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# Power Smoothing Control of Photovoltaic Power Generation System based on Hybrid Energy Storage

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**Abstract.** Among many renewable energy sources, solar energy is widely used, and photovoltaic power generation has become an effective way of solar energy utilization. In recent years, it has been widely studied and applied, and remarkable results have been achieved. However, due to the influence of sunlight intensity and temperature, the power of the photovoltaic power generation is relatively fluctuating, so there are still some problems in large-scale grid-connection technology. In this paper, to direct at the power fluctuation of photovoltaic power generation caused by the change of illumination intensity and temperature, an energy storage photovoltaic grid-connected power generation system was proposed. A simulation model of photovoltaic power generation system based on mixed energy storage system was built in MATLAB/Simulink, and relevant simulation analysis and researches were conducted.

## 1. Introduction

With the shortage of non-renewable energy and the progress of human society, solar power generation has developed rapidly in recent years. In the photovoltaic grid-connected power generation system, as the photovoltaic array is installed in the vacant space of the roof of various buildings, the land resource is not occupied much, which is more conducive to its wide application.

This paper is a photovoltaic power generation system power smoothing control based on mixed energy storage, mainly to provide theoretical basis and certain technical support for photovoltaic power generation system grid-connection and independent photovoltaic power generation system. The performance of the energy storage system are optimized to improve the defects of the large fluctuations in the photovoltaic power generation system, so that the photovoltaic system can be incorporated into the power grid more safely and stably.

## 2. Structure of photovoltaic power generation system

### *2.1. Formatting the title*

Photovoltaic systems are made up of many different components, like the computer data unit Bite, and the smallest component of a photovoltaic system is a battery cell. In photovoltaic systems, the order of magnitude of components is greater than that of units, and the largest is the array. We usually look at pv cells at the component level. The research in this paper will build on the circuit model with the same

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effect as the photovoltaic array, and then make the analogy analysis after obtaining the relevant data, so as to acquire the result data and relevant characteristic curve of the pv cell.

*2.2. Selecting the MPPT method*

Because changes in external environment and other conditions will have a huge impact on the output of pv cells, MPPT should be added to track the maximum power point in order to capture the maximum power output of pv cells when external conditions (such as light intensity and temperature) change.

The voltage and current output of the pv cell can be used to find its maximum power point. Therefore, MPPT is a process of optimization. Only when the output voltage and current are known, can it be judged exactly where the pv cell is running at this time.

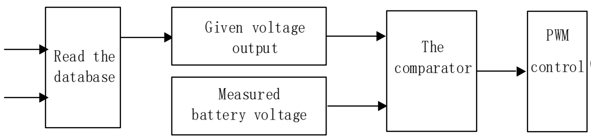



Figure 1. Control diagram

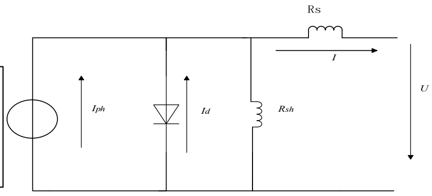



Figure 2 Equivalent circuit model

For tracking the maximum power point conveniently, this paper chooses disturbance observation to control the MPPT, for little data of the disturbance observation which need to be measured and the relatively simple structure.

## 3. Photovoltaic power generation system

*3.1. The equivalent model of pv cells*

The principle of pv cell: based on the photovoltaic effect of p-n junction, under normal lighting conditions, the sun shines on the surface of the semiconductor, so that the semiconductor can absorb the energy of light. Therefore, the two ends of p-n junction inside of the semiconductor generate photo-induced electromotive force, which is known as the photovoltaic effect. In practical applications, many pv cell modules are usually connected in series or in parallel to form a photovoltaic array, which is then used in the photovoltaic power generation system.

Pv cells have the following important parameters: open circuit voltage, maximum power point voltage, short-circuit current, maximum power point current, maximum power output power, etc. Fig.2 is the equivalent circuit model of pv modules.

*3.2. Pv grid-connected DC-AC inverter*

In order to connect the photovoltaic array to the grid, we need to convert the DC current into alternating current, so the dc-ac inverter is an indispensable link. The model of single-phase full-control bridge circuit is shown in figure 3. When TI, T4 is on, T2 and T3 are off. On the contrary, when T2 and T3 are switched on, T1 and T4 are turned off. The current flows through, making the inverter current into sine wave, and the output voltage inverts into alternating current, and is of the same phase and frequency with the grid.

