AUTOMATIC DESIGN OF SINGLE-STAGE SOLAR PHOTOVOLTAIC GRID-CONNECTED INVERTER SYSTEM

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Abstract - This study aims to improve the efficiency of energy conversion, and optimize the design of the solar cell structure based on the single-stage solar photovoltaic grid-connected power generation technology. Firstly, the characteristics of conventional power batteries are analyzed. Additionally, the inverter structure analysis is the characteristic research method of the inverter system. The advantages and characteristics of the system are analyzed through the re-architecture of the photovoltaic grid-connected inverter system. In addition, the solar power generation cooling and heat dissipation technology are systematically re-optimized through experimental simulation. The results show that, compared with the traditional power battery, the solar photovoltaic grid-connected solar cell design is more stable in current and voltage. The energy conversion efficiency of the battery is increased by 23%, which can better realize the continuous and efficient use of solar energy. When the outer resistance region is infinite, the current of the battery rapidly rises to nearly 300A, while the voltage rapidly drops to 0V. Additionally, through the simulation experiment, the simulation cloud diagram and the temperature rise curve compare the thermal characteristic parameters of the traditional power battery and the solar battery under different charge and discharge rates. The life and safety of the power system are studied and the changes of the battery under high and low temperature conditions are analyzed. Battery life decay and thermal runaway are simulated. The results show that with the increase of charge-discharge rate and the increase of cycle times, the usable capacity of the battery will decrease seriously. When the battery is internally short-circuited, the local current inside the battery is too large and the battery thermal runaway occurs. The results have practical reference value for the optimal design of solar photovoltaic grid-connected systems and the efficient utilization of solar energy resources.

Keywords: Solar energy; Photovoltaic grid-connected; Inverter system; Automation design.

1. Introduction

Energy is the material basis for maintaining basic human social activities. In the traditional energy structure, people mainly use fossil energy such as oil, coal and natural gas. The total amount of these fossil energy resources is limited [1, 2]. With the increase of the speed of social development, human's demand for energy is increasing rapidly, and the consumption of fossil energy continues to increase due to the unrestricted exploitation. Additionally, the extensive use of traditional fossil energy has caused pollution and damage to the environment. At present, the core of the world's energy work is to find and utilize renewable energy.

As a natural and renewable energy source, solar energy has received extensive attention in the energy field [3, 4]. The silicon content in solar cells is very rich. The cost and loss of solar power generation systems have dropped rapidly with the rapid development of solar cell research and the continuous improvement of energy conversion efficiency.

Additionally, as countries around the world increase investment in the development of new energy, as a new form of energy with market competition potential, solar power generation systems based on photovoltaic grid inverter power generation facilities have become an inevitable trend for future clean energy applications.

Solar photovoltaic power generation has great advantages. 1. solar energy is non-polluting and renewable. The resources are basically not restricted by regions, and high-quality electric energy can be directly delivered. 2. The energy storage is high, and the transmission line can be easily used for transmission, use and storage. 3. The distributed power system based on photovoltaic power generation can improve the security of the entire energy system.

Additionally, the energy loss of remote power transmission equipment can also be greatly saved. Therefore, solar energy storage and utilization will surely occupy an important position in the future development of human society.

However, the traditional solar energy conversion and utilization methods use light-thermal conversion and photo-chemical conversion. These methods have high cost and low energy conversion efficiency [5]. The production scale of solar cells is small, which is difficult to meet people's daily energy use needs. This study takes cost and energy conversion efficiency as the basic starting point, and analyzes the thermodynamic performance of traditional power batteries and solar cells. An improved solar photovoltaic grid-connected inverter system is proposed. Additionally, the inverter specifications used in the system automation design are analyzed and compared. A performance optimization method of solar photovoltaic cells based on photovoltaic grid-connected inverter system is proposed. These results can provide reference and reference for the optimization of solar power generation facilities and the sustainable development of clean energy.

2. Recent Related Work

2.1 Research on Energy Storage and Solar Power Generation Facilities

Scholars have conducted numerous studies on the development of energy storage and solar power generation facilities. Khan et al. (2018) [6] studied renewable energy in Bangladesh, through a comparative analysis of two power generation technologies, natural gas power generation and solar power generation. The results show that the utilization of renewable energy mainly based on solar power generation technology can alleviate the huge power pressure in Bangladesh, and provide resource support and technical guarantee for sustainable energy development. Jin et al. (2019) [7] estimated the public's willingness to pay for solar energy research and development (R&D) in Beijing, through a related study on the payment for solar power R&D in Beijing, China. The results show that respondents' education level, household income, risk attitudes, and attitudes and beliefs about energy issues have significant positive effects on their willingness-to-pay decisions. Bid value has a significant negative impact on its willingness to pay decision. Their research has a positive impact on the research and development of solar power generation technology and the utilization of renewable energy. Emmanuel et al. (2020) [8] studied power system planning and operating models for flexibility assessment in high solar penetration scenarios. By reviewing the flexibility assessment of power systems, they propose power supply security strategies to ensure transient stability under high penetration rates of asynchronous renewable energy sources. They focus on the high penetration of solar energy and other variable renewable energy sources.

