Study on the Energy Storage Device in PV Generation System

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Abstract. In recent years, the photovoltaic generation has become an important form of distributed generation. PV is greatly influenced by outside conditions such as light and temperature, and causes the stronger intermittent and randomness of the power output. As a result, storage devices are needed to improve the dynamic and static characteristics of the whole system in practice. The battery is one kind of the energy storage device which has the characteristics of high energy density and low power density. But the super capacitor has high power density and its energy density is low. The paper studies the characteristics of super capacitor and battery hybrid energy storage solutions, and puts forward the corresponding model.

Introduction

Looking for new energy sources to achieve clean and renewable power generation, is the urgent demand of the sustained and healthy development of human society. As one kind of renewable energy, solar energy has the advantages of rich resources, convenient development, pollution-free and so on. As the main application forms of solar power, PV power generation has become an important means of distributed generation technology

A stand-alone PV system is usually equipped with storage battery because of its instable and frequently input energy, which is caused by cloud and periodical day and night change. On account of the advantages and disadvantages of various energy storage battery, it is hard to maximize the use of PV generation to produce energy if using a single energy storage batteries. Through the use of a variety of storage devices and give full play to the advantages of those devices, the energy of PV system can be used efficiently. Therefore, hybrid energy storage solutions have been paid much attention. In recent years, some colleges and research institutes at home and abroad make a preliminary study of the solutions.

The following is the research of the super capacitor and battery hybrid energy storage solutions, including of the characteristics and the model.

PV Generation

Photovoltaic cell is the most basic power generating unit of the PV power generation system and the output power of the monomer battery is smaller. Therefore the PV cell need to be connected with each other in series and parallel to obtain higher output voltage and larger power output. Commonly used PV model can be divided into the ideal model, single diode model and double diode model. Among them, the single diode equivalent circuit model is suitable for the single crystal silicon photovoltaic cells and consists of PV current source I_{ph} connected with a nonlinear diode D in parallel and the internal losses R_s and R_{sh} are also taken into account. The circuit structure is shown in Fig 1.

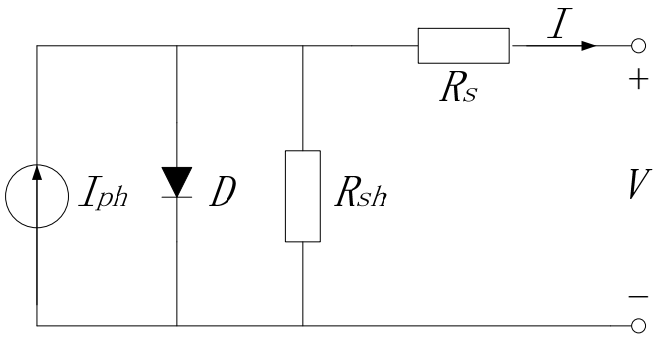

Fig 1. The single diode equivalent circuit model of PV

The corresponding circuit voltage-current characteristics is shown in equation (1).

$$I = I_{ph} - I_s(e^{\frac{q(V+IR_s)}{AkT}} - 1) - \frac{V + IR_s}{R_{sh}} \tag{1}$$

Battery

The equivalent circuit model of battery is most suitable for dynamic characteristics simulation. Battery has a number of different equivalent circuit model, and different simulation model can be chosen according to different simulation purposes. Based on Shepherd battery model, literature [1] proposes a general equivalent circuit for the dynamic simulation. The equivalent circuit use the state of charge (SOC) as the only state variables and at this point, the battery can be equivalent to a controlled voltage source and a resistor in a series circuit as shown in Fig 2.

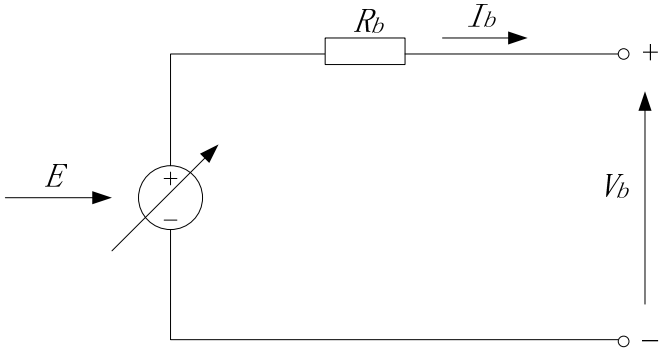

Fig 2. Battery equivalent circuit model

The expression of the controlled is shown in equation (2).