In figure 3, there is a total of four bridge arms in the inverter circuit, that is the combination of the two and a half bridge. The amplitude of the output voltage through the DC-AC inverter circuit is twice as large as that of the output voltage from the empty bridge circuit. If you want to change the output voltage of the AC, it will have to change the input voltage of the DC side, therefore, to keep the voltage consistent with the grid, so you need to adjust the output of the pv array size. As for phase, you can change the output voltage phase by phase shift.

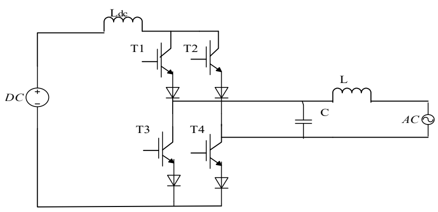



Figure 3. Model diagram

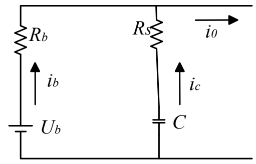



Figure 4. Parallel equivalent circuit

In this paper, the battery and supercapacitor are combined to form a hybrid energy storage system, mainly because of their good complementarity in performance. For hybrid energy storage system, we need to put battery and super capacitor in parallel, as for the parallel way, we can simply directly in parallel, as shown in figure 4, but because of the direct parallel, leads to the effect of super capacitor can't play the original, and such design makes a little big load fluctuation, so it's not very well.

### *3.3. Hybrid energy storage model*

Considering the above problems, in addition, in order to rationalize the energy storage process and improve the performance of the hybrid energy storage system, this paper chooses to control the energy of the battery and supercapacitor through the dc-dc converter. The relevant structure is shown in figure 5. Such a structure would be sufficient to cope with uncertain weather conditions and uncertain environmental factors, thus minimizing the impact of the entire pv system on the grid.

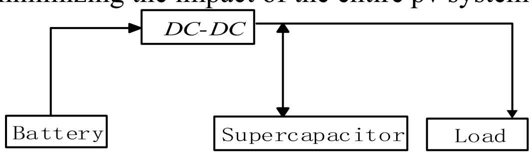



Figure 5. Structure diagram of hybrid energy storage through DC-DC converter

## 4. Matlab simulation of photovoltaic power generation system based on mixed energy storage

### *4.1. Matlab simulation of pv cells*

In order to see the relevant characteristics of pv cells more intuitively, Matlab is used to build the model of pv cells for simulation. We need to set some unknown parameters in the formula. Tref=25℃/m2, S=1000W/m2, a=0.0025, b=0.5, c=0.0028. Ioc=4.2A, Uoc=21V, Um=17V, Im=3.5A.

Through the simulation of pv cells, we get the simulation diagram of the output characteristics of pv cells. In figure 6 and figure 7, we can clearly see the relationship between I-U and P-U of pv cells under certain light conditions and temperature. According to the observation and analysis, when T(ambient temperature) and S(light intensity) and other external conditions remain unchanged, the parameters I, U and P will be consistent with the curve on the graph and remain unchanged. When external conditions change, such as lighting and ambient temperature, the curve changes accordingly. Therefore, from figure 6 and figure 7, we can infer that the output characteristics of pv cells are determined by T and S together.