The results show that the flexibility to use planning, operational and dynamic models to assess a range of spatial and temporal resolutions can help ensure safe, economical and reliable power operating systems. Ustemirov (2021) [9] proposed an improved solar heat transfer system for heating and hot water supply to buildings. Through related research on solar hot water supply equipment, it is assumed that the heat source can fully meet the expected demand of users. The research shows that the proposed solar heat transfer system can satisfy the user's supply of heat. These results have practical reference significance for the study of solar energy utilization and solar power generation technology.

In addition, studies on solar power generation facilities also demonstrate the importance of solar technology in future development. Hardianto (2018) [10] studied solar power plants in Indonesia. The results show that compared with traditional fossil energy sources such as coal, oil, and natural gas, solar power generation can continuously provide electricity. Additionally, solar power generation facilities do not require personal maintenance costs and can meet the electricity demand in rural and remote areas. Wang et al. (2019) [11] proposed a renewable energy utilization system based on solar energy and seawater desalination devices, using concentrated solar power plants and island solar energy utilization systems. This thermal storage system can save investment in battery storage by utilizing seawater desalination. The simulation results show that the proposed power supply system improves the utilization efficiency of renewable energy and the capacity factor of generator sets. Peak load demand is reduced, and unit capacity allocation is also reduced. Comparisons with other advanced systems show that the system is more cost-effective in areas with abundant renewable energy resources and high fuel costs. Gosens et al. (2020) [12] conducted a comprehensive study of China's development in the field of concentrated solar energy, and proposed a framework to compare the characteristics of formative and mature sectors. This framework is applied to the global concentrating solar power generation field.

The results show that the gap between China and the global leader in solar power technology capabilities and market competitiveness is significantly narrowing. Sahouane et al. (2021) [13] evaluated and studied the energy and economic benefits of photovoltaic grid-connected power generation systems in the Sahara Desert, and used the most appropriate and relevant performance indicators to analyze the performance of photovoltaic systems. The performance analysis results show that the losses of photovoltaic systems in deserts are high due to environmental factors.

Additionally, changes in environmental parameters have a direct impact on the performance of energy conversion efficiency and system losses.

2.2 Related Research on Photovoltaic Grid-connected Power Generation System and inverter

Among the many utilization schemes of solar energy resources, the use of photovoltaic grid-connected power generation systems for solar energy conversion and resource utilization is the focus of scholars' research. Kong et al. (2019) [14] proposed a model and control strategy for a hybrid power generation system. The simulation experiment of hybrid system verifies the validity of the model through the modeling and simulation research of grid-connected photovoltaic power generation system. This result has practical reference value for solving the strong randomness and obvious intermittency of photovoltaic power generation systems. Wang et al. (2020) [15] analyzed and studied the dynamic modeling process of distributed photovoltaic grid-connected systems, based on the average model and the corresponding linearization results. The key effects on the small-signal stability of the system are determined by eigenvalue analysis and root locus methods. The vector simulation and modeling results show that the power intensity of the Alternating Current (AC) system output by the photovoltaic array is a key factor affecting the signal stability of the distributed photovoltaic grid-connected system. Okundamiya (2020) [16] optimized and designed about the sizing of grid-connected power systems, and proposed the optimal architecture for the sizing of hybrid systems for unreliable grids and established using an energy balance approach. The findings suggest that the application of hybrid systems may help alleviate energy shortages in both rural and urban areas. This could provide a solution to the electricity problem that is holding back Nigeria's economic growth. Chikh et al. (2021) [17] used the power ratio and performance indicators to analyze the experimental performance of photovoltaic power generation, and conducted performance evaluation and research on multi-technology photovoltaic grid-connected test stations in arid regions.

The results showed that the plant performed best when the ambient temperature was between 2°C and 45°C. Based on the energy production and thermal stability results, their proposed photovoltaic system is the most efficient and most suitable solar power facility for dryland conditions.