$$E = E_0 - K\frac{Q}{Q - \int i_b dt} + A\exp\left(-B \bullet \int i_b dt\right) \tag{2}$$

As shown in the expression: E_b is the battery's no-load voltage (V); E_0 is the battery's constant voltage (V); K is polarization voltage (V); Q is the battery's capacity (A·h); A is the amplitude of the exponential region (V); B is the reciprocal of time constant of the exponential region ($A \cdot h^{-1}$).

The model assumes that the battery's internal resistance keep constant in the process of charging and discharging. The parameters of the battery are got according to the discharge characteristic curve.

Super Capacitor

Super capacitor is a large capacity on the basis of the principle of electric double layer. When the applied voltage act on the two polar plates, the storage charge is that the positive electrode corresponds to positive charge and negative electrode corresponds to negative charge. In addition, if

affected by the external electric field, there will be the opposite charge between electrolyte and polar plate. The positive and negative charge are respectively in different contact surface this moment, and the load distribution belong to electric double layer under such condition. This is the working principle of super capacitor.

This paper use the improved RC circuit model to analyze the performance of the super capacitor, the model which consists of ideal capacitance C connected with equivalent resistance *Rs* in series and equivalent resistance *Rp* in parallel is shown in Fig 3. The equivalent resistance *Rp* in parallel represent the leakage current effect of the super capacitor which influence the super capacitor's long-term energy storage capacity. Relative to the RC circuit model, this model can accurately describe the capacitor long-term working condition.

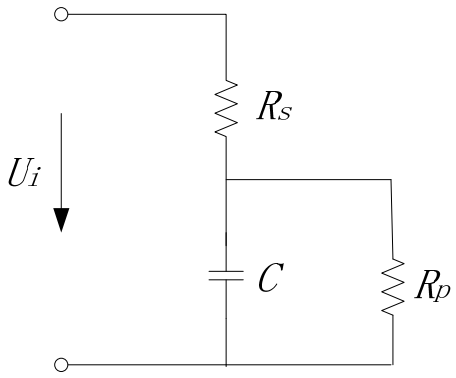

Fig 3. Super capacitor improved RC circuit model

Hybrid Energy Storage

This paper presents a more reasonable way of control. When solar energy is sufficient, the solar panels put into operation and battery and super capacitor can be charged to be put into use next time at the same time. When solar energy is insufficient, the power generation system need complementary power generation, the super capacitor can be put into use to achieve a smooth transition of the system output voltage and power. When a power source can't meet the requirement of the power supply and need to exit, the super capacitor should be used to switch power supply instantaneously and the battery should be put into use simultaneously. After the battery running stability, super capacitor will run out and be charged. The simulating schematic diagram of the system is shown in Fig 4.

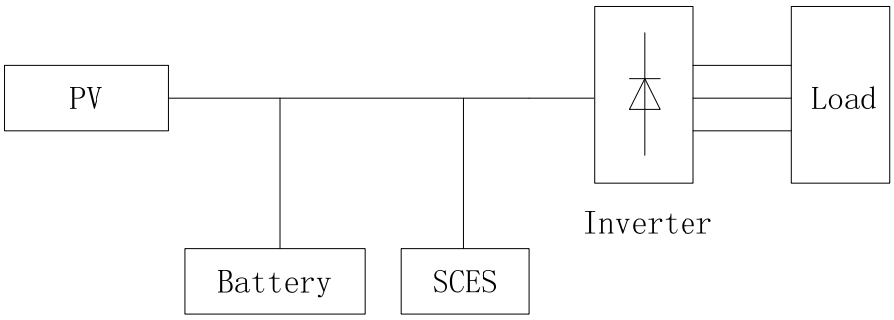

Fig 4. Simulating schematic diagram of the system

Conclusions

Based on the individual characteristics of battery and super capacitor, this paper studies on the hybrid energy storage for PV system and puts forward a hybrid energy storage solution. After analyzing the control strategy of the solution's charge-discharge, the paper puts forward the corresponding model. In follow-up work, we will simulate the model to verify the rationality of the solution.

Acknowledgements

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