. 3 (2) is used to adjust the output voltage of the solar panel to the charging voltage of the battery, the battery is used to store the electric energy, the ammeter I\(_1\) and the voltage table V\(_1\) are used to measure the output current, voltage, ammeter I\(_2\) and Voltage meter V\(_2\) is used to measure the output current and voltage of the battery. The sliding rheostat is used as a variable load. The switches S\(_{s\text{ol}}\) and S\(_{s\text{bat}}\) are used to switch on the experimental circuit. The single-crystal silicon solar panel has a rated power of 100 W and a rated voltage of 12 V, the size is 840 mm \(\times\) 840 mm.

![Diagram of Three-dimensional Solar Power Experimental Principle](image1)

![Diagram of Flat-panel Solar Power Experimental Principle](image2)

Figure 3. Experimental schematic diagram of solar power

3.2. Experimental Results of Comparative Analysis

Through the experiments in sunny, cloudy, overcast and rainy days, the data of generation of flat-panel and three-dimensional solar power were obtained. As the solar panels used by the two power sources are different in area during the experiment, in order to effectively compare the power generation of the two power sources, the area of solar panels of the two power sources is converted into 1 m\(^2\), and the conversion results are shown in Table 1.

| Power Structure | Actual Area/mm\(^2\) | Conversion Coefficient | Converted Area/m\(^2\) |
|-----------------|----------------------|------------------------|-----------------------|
| Flat-panel      | 705600               | 1.42                   | 1                     |
| Stereo-type     | 20184                | 49.54                  | 1                     |

Table 1. The Result of Area Conversion of Solar Panels.
According to the conversion coefficient in Table 1, the experimental data of the two solar power sources in sunny, cloudy, overcast and rainy conditions are converted, and the converted data is shown in Table 2.

Table 2. The Output Power of Solar Power after converting to the same area

| Time | Flat-panel Sunny | Cloudy | Overcast | Rainy | Sunny | Cloudy | Overcast | Rainy |
|------|-------------------|--------|----------|-------|-------|--------|----------|-------|
| 7    | 1193              | 596    | 1044     | 447   | 5202  | 3270   | 446      | 149   |
| 8    | 2982              | 1193   | 1491     | 447   | 13673 | 3120   | 446      | 2081  |
| 9    | 17594             | 8350   | 2535     | 1044  | 17537 | 4310   | 8471     | 8917  |
| 10   | 17743             | 7455   | 2684     | 2535  | 11890 | 9809   | 4756     | 1189  |
| 11   | 17296             | 12823  | 5666     | 3131  | 12633 | 8769   | 7728     | 1338  |
| 12   | 18638             | 14612  | 6411     | 2237  | 11295 | 11147  | 6688     | 297   |
| 13   | 19234             | 14165  | 7306     | 2237  | 29278 | 15754  | 743      | 4161  |
| 14   | 18936             | 12524  | 7306     | 3578  | 15011 | 7580   | 4161     | 3270  |
| 15   | 19234             | 10586  | 3429     | 3578  | 21996 | 10552  | 4310     | 223   |
| 16   | 9095              | 895    | 1491     | 746   | 11147 | 7134   | 1338     | 193   |
| 17   | 7008              | 596    | 1491     | 149   | 6539  | 7728   | 594      | 178   |
| 18   | 2237              | 596    | 1044     | 149   | 1040  | 892    | 297      | 178   |

According to the experimental data in Table 2, it can estimate the daily output power of the two solar power sources under the four operating conditions after conversion, and draw them as the chart shown in FIG. 4.

Figure 4. Daily Output Power Statistical Graph of Stereo Solar Power

According to the statistical results in Fig. 4, the average power percentage of the three-dimensional solar power supply can be calculated as compared with that of the flat-panel solar power supply under the four conditions. The calculation results are shown in Table 3.

Table 3. The Daily Power Increase Percentage of Stereo Solar Power

|        | Sunny | Cloudy | Overcast | Rainy |
|--------|-------|--------|----------|-------|
| 4.0%   | 6.7%  | 4.7%   | 9.3%     |
Table 3 shows that in the same weather conditions, the three-dimensional solar power daily average output power is higher than the flat-panel solar power.

4. Application of Stereo Solar Power

Table 4 shows the power consumption requirements of China Southern Power Grid for on-line monitoring devices of transmission lines [9], in which the online status table terminal normally collects, transmits data and network communication and can respond to the status of the instruction issued by the master station in real time; Function is off, the network communication is not online, but can be promptly switched to the online status by SMS command; static refers to the sensor is turned off; daily power consumption refers to the on-line monitoring device only battery power supply (working voltage is 12 V) Online, the collection interval of 10 min, online monitoring device consumes the total amount of electricity within 24 h.

| Type of power Consumption                  | Demand of Power Consumption |
|-------------------------------------------|-----------------------------|
| Peak power consumption                    | ≤15.0W                      |
| Online acquisition power consumption      | ≤3.5W                       |
| Online static power consumption           | ≤1.0W                       |
| Acquisition power consumption in dormancy | ≤2.0W                       |
| Static power consumption in dormancy      | ≤0.6W                       |
| Daily power consumption                   | ≤2.5Ah                      |