3. Structure Comparison and Structure Optimization Design of Photovoltaic Grid-connected Inverter System

3.1 Structural Analysis of Inverter and Research on Characteristics of Photovoltaic Grid-connected Power Generation System

The traditional power battery mainly relies on the insertion and extraction of lithium ions between the positive and negative electrodes in the battery to complete the charging and discharging process (that is, the storage and release of electrical energy) [18, 19]. The packaging methods of commercial power lithium-ion battery cells are generally divided into winding packaging or stacking packaging. Cylindrical batteries are generally packaged by winding, and polymer square or soft-pack batteries are generally packaged in layers.

The two batteries are only packaged differently, and their internal materials and components are basically the same. In addition, the traditional photovoltaic grid-connected power generation system consists of a controller, an inverter and a photovoltaic array module. The inverter needs to be directly connected to the grid. In order to ensure the power quality transmitted by the grid, the output distortion of the inverter should be smaller than the sine wave. In order to increase the switching frequency of the inverter, the numerical control inverter system and the power field effect transistor are used to carry out the fusing operation of the small-capacity low-voltage system. Additionally, in order to prevent the islanding effect and ensure the safe and reliable operation of the power grid and the inverter, the transformer is used to effectively isolate the power grid.

The structural design of the photovoltaic grid-connected power generation system is shown in Figure 1.

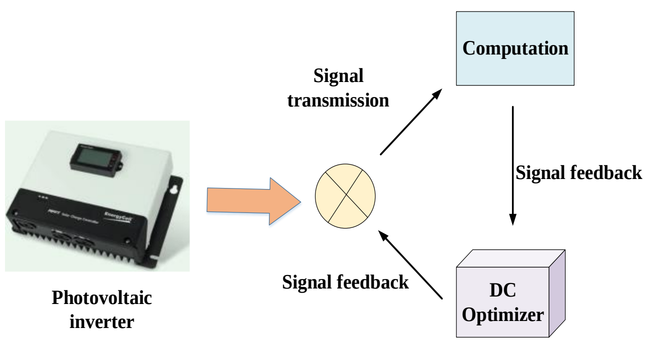


Figure 1: Frame diagram of the structural design of the photovoltaic grid-connected power generation System

3.2 Cooling and Heat Dissipation Technology and Heat Generation of Solar Power Generation

At present, there are many studies on photovoltaic grid-connected power generation technology and solar cell cooling and heat dissipation theory [20], and many mathematical models have also appeared. The internal heat generation of the solar cell is accurately described by the equation, as shown in equation (1):

$$\hat{U}_{SPV} = \hat{U}_{PV} + \frac{\hat{U}_{AC}}{N} + \hat{U}_{\text{lealage}} \tag{1}$$

$\hat{U}_{SPV}$ represents the voltage amplitude of the solar grid pipeline. N is the transformation ratio of the secondary side of the transformer. $\hat{U}_{AC}$ represents the clamp circuit voltage. $\hat{U}_{PV}$ represents the electrode voltage. $\hat{U}_{\text{lealage}}$ represents the parallel voltage of the PV array modules.

The photovoltaic power plant voltage ϕ_i of the photovoltaic array module is shown in equation (2):

$$\phi_i = \frac{k \cdot T}{q} \cdot \ln\left(\frac{N_a \cdot N_d}{n_i^2}\right) \tag{2}$$

N_a and N_d represent electron and hole densities, respectively. n_i^2 is the minority carrier density. k is the Boltzmann constant. q is the electron charge. T is the absolute temperature,

During the heat dissipation process of the battery, the heat is dissipated by transfer, heat convection and heat conduction. For common thermal management methods, the temperature of the fluid in the battery is mainly controlled by heat transfer and heat convection.

The structure optimization of the solar power generation system of the photovoltaic grid-connected inverter system is shown in Figure 2.