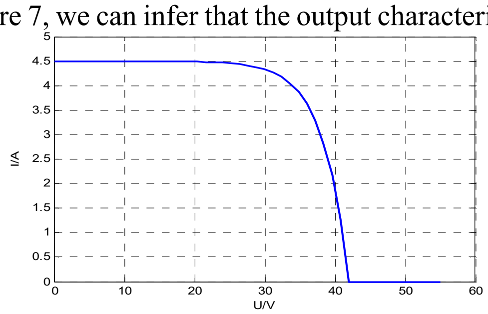



Figure 6. I-U curve

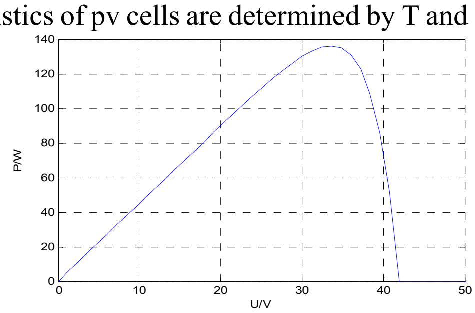


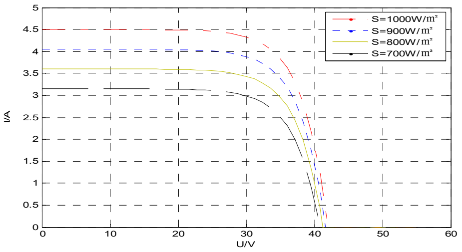

Figure 7. P-U curve

In order to understand the characteristics of pv cells more intuitively, the output characteristic curve of pv cells under different lighting conditions and environmental temperatures should be studied.

IOP Conf. Series: Earth and Environmental Science **237** (2019) 062009 doi:10.1088/1755-1315/237/6/062009

Meanwhile, control variable method is adopted to conduct simulation analysis for the convenience and thorough understanding.

First of all, we keep the environment temperature is constant value (T = 25 ℃), and then light conditions is dropped from the 1000 S w / ㎡ to 100 w/m2 to about 700 w / ㎡, and concluded I - U and P - U curve, as shown in figure 8 and figure 9.



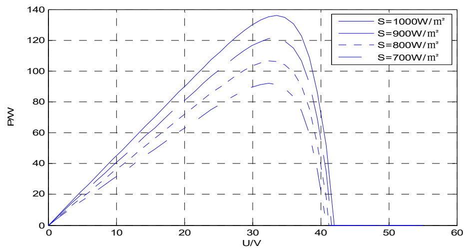
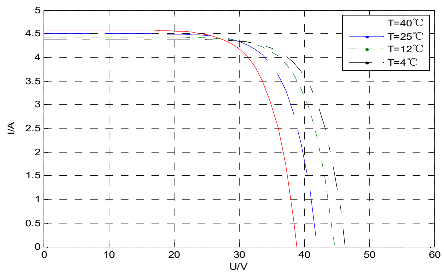




Figure 8. I - U curve Figure 9. P - U curve

Second keep light intensity for the fixed value (S = 1000 w / ㎡), 40 ℃ ambient temperature from gradually reduced, get I - U curve and P - U curve, as shown in figure 10 and shown in figure 11.



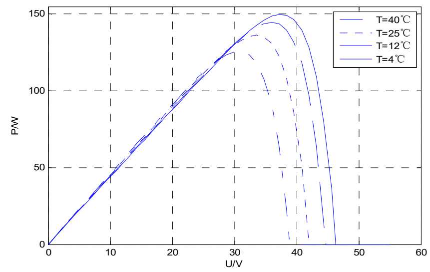




Figure 10. I-U curve Figure 11. P-U curve

Through analysis the following conclusions: with the illumination intensity is abate, photovoltaic battery short circuit current will with significantly reduced, with the decrease of light intensity of the open circuit voltage decreases slightly, but the short circuit current is affected by light intensity is very large, and for the output power of pv cells, and in the light intensity increase, the output power is growing, at the same time the change of open circuit voltage is not very obvious. With the gradual increase of temperature, the open circuit voltage of pv cells shows a downward trend, and the increase of temperature has a much greater impact on the open circuit voltage than the short-circuit current. However, the impact on the output power of pv cells is slightly less, and the output power decreases not much.

According to the above analysis, it can be roughly known that the pv cell's output power increases when the temperature decreases, so it can be inferred that it has a negative temperature coefficient. As for the intensity of light, it is directly proportional to the output of the pv cell. When the sunlight exposure becomes strong, the output power will increase accordingly.

### *4.2. MPPT modeling and simulation analysis*

In this paper, the maximum power tracking simulation is carried out based on the disturbance observation method, and the specific model construction is shown in figure 12.

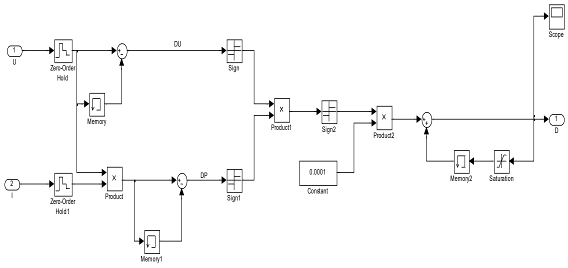


Figure 12. MPPT model

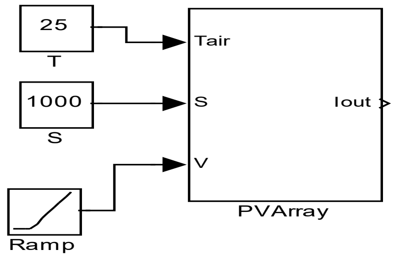



Figure 13. Pv cell packaging model

To simulate MPPT, we need not only the module of perturbation observation, but also the module of pv cell, bidirectional module, pulse modulation module and perturbation observation. Only in this way can we form a whole to get the waveform we want in the theory.

Firstly, we need to encapsulate the pv cell module, as shown in figure 13 is the encapsulated battery module.

*4.3. Hybrid energy storage system simulation*

For hybrid energy storage system, power simulation model is built in Matlab/Simulink, and then set the main parameters of the model, combines the super capacitor and battery, and jointly work for photovoltaic system, the pv cells due to uncontrollable factors such as the weather affect the output power, use this link to make the power of the whole system tends to be smooth, the output power is not enough, the output by super capacitor added, when the lighting conditions at a comfortable temperature, excess electricity is stored in battery.

Photovoltaic power generation system needs proper energy storage system to operate in combination with it. In this paper, charging and discharging power of battery and supercapacitor are simulated, as shown in figure 14 and figure 15.

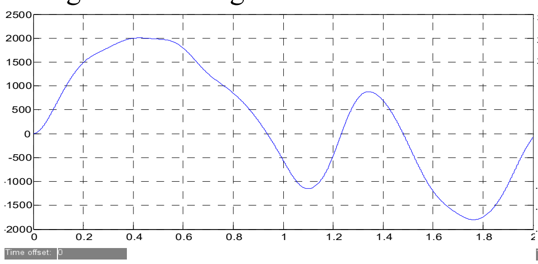


Figure 14. Power simulation model

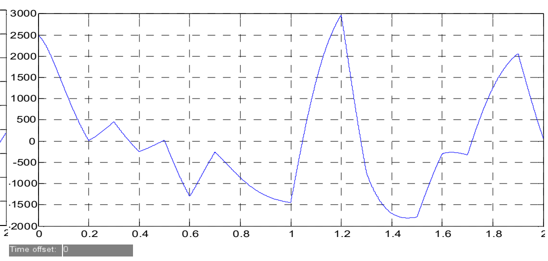


Figure 15. Supercapacitor power

Put charge and discharge of the battery and super capacitor in the same coordinate system, we can clearly see that the super capacitor is power density is bigger than the battery, and battery charge and discharge time is longer than the super capacitor obviously, charging efficiency and super capacitor, we can clearly found from the figure, the performance of the battery and super capacitor is very complementary, so choose both in photovoltaic power generation system as a hybrid energy storage is a very good choice.

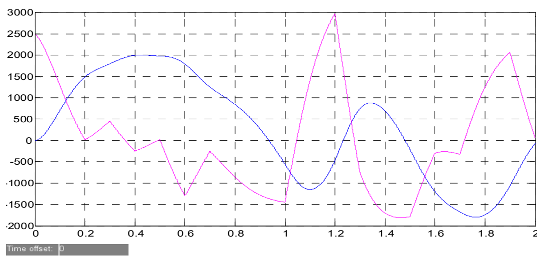


Figure 16. Hybrid energy storage with battery and ultracapacitor

IOP Conf. Series: Earth and Environmental Science **237** (2019) 062009 doi:10.1088/1755-1315/237/6/062009

## 5. Conclusion

The study of photovoltaic power generation system is based on hybrid energy storage power smoothing control, and the photovoltaic (pv) grid power generation system of photovoltaic array, MPPT, DC - DC converter, the hybrid energy storage researched mainly, as to solve the instability of the output power when the weather changes conditions, so that it is more conducive to be transmitted to the grid, preventing system to produce larger fluctuation and cause damage to power network, so that we can fully improve the performance of photovoltaic power generation systems.

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