Research on the Capacity Test Method of Photovoltaic Solar Cells under the Application of Clean Energy

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Abstract: Online testing of photovoltaic solar cell capacity can effectively maintain the service life of photovoltaic solar cells. When the photovoltaic solar cell capacity is tested by the traditional test method, the obtained photovoltaic solar cell capacity has an error and the error is large. A test method of photovoltaic solar cell capacity based on improved Coulomb measurement is proposed. The test data information of the photovoltaic solar cell capacity is classified. The Coulomb measurement principle is used to describe the transfer rules between photovoltaic solar cell capacity data information, and the median filtering is used to construct the nonlinear median filter state equation and observation equation of photovoltaic solar cell capacity. Taking the electric energy consumed by the photovoltaic solar cell as the median filter state variable, and the voltage as the observed signal value of the photovoltaic solar cell capacity, we can obtain the online estimated value of the photovoltaic solar cell capacity at the current time, which effectively eliminates the measurement error generated in the test of photovoltaic solar cell capacity and completes the test of the photovoltaic solar cell capacity. Simulation experiment shows that the test method of photovoltaic solar cell capacity based on improved Coulomb measurement method maintains the service life of photovoltaic solar cells and ensures the normal operation of photovoltaic solar cells.

Keywords: Charge; Median filtering; Cell capacity test

1. Introduction

With the enhancement of environmental protection awareness, the development of clean energy has become one of the important means of sustainable development. Photovoltaic energy is also becoming more popular in current energy applications. How to effectively find photovoltaic solar cells with reduced performance and improve the reliability of power supplies have become the main problems to be solved in this field. Testing photovoltaic solar cell capacity to detect photovoltaic solar cells with obvious reduced performance is the core way to solve this problem, which has attracted the attention of many experts and scholars. Since the test method of photovoltaic solar cell capacity has profound significance, it has become a research focus in this industry which has received extensive attention. And many good methods have appeared.

This paper presents a test method for photovoltaic solar cell capacity based on improved Coulomb measurement. The test data information of the photovoltaic solar cell capacity is classified and integrated into the median filtering method. Taking the electric energy consumed by the photovoltaic solar cell as the median filter state variable, and the voltage as the observed signal value of the photovoltaic solar cell capacity, we can obtain the online estimated value of the photovoltaic solar cell capacity at the current time, which effectively eliminates the measurement error generated in the test of photovoltaic solar cell capacity.

2. Test of Photovoltaic Solar Cell Capacity

When the photovoltaic solar cell capacity is tested by the traditional test method, the obtained photovoltaic solar cell capacity has an error and the error is large. A test method for photovoltaic solar cell capacity based on improved Coulomb measurement is proposed.

2.1. Measurement of cell capacity and real-time power

In the optimization test of photovoltaic solar cell capacity, from the perspective of energy balance, the test data information of photovoltaic solar cell capacity is classified in detail. The Coulomb measurement principle is used to describe the transfer rules between photovoltaic solar cell capacity data information. The specific steps are as follows:

The test data information of photovoltaic solar cell capacity is classified in detail using Coulomb

measurement principle. The obtained electrical parameters are retained and the equation is:

$$U = E\left(1 - \frac{Q}{S_{SC}}\right) \quad (1)$$

The test data is classified. And based on the acquired parameters, the discharge is obtained and expressed by the following formula:

$$C_{rec} = \sum_{n=0} UI_{rec} * t_n \quad (2)$$

In the above equation, Crec represents the discharge obtained, Irec represents the current output from one end of the photovoltaic solar cell, and tn represents the sampling time interval.

The capacity of photovoltaic solar cells is calculated to provide a basis for the calculation of actual power. Assuming that Cpre represents pre-stored cell capacity, which is satisfied with the condition that Cpre=70Ah, the following equation is used to calculate the cell capacity of photovoltaic solar cells:

$$C_a = C_{rec} - C_{\Pr e} \quad (3)$$

In the above equation, Ca represents the obtained capacity of photovoltaic solar cell.