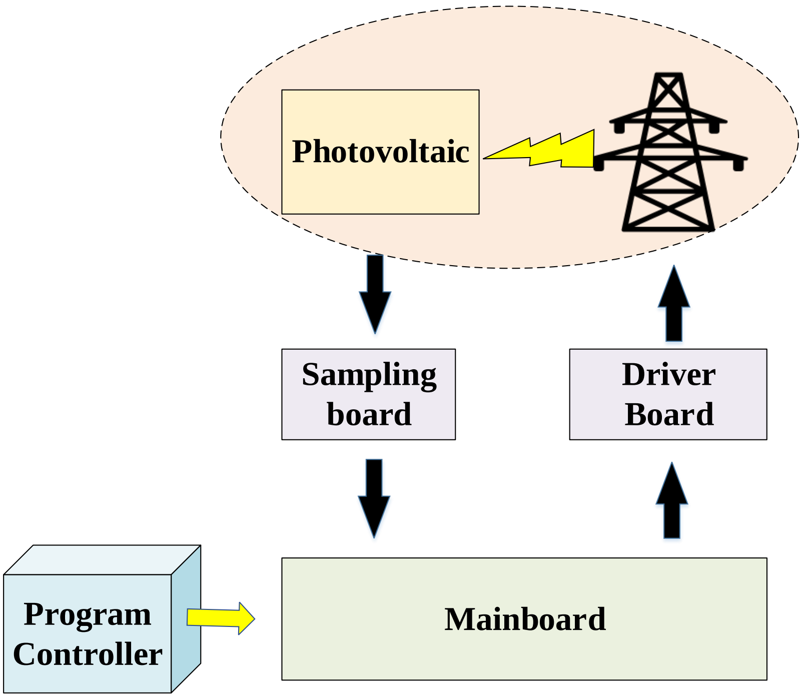


Figure 2: Structure optimization diagram of solar power generation system based on photovoltaic grid connection

When solving the photovoltaic grid model, it is necessary to measure the electrical conductivity of photovoltaic cells. Among them, the forbidden band width is an important physical quantity. The experience of the forbidden band width E_g is shown in equation (3):

$$E_g = E_{g(0)} - \frac{\alpha \cdot T^2}{\beta + T} \tag{3}$$

$E_{g(0)}$ is the forbidden band width at absolute temperature. α and β are experimental constants. The energy ε of solar photon radiation is shown in equation (4):

$$\varepsilon = h \cdot f = \frac{h \cdot c}{\lambda} \tag{4}$$

h is Planck's constant, f is the incident photon frequency, c is the speed of light, and λ is the wavelength.

When the temperature rises, the incoming sunlight will bring more electrons. The generation of photocurrent is shown in equation (5):

$$I_{ph} = \left(I_{ph,STC} + k_{temp} \cdot (T - T_{STC})\right) \cdot \frac{S}{S_{STC}} \quad (5)$$

I_{ph} and $I_{ph,STC}$ represent the amount of photogenerated current at the operating point and standard test conditions, respectively. k_{temp} is the temperature coefficient of the photogenerated current I_{ph}. T and T_{STC} are the battery temperature under actual and standard test conditions, respectively. S and S_{STC} represent the light intensity under the working point and standard test environment.

The internal heat of the battery of the solar photovoltaic grid is exchanged, and the current I_d flowing through the internal diode of the grid is shown in equation (6):

$$I_d I_0 = I_0 \cdot \left(\exp\left(\frac{q \cdot U_d}{k \cdot A \cdot T}\right) - 1\right) \quad (6)$$

Among them, I_0 is the reverse saturation current of the diode inside the photovoltaic cell. A is the carrier curve coefficient. U_d is the voltage of the equivalent diode. The variation model of the diode's reverse saturation current with temperature rise is shown in equation (7):

$$I_0 = I_{0,STC} \cdot \left(\frac{T}{T_{STC}}\right) \cdot \exp\left(\frac{E_g(\cdot q)}{k \cdot A} \cdot \left(\frac{1}{T_{STC}} - \frac{1}{T}\right)\right) \quad (7)$$

$I_{0,STC}$ is the saturation current under standard test conditions. $E_g(\cdot q)$ represents the conversion of the forbidden band width E_g from the amount of electrons to the amount of joules. For the cell resistance inside the photovoltaic grid, the signal impedance model of the instrument element is expressed as equation (8):

$$R_{PN} = -\frac{du_{pv}}{di_{pv}} = \frac{k \cdot A \cdot T}{q \cdot (I_d + I_0)} = \frac{k \cdot A \cdot T}{q \cdot \left((I_{ph} - I_{pv}) + I_0\right)} \quad (8)$$

R_{PN} represents the maximum impedance of the power point. u_{pv} represents photovoltaic voltage. i_{pv} represents photovoltaic current. $\frac{k \cdot A \cdot T}{q \cdot (I_d + I_0)}$ represents the photovoltaic resistance. The resistance of the plate capacitor is given by equation (9):

$$C_d = A_{disc} \cdot \sqrt{\frac{1}{2} \cdot \frac{q \cdot \varepsilon_0 \cdot \varepsilon_r}{\phi_i - U_d} \cdot \frac{N_a \cdot N_d}{N_a + N_d}} \quad (9)$$

