Research on Optimal Control of Power Tracking of Solar Photo-voltaic Power Generation System

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Abstract: In order to solve the problem of low efficiency of power generation control in conventional solar photo-voltaic power generation system, the research on optimal control of power tracking in solar photo-voltaic power generation system is proposed. Power tracking optimization based on solar photo-voltaic power generation system, optimization of solar photo-voltaic power tracking control drive and design of optimal control program of power tracking of solar photo-voltaic power generation, thus to realize the optimal control of power tracking of solar photo-voltaic power generation system, experimental result shows that the proposed tracking optimization control increases the integrated power control efficiency by 13.87% compared with the conventional control method.

Keywords: Solar energy; Photo-voltaic power generation; Tracking optimization; Power control

1. Introduction

The power of solar power generation system is an important index to measure the solar power generation capacity, and the lower the power of solar power generation system, the weaker the solar power generation capacity [1]. Since the position of the sun is constantly moving relative to the earth, if the solar panel is fixed at a constant Angle, the solar power generation system will be in the best state only when the sunlight is incident at the best angle in a certain period of time. The power generation control method of conventional solar photo-voltaic power generation systemonly can optimize at fixed Angle. According to the fixed value calculation, different angles are adjusted in each time period. However, in order to consider the seasonal change, the movement of the Tropics of Cancer and Capricorn, and the influence of other special conditions, there is a deficiency of low control efficiency of power generation system. Therefore, a study on the optimal control of power tracking of the solar photo-voltaic power generation system is proposed. Key parameters are determined based on the optimal calculation of the power tracking of the solar photo-voltaic power generation system. Relying on the driving optimization of the power tracking control of the solar photo-voltaic power generation, and combining the designing of optimal control program of power tracking of solar photo-voltaic power generation, thus to realize the optimal control of power tracking of solar photo-voltaic power generation system. In order to ensure the effectiveness of the proposed tracking optimization control method, field tests were carried out and different types of solar photo-voltaic panels were used, by adopting the two control methods to do the comparative test of power generation control efficiency. The test results show that the proposed tracking optimization control method is highly effective.

2. Power Tracking Optimization Control of Solar Photo-voltaic Power Generation System

2.1. Optimization calculation of power tracking of solar photo-voltaic power generation system

The purpose of power tracking optimization calculation of solar photo-voltaic power generation system is to determine the optimal power tracking scheme of power generation system at different times and locations. According to the best inclination of the solar panel, the best transmission current of the solar panel, the best controllable load of the solar panel, the best power of the solar panel, and the movement law of the solar celestial body, the power tracking optimization calculation of solar photo-voltaic power generation system was done.

Where, the optimal inclination angle of solar panel can be calculated by formula (1) [2]:

$$q = \frac{1}{U}\sum_{i=1}^{j}\frac{ZSF^{2}}{Idh} \tag{1}$$

Where, SF represents the longitude and latitude of the solar panel installation site; I represents the maximum current of the solar panel, its unit is A; U represents the maximum voltage of the solar panel, its unit is U; Z represents the maximum load of the solar panels, its unit is Ω; h represents the maximum consumption rate of

solar panels; d represents the time point of effective illumination.
The optimal transmission current of solar panel can be calculated by formula (2) [3]:

$$\hat{s} = \iint Q^2 p(q \mid T) dq \tag{2}$$

Where, T represents the capacitance of the solar panel, its unit is F; Q represents the solar panels of reactance, the unit is Ω.
The optimal controllable load of solar panel can be calculated by formula (3) [4]:

$$I = \sum_{j=0}^{n} \hat{s} \left(\mathbf{C}_{\substack{i=0 \\ i \neq j}}^{n} \frac{x - x_i}{Z} \right) \tag{3}$$

Where, x represents the design of controllable maximum angel, the unit is °; x_i represents the design of controllable minimum angle, the unit is °.
The optimal power of solar panel can be determined by formula (4) [5]:

$$l = P \frac{d\hat{s}}{QUI} q \tag{4}$$

Where, P represents the motion law of solar celestial bodies. Based on the calculation of the optimal inclination angle of solar panel, the calculation of the optimal transmission current of solar panel, the calculation of the optimal controllable load of solar panel, and the determination of the optimal power of solar panel, the optimal power tracking calculation of solar photo-voltaic power generation system is realized. The optimal tracking scheme of power generation system in different time and position is determined.

2.2. Optimization of solar photo-voltaic power tracking control drive

The power control method of conventional solar photo-voltaic power generation system adopts mechanical drive mode to adjust the optimal inclination of solar panels, so as to obtain the maximum visible illumination. However, conventional mechanical transmission is discontinuous, which is related to the mechanical design principle, and it is difficult to produce high-precision transmission gear, and increases the cost of solar photo-voltaic power generation system. For this reason, this paper chooses the hydraulic continuous transmission scheme for the optimization of solar photo-voltaic power tracking control drive.
Different from the conventional solar photo-voltaic power generation system, which adjusts the angle every few minutes, the proposed optimal control method adopts the hydraulic continuous adjustment mechanism to adjust with the change of time. The optimal inclination angle of solar panels at different times is calculated based on the different time points, and a time angle function is constructed, which is controlled by the solar photo-voltaic power tracking control optimization program.
Its tracking control drive optimization diagram is shown in Figure 1:

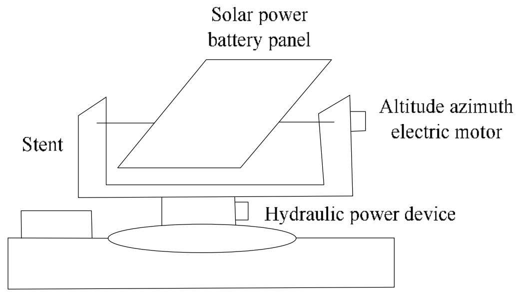

Figure 1. Tracking control drive optimization diagram

2.3. Design of solar photo-voltaic power tracking control optimization program

Relying on different time points to calculate the best inclination of solar panels at different times, building a time angle function, and using the solar photo-voltaic power tracking control optimization program to control its time angle function. The independent variable of the solar photo-voltaic power tracking control optimization program is time, and the only Beijing time is adopted as the reference in China. The controlledangle uses C language to control the way of program optimization design, writing commands, so that the executive structure of the hydraulic device in accordance with the time for the top out of the retraction. The key program of C language control is shown in figure 2:

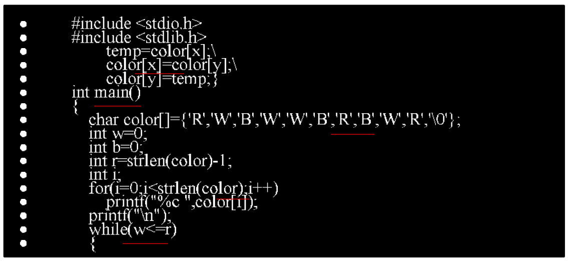
```
#include <stdio.h>
#include <stdlib.h>
      temp=color[x];\
      color[x]=color[y];\
      color[y]=temp;}
int main()
{
   char color[]={'R','W','B','W','W','B','R','B','W','R','\0'};
   int w=0;
   int b=0;
   int r=strlen(color)-1;
   int i;
   for(i=0;i<strlen(color);i++)
      printf("%c ",color[i]);
   printf("\n");
   while(w<=r)
   {
```

Figure 2. C language control of key program

The key parameters are determined based on the optimal calculation of the power tracking of the solar photo-voltaic power generation system. The optimal control of the power tracking control of the solar photo-voltaic power generation system is realized by relying on the driving optimization of the power tracking control of the solar photo-voltaic power generation system and combining with the optimization program design of the power tracking control of the solar photo-voltaic power generation system.

3. Case Analysis

In order to verify the effectiveness of the proposed research on optimal control of power tracking of solar photo-voltaic power generation system, comparative test analysis on the power control efficiency of solar photo-voltaic power generation system was carried out. The power generation control method of conventional solar photo-voltaic power generation system is adopted as the comparison object, and the example analysis is carried out by combining different solar radiation amount, load power, output voltage and starting current.

3.1. Data preparation and experimental process

The power of solar photo-voltaic power generation system is an important power generation parameter of solar panels, which directly affects the power generation efficiency of solar panels. Whether the power of the solar photo-voltaic power generation system can be effectively controlled is the key factor to measure the stability of the photo-voltaic power generation system. Therefore, the power generation control test of the solar photo-voltaic power generation system is carried out.

During the test, 24 solar photo-voltaic panels were prepared. The power tracking optimization control method of solar photo-voltaic power generation system and the power generation control method of conventional solar photo-voltaic power generation system are respectively used for control. Each group controls 12 solar photo-voltaic panels.

In order to ensure the accuracy of the experiment, each group of solar photo-voltaic panels adopts the same solar panel manufacturers' products to test, including six kinds of solar panels, which are monocrystalline silicon solar panel, polycrystalline silicon solar panels and amorphous silicon solar panels, cadmium sulphide solar panels, gallium arsenide solar panels, copper indium selenium, two pieces of each type.

Put two groups of 24 solar panels on the open field, connecting the solar photo-voltaic power generation system as required, conducting debugging, and starting the test on the premise of ensuring the reasonable operation of the control system. For all-weather test cycle for 7 days and the test environment including common nature like sunny day, rainy day, fog weather, the maximum temperature difference between day and night is± 12 ℃. At the same time, the instantaneous generation power sensor is connected to record the change of generation power of the solar photo-voltaic power generation system. The power generation control of solar photo-voltaic power generation system with two control methods is analyzed.

3.2. Analysis of test results

During the test process, since the two control methods were tested in the same test environment and experienced the influence of common weather such as sunny days, rainy days and foggy days, therefore, the influence of weather was not analyzed. Only different operating periods and the average hourly illumination time, the average hourly unit area power of solar photo-voltaic power generation within the operating period are analyzed, and the change of the average generating power of the conventional control method and that of the proposed control method is obtained. The average generation power variation of conventional control methods is shown in Table 1:

Table 1. Variation of Average Generation Power of Conventional Control Methods

Operating Period	Average Hourly Illumination Time /h	Average Power Generation W/m2
04:00-06:00	41.25	95.72
06:00-08:00	56.84	101.74
08:00-16:00	60.00	148.99
16:00-18:00	57.41	108.77
18:00-20:00	42.35	98.52
20:00-04:00	0.00	0.00

The average generation power variation of proposed control method is shown in Table2:

Table 2. Variation of the Average Generation Power of the Proposed Method

Operating Period	Average Hourly Illumination Time /h	Average Power Generation W/m2
04:00-06:00	41.25	115.75
06:00-08:00	56.84	137.36
08:00-16:00	60.00	149.89
16:00-18:00	57.41	138.75
18:00-20:00	42.35	116.75
20:00-04:00	0.00	0.00

The variation table of the