According to the daily electricity consumption data of the on-line monitoring device of transmission lines in Table 4, the minimum average power to be provided by the three-dimensional solar power supply can be calculated as.

\[
P = \frac{2.5\text{Ah} \times 12\text{V}}{24\text{h}} = 1.25\text{W}
\]

(1)

Because the minimum average power is lower than the acquisition power and peak power consumption, the acquisition power consumption and peak power consumption can be met by reasonably designing the monitoring strategy and energy storage. Otherwise, the three-dimensional solar power needs to provide more than 15 W of output power at any moment in time to meet the peak power consumption requirement of the on-line monitoring device. However, when the monitoring device consumes less power, the energy is wasted. Therefore, in this paper, the minimum average power required by the power supply is taken as an indicator to study the application of the three-dimensional solar power.

Based on the daily average power statistics of the three-dimensional solar power system in Table 5, the daily average output power of the three-dimensional solar power system in the worst rainy weather conditions is 36.42 mW, while the three-dimensional solar power supply provides has a minimum average power of 1.25 W, the current design of a single three-dimensional solar power supply is insufficient for the transmission line on-line monitoring device.

| Sunny               | Cloudy     | Overcast | Rainy  |
|---------------------|------------|----------|--------|
| 264.67              | 151.25     | 73.75    | 36.42  |

If the three-dimensional solar power designed in this paper is used to supply the on-line monitoring device of transmission line, 35 sets of solar power must be installed on the transmission tower.
Considering that it is not feasible to install 35 sets of solar power on the transmission tower, Therefore, it is proposed to increase the effective area of a single set of three-dimensional solar energy units and to use a smaller number of solar cells to supply power to the on-line monitoring device of the transmission lines. As a result, the following design model was established:

\[ d = \sqrt[3]{\frac{35 \times S}{6n}} \]  

(2)

Where \( S \) is the total surface area (\( S = 20184 \text{ mm}^2 \)) of the current three-dimensional solar power source, \( n \) is the number of three-dimensional solar power units that meet the daily power consumption requirement of the on-line monitoring device, \( d \) is the side length of each solar panel in the improved three-dimensional solar power source. Due to the transmission tower and the installation conditions, so the actual situation of the three-dimensional solar power sets to choose.

5. Conclusion

Through the three-dimensional solar power hardware design, experimental research and application design, draw the following conclusions:

(1) Three-dimensional solar power using a cube power and reflective films structure, compared with the flat-panel structure can significantly improve the efficiency of solar energy. At the same time, the use of a high transparency shell reduces direct damage to the solar power by wind and rain.

(2) Through the comparison experiments of three-dimensional and flat-panel solar power, the three-dimensional solar power model can increase the utilization efficiency of solar energy by 4%, 6.7%, 4.7% and 9.3% respectively in four conditions of sunny day, cloudy day, overcast day and rainy day, the most obvious improvement is in rainy days.

(3) In order to apply the three-dimensional solar power to the on-line monitoring device of transmission lines, taking the power consumption demand of the on-line monitoring device of transmission line as an example, the design of the corresponding solar power application scheme is designed.

The development and trial word of actual device will be carried out afterwards.

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References

[1] LV Lili. Research on state online monitoring for high-voltage transmission lines. Wuhan, China: Huazhong University of Science and Technology, 2013.

[2] XU Wei. The research about monitoring device of tower of transmission electricity. Wuhan, China: Wuhan University of Science and Technology, 2012.

[3] WANG Kai, CAI Wei, DENG Yurong, et al. Application and management information platform for transmission line monitoring system. High Voltage Engineering, 2012, 38 (05): 1274 - 1280.

[4] DAI Dong, ZHANG Min, ZHAO Dongsheng, et al. On-line monitoring device for transmission lines and its communication network application. High Voltage Engineering, 2015, 41 (12): 3902 - 3908.

[5] CHU Qiang, LI Gang, ZHANG Jiancheng. Power supply of transmission line online monitoring system based on super-capacitor. Electric Power Automation Equipment, 2013, 33 (03): 152 - 157.

[6] XIONG Lan, HE Youzhong, SONG Daojun, et al. Design on power supply for the transmission line on-line monitoring equipment. High Voltage Engineering, 2010, 36 (09): 2252 - 2257.
[7] SUN Shuai. The Research and Design of Power System for Insulator Contamination on-line Monitoring. Xi’an, China: Xi’an University of Science and Technology, 2013.

[8] HE Youzhong. Study on power supply of on-line monitoring equipment for high voltage equipmen. Chongqing, China: Chongqing University, 2011.

[9] ZHAO Dongsheng, DAI Dong, LI Licheng, et al. Electric field energy harvesting around AC transmission line using impedance conversion of transformer. High Voltage Engineering, 2015, 41 (12): 3967 - 3972.

[10] Q/CSGXXX-2011, Technical specification for icing monitoring terminal device of transmission line of Southern Power Grid (Trial Version). 2011.