Calculate real-time power of the cell. Assuming that Vrec represents the voltage of the photovoltaic solar cell, Trec represents the temperature of the photovoltaic solar cell itself, and Prec represents the real-time power of the photovoltaic solar cell, then the following formula can be obtained:

$$P_{rec} = \left\{\frac{V_{rec} * I_{rec}}{C_a}\right\} \times t_n \quad (4)$$

In the above formula, the value of tn is controlled within the range of 1S, and its function is to find the minimum time unit of the cell capacity.

To sum up, the test data is classified to acquire parameters. Using the Coulomb measurement principle to calculate the discharge, the real-time power of the photovoltaic solar cell is obtained, which lays a foundation for the optimization test of the photovoltaic solar cell capacity.

2.2. Optimization of photovoltaic solar cell capacity test

According to the real-time power of photovoltaic solar cells obtained from formula (8), the nonlinear median filter state equation and observation equation of photovoltaic solar cell are constructed. Median filtering method is applied. Taking the electric energy consumed by the photovoltaic solar cell as the median filter state variable, and the voltage as the observed signal value of the photovoltaic solar cell capacity, the online estimated value of the photovoltaic solar cell capacity at the current time can be obtained, which effectively eliminates the measurement error generated in the test of photovoltaic solar cell capacity. Specific methods are as follows:

Calculate the relationship between real-time power and current of photovoltaic solar cells, and obtain the electricity consumed by photovoltaic solar cells. The state equation and observation equation of photovoltaic solar cell capacity are constructed according to nonlinear median filtering method. Select the voltage and current of photovoltaic solar cell at a certain moment, and I(t) represents the current at time t. According to the real-time power of photovoltaic solar cells, the relationship between them can be:

$$\frac{U(t)}{I(t)} = OCV - \frac{1}{C}\int(dt - R_O I_O - R_P I_P) \times \frac{dI_P / dt}{P_{rec}} = (I_O - I_P)/\tau \quad (5)$$

τ represents the polarization coefficient, Io is the load current of the battery, Ip is the current flowing through the polarized internal resistance, Ro is the internal resistance of the cell, Rp is the polarized internal resistance of the cell, C represents the capacitance, and i represents the discharge current of the photovoltaic solar cell at time point t. Find the electricity used by the photovoltaic solar cell. The formula is as follows:

$$W_S(t) = \int U(t) I(t) dt \frac{\eta_v(t)}{\eta_i(t)} \times \frac{U(t)}{I(t)} \quad (6)$$

η v(t) and η i(t) represent the resistance voltage coefficient and the resistance current coefficient of the photovoltaic solar cell at a certain time.

In the optimization process of the cell capacity, the capacity measurement of the photovoltaic solar cell can be expressed by testing the cell's charge U(t). During the measurement process of cell capacity, it is necessary to repeatedly accumulate the instantaneous charge I(t) and the working time t to calculate the result. There are inevitable measurement errors and calculation errors in the measurement process. In order to eliminate the influence of error on cell capacity measurement, the median filtering method is used to construct the nonlinear median filter state equation and observation equation, which are:

$$X_K = \frac{f\left[X_{K-1}, k-1\right] + \Gamma_{k-1} w_{k-1}}{W_S(t)} \quad (7)$$

$$Z_K = \frac{h\left[X_k, k\right] + v_k}{U(t)/I(t) X_K} \quad (8)$$

Xk is the signal state vector of the test system at a certain moment k, Zk is the observation signal vector of the test system at a certain moment k, f and h are the state equation and observation equation of the signal, wk and vk are the electrical noise and its measured value of the test system, and Tk-1 is the constant at the moment k-1.

After obtaining the state equation and the observation equation, the estimated value of charge is obtained through discretization. The state variable of median filter

is used to represent the charge consumed by the photovoltaic solar cell. According to the discrete median filter principle, the state equation and the observation equation are discretized, and the formula is:

$$X_K = \frac{X_{K-1} + \Delta T + w_k}{X_K = W_S(k)} \otimes \frac{\overline{u}(t)}{Z_K = U(k)} \tag{9}$$

$$Z_K = \frac{-(RI_O - OCV) + \sqrt{(RI_O - OCV)}}{2} X_K \tag{10}$$

In the above formula, ΔT represents the time constant. The following equation is used to obtain the online estimated value of photovoltaic solar cell capacity at the moment k:

$$\hat{X}_K = \frac{\hat{X}_{K/K-1} + K_K\left(Z_K - h\left[\hat{X}_{K/K-1}, k\right]\right)}{\hat{W}_S(t)} \tag{11}$$

In the above formula, $\hat{W}_S(t)$ represents the estimated value of the charge consumed by the photovoltaic solar cell at time k, and $\hat{X}_{K/K-1}$ represents the online estimated value of the photovoltaic solar cell capacity from time k to time k-1, Kk represents the error of initial filtered mean square of the test system, $\hat{X}_K$ represents the online estimated value of the photovoltaic solar cell capacity at time k.

Determine the online estimated value and further process it to eliminate the measurement error generated during the test of photovoltaic solar cell, obtain the estimated value of the photovoltaic solar cell capacity at the current time point kkm, and complete the test of the photovoltaic solar cell capacity. The formula can be expressed as:

$$\hat{k}_{km} = 1 - \hat{X}_K / W_N \tag{12}$$

In summary, by constructing the nonlinear median filtering state equation and observation equation of photovoltaic solar cell capacity, the online estimated value of photovoltaic solar cell capacity at the current time point can be obtained, which effectively eliminates the measurement error generated in the test of photovoltaic solar cell capacity and completes the test of the photovoltaic solar cell capacity.

3. Experiment and Simulation

In order to prove that the proposed test method of photovoltaic solar cell capacity based on improved Coulomb measurement is effective, an experiment is required. The experiment simulates the test of photovoltaic solar cell capacity under HEV conditions.

The capacity of photovoltaic solar cell is tested by the improved method and the traditional test method based on CAN bus. When the experiment times are different, the accuracy, reliability, and average error rate of the two methods are compared. The comparison results are shown in Table 1 and Table 2.

Table 1. Overall effectiveness of the traditional test method

Experiment times(times)	Average error rate of the traditional test method (%)	Reliability of the traditional test method (%)	Accuracy of the traditional test method (%)
15	0.6	69	75
25	0.8	70	70
35	0.6	69	70
45	0.8	69	75
55	0.8	70	70
65	0.8	69	70
75	0.8	70	75

Table 2. Overall effectiveness of the improved test method

Experiment times(times)	Average error rate of the improved test method (%)	Reliability of the improved test method (%)	Accuracy of the improved test method (%)
15	0.01	97	98
25	0.01	97	98
35	0.01	97	97
45	0.01	96	97
55	0.01	97	97
65	0.01	96	98
75	0.01	97	98

It can be seen from Table 1 and Table 2 that the accuracy, reliability and error rate of the improved test method of photovoltaic solar cell capacity are superior to the traditional method. This is because the improved method can better reflect the voltage variation of the photovoltaic solar cell in different states, thus effectively ensuring the accuracy of photovoltaic solar cell capacity test.

The experiment and simulation show that the test method of photovoltaic solar cell capacity based on improved Coulomb measurement can effectively maintain the service life of the photovoltaic solar cell and ensure the normal operation of the photovoltaic solar cell.

4. Conclusion

When the photovoltaic solar cell capacity is tested by the traditional test method, the obtained photovoltaic solar cell capacity has an error and the error is large. A test method of photovoltaic solar cell capacity based on improved Coulomb measurement is proposed. The test data information of the photovoltaic solar cell capacity is classified. The Coulomb measurement principle is used to describe the transfer rules between photovoltaic solar cell capacity data information. Find out the discharge and the charge of photovoltaic solar cell. The median filtering is used to construct the nonlinear median filter state equation and observation equation of photovoltaic solar cell capacity. We can obtain the online estimated value of the photovoltaic solar cell capacity at the current time, which effectively eliminates the measurement error generated in the test of photovoltaic

solar cell capacity. Simulation experiment shows that the test method of photovoltaic solar cell capacity based on improved Coulomb measurement method maintains the service life of photovoltaic solar cells and ensures the normal operation of photovoltaic solar cells.

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