ε_0 is the dielectric constant. ε_r is the relative permittivity of the semiconductor material. A_{disc} is the area of the upper and lower plates. C_d represents the capacitance value of the photovoltaic array module. N_a and N_d represent the width and height of the battery. The heat generated by the photovoltaic cell T_{Ploss} is given by equation (10):

$$T_{\text{Ploss}} = P_{\text{loss}} \cdot \frac{R_{\theta,JA}}{s \cdot R_{\theta,JA} \cdot C_\theta + 1} \quad (10)$$

T_{Ploss} represents the total heat generated by the photovoltaic cell. P_{loss} is the energy converted to heat. $R_{\theta,JA}$ is the thermal resistance. C_θ is the thermal capacitance. s is the ambient temperature. $R_{\theta,JA}$ is the Laplace operator of photovoltaic cells.

3.3 Experimental Simulation of Solar Single-stage Cells

The solar cell simulation experiment is based on Comsol software for solar-electric coupling. The software's conjugate heat transfer and electrical energy interfaces are utilized in the simulation. A one-dimensional single-stage battery model simulates the electrochemical process. A 3D lithium-ion battery model simulates battery heat transfer.

The two models are coupled through the temperature variable T, enabling a coupled solar-electrical simulation. The performance difference between power battery and solar battery is shown in Figure 3.

(a) (b)

Figure 3: Comparison of power battery and solar cell (a. power battery; b. solar cell)

In the simulation, the initial temperature is set to 25 °C, and the battery size is 230 × 160 × 8 mm. The ambient temperature is set to 25°C, and the inlet air velocity is set to 0.1 m/s to simulate the air flow due to the slight disturbance of hot air during natural cooling. The battery charge and discharge rate is 1C. In addition, computer software is used to perform data performance analysis.

The operating system of the software is Linux 64-bit, the Python version is Python 3.6.1, and the development platform is PyCharm. In hardware, the CPU is Intel Core i7-7700@4, 2GHz 8-core, and the memory is Kingston ddr4 2400MHz 16G. The results of the thermal simulation of the solar cell are shown in Figure 4.

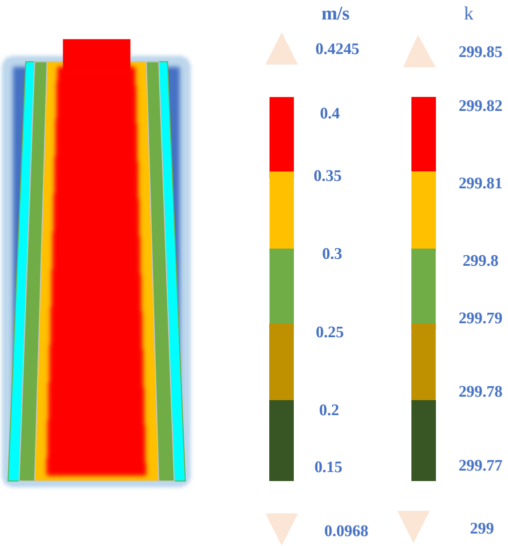


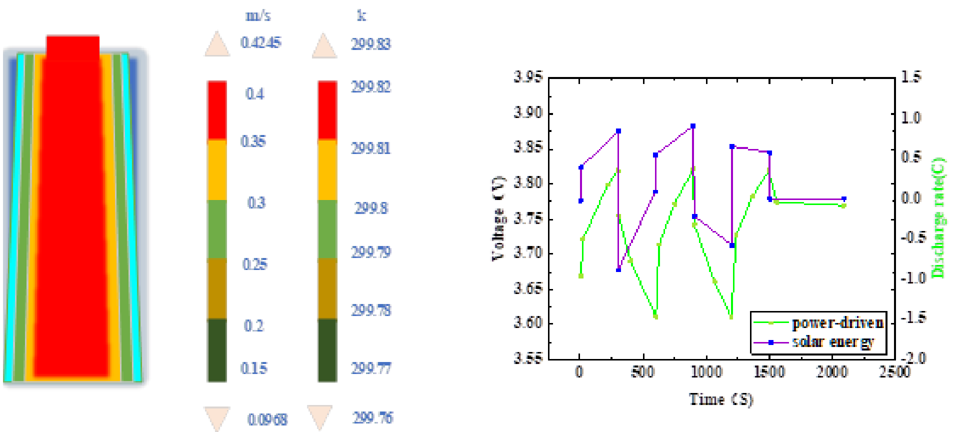
Figure 4: Experimental results of thermal simulation of solar single-stage battery

4. Experimental Results

4.1 Performance Analysis of Solar Cell Simulation

Generally, the mandrel wound inside the commercial cylindrical battery is the nylon mandrel. It has a low thermal conductivity and is prone to heat accumulation, resulting in battery performance degradation.

Therefore, a novel cylindrical solar photovoltaic cell structure is proposed. It uses the heat pipe to replace the nylon mandrel to improve the heat dissipation performance of the single battery, and uses software to simulate the effect of the new structure. The current-voltage curves and simulated temperature distributions of the power battery and the solar battery are compared and analyzed under the 1C charge-discharge condition, as shown in Figures 5 and 6.



(a) (b)

Figure 5: Comparison of the current-voltage curve and simulated temperature distribution of the traditional power battery (a. the simulated temperature distribution of the power cylindrical battery under the 1C charge-discharge condition; b. the current-voltage curve of the power cylindrical battery under the 1C charge-discharge condition)

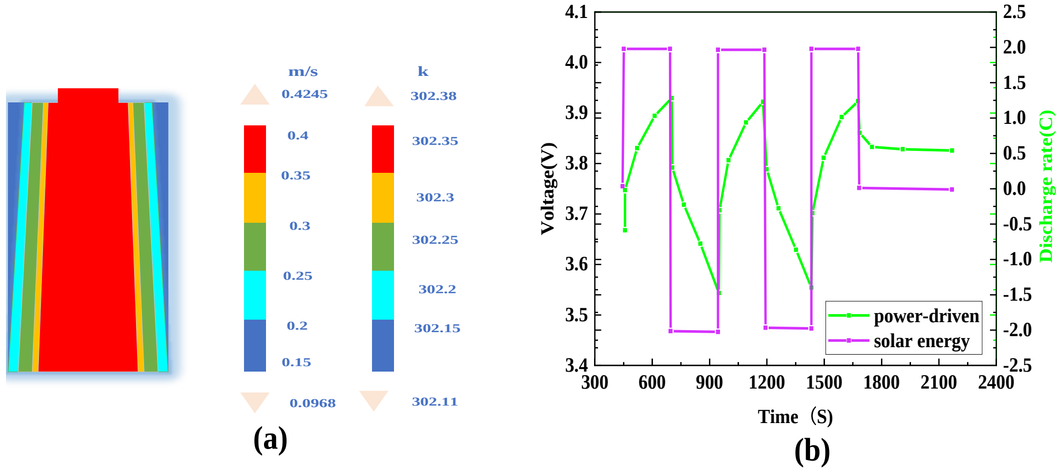


Figure 6: Comparison of the current-voltage curve of the solar photovoltaic cell and the simulated temperature distribution (a. the simulated temperature distribution of the solar photovoltaic cell under the 1C charge-discharge condition; b. the current and voltage of the solar photovoltaic cell under the 1C charge-discharge condition curve)

In Figures 5 and 6, under the cooling condition of 0.1m/s and the charge-discharge condition of 1C, the maximum battery temperature is 299.83 K after the power battery has been cycled for 1500 s. This is about 0.5°C higher than the initial temperature, which is slightly higher but almost unchanged. Under the same conditions, the temperature of the solar photovoltaic cell increased by 3.23 °C during discharge. The temperature rise is more intense compared with the discharge of the power battery. The larger the discharge rate in the temperature cloud diagram, the worse the thermal uniformity of the single battery, that is, the greater the temperature difference between the various parts of the battery. The data results show that the discharge efficiency of solar cells can be increased by 23% compared with traditional batteries. The energy conversion efficiency is greatly improved.

4.2 Battery Cooling and Heat Dissipation Optimization Performance

Generally, the mandrel wound inside a commercial cylindrical battery is a Nylon mandrel, which has low thermal conductivity and is prone to heat accumulation, resulting in battery performance degradation. Therefore, a new cylindrical solar cell structure is proposed: the heat pipe is replaced by the Nylon mandrel to improve the heat dissipation performance of the single cell, and a simulation experiment is carried out to verify the effect of the new structure, as shown in Figure 7.

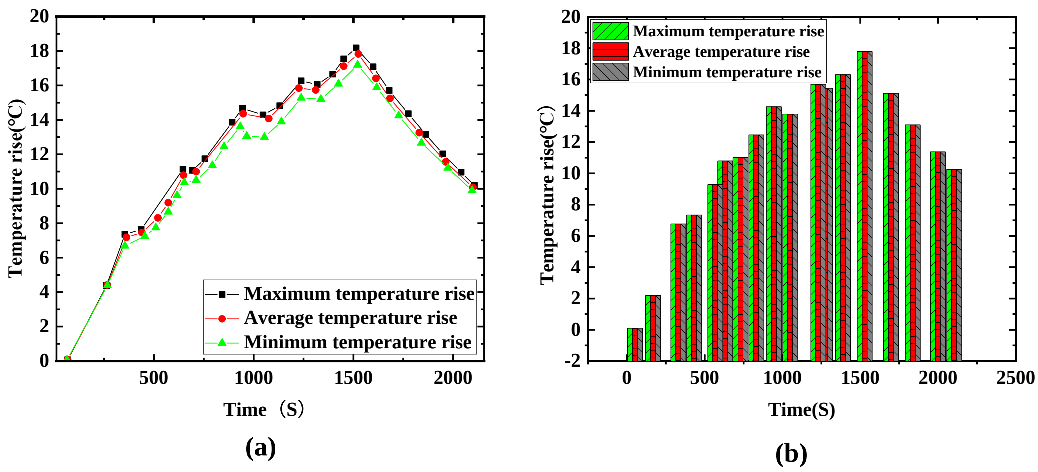


Figure 7: Comparison of the temperature rise of the heat pipe mandrel and the nylon mandrel in the power grid inverter system (a. The temperature rise curve of the inverter system using the heat pipe mandrel; b. The temperature rise curve of the inverter system using the nylon mandrel)

The three-dimensional model of the battery uses a cylindrical battery as a prototype, that is, a battery with a diameter of 18 mm and a length of 65 mm. The cells are charged and discharged at a 3C charge-discharge rate with an initial temperature of 25 °C. The inlet air velocity is set to 0.5 m/s to simulate the state of the battery under air cooling. The temperature nephogram of the simulation results of the Nylon mandrel shows that the temperature of the center of the battery is higher than that of the surface, and the maximum temperature difference of the whole battery is 1.14°C. The replaced temperature distribution cloud map shows that its maximum temperature is 315.95 K, which is significantly lower than the temperature of 316.46 K of the Nylon mandrel. In addition, the maximum temperature difference of the battery body is 0.17°C, which is also significantly lower than the 1.14°C before being replaced. The heat pipe mandrel is replaced with the Nylon mandrel, the maximum temperature rise of the battery was reduced, and the temperature difference of the battery was significantly improved.

After being replaced, the heat dissipation performance is significantly improved, which can improve the solar energy conversion efficiency of the grid inverter system.

4.3 Analysis of Power System Loss and Battery Life Attenuation Performance

The attenuation and degradation of photovoltaic grid-connected power systems are affected by many factors, which are related to the current density and material concentration distribution at different locations. To simulate the effect of different charge-discharge rates on battery performance, a software electrochemical interface is used to model the decay of medium and renewable energy sources. The simulation process uses a one-dimensional lithium-ion battery model as a basis to model the solar organic cations. The voltage curves of the first charge and discharge of the battery under the conditions of 1C, 2C, and 3C charge and discharge cycles are shown in Figure 8:

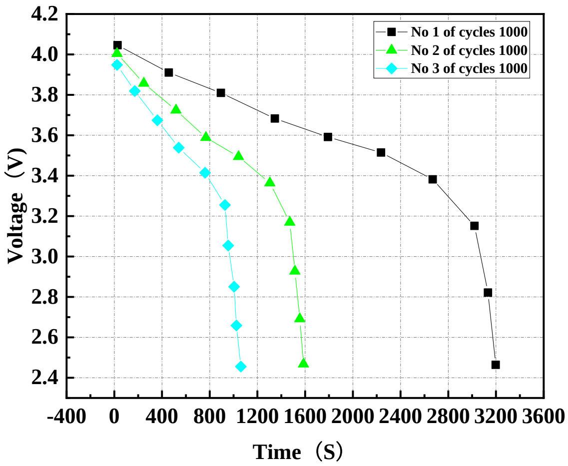


Figure 8: Comparison of the cycle voltage drop of solar photovoltaic cells at different charge and discharge rates

In Figure 8, the voltage drop of the battery increases as the rate of charge and discharge increases. When discharging at 3C, it takes 1050s for the voltage to drop to the cut-off voltage. The 1C and 2C discharge times required 3000s and 1480s, respectively. In addition, the voltage drop during the discharge cycle of the last cycle is also significantly different from that during the discharge cycle of the first cycle. The voltage drop at the last cycle discharge is faster. A large rate of charge and discharge will significantly reduce the performance of the battery.

4.4 Safety Performance Analysis of Solar Photovoltaic Cells

The maximum voltage of the solar cell used in the simulation is 4.2V at full capacity. In the simulation, a two-dimensional axisymmetric model is used for modeling, and the ambient temperature and the initial temperature are set to 25 °C. The open-circuit current and short-circuit voltage of the solar photovoltaic cell are shown in Figure 9.

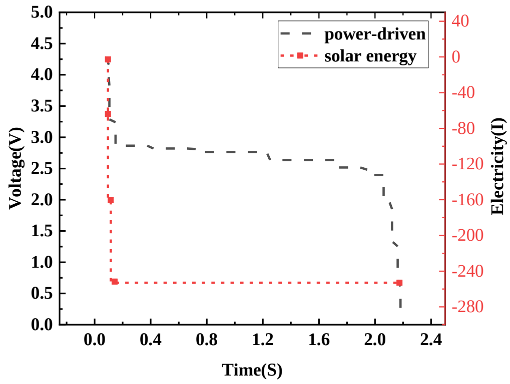


Figure 9: Solar cell open circuit voltage and current curve

In Figure 9, when the external resistance region is infinite, the current rapidly rises to nearly 300 A. The voltage drops rapidly to 0V. Solar cells have stronger safety performance and are generally not prone to short circuits compared with traditional power batteries.

In addition, the conversion efficiency is low, and the energy of the solar photovoltaic module cannot be fully utilized. Based on the solar photovoltaic grid-connected power generation system, the structure of the existing photovoltaic module inverter system is analyzed and compared from the perspective of cost and energy conversion efficiency. Simulation cloud images and temperature rise curves are used to compare the thermal characteristics of traditional power batteries and solar cells at different charge and discharge rates.

The results show that with the increase of charge-discharge rate and the increase of cycle times, the usable capacity of the battery will decrease seriously.

However, the proposed solar temperature change of the cell during the external short circuit of the solar cell is shown in Figure 10.

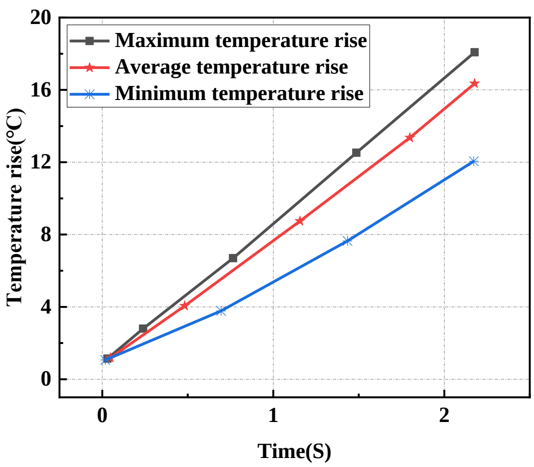


Figure 10: Instantaneous temperature rise change diagram of the inverter inside the solar cell

Figure 10 shows the maximum temperature rise, average temperature rise and minimum temperature rise of the battery at the moment when an external short circuit occurs. The battery temperature curve shows that the maximum temperature rise inside the inverter of a single solar photovoltaic system can reach nearly 20°C within about 2s after the short circuit occurs. The minimum temperature rise is around 12°C, and the temperature difference of the transformer inside the single cell can reach 8°C. This can seriously affect the performance and safety of the battery.

5. Conclusions

The traditional photovoltaic grid-connected power generation system is too large and inflexible in design. There is a large energy loss between each photovoltaic module, and the energy conversion efficiency is low, and the energy of the solar photovoltaic module cannot be fully utilized. Based on the solar photovoltaic grid-connected power generation system, the structure of the existing photovoltaic module inverter system is analyzed and compared from the perspective of cost and energy conversion efficiency. Simulation cloud images and temperature rise curves are used to compare the thermal characteristics of traditional power batteries and solar cells at different charge and discharge rates. The results show that with the increase of charge-discharge rate and the increase of cycle times, the usable capacity of the battery will decrease seriously. However, the proposed solar photovoltaic grid-connected system and battery scheme are only at the theoretical research level, and the simulation of single cells is only a preliminary research result. Therefore, some deficiencies still exist. These areas need to be improved:

(1) Due to the limitation of computer performance, the battery model is simplified. When studying the battery, the battery is regarded as a uniform heat generating body. The internal structure of the battery will be refined, and the positive and negative terminals of the battery will be added to enhance the accuracy of the theoretical simulation data.

(2) The parameters of the battery are calculated by the weighted average algorithm of the theoretical equation and are fixed and do not have high precision. In the future, various battery data will be dynamically detected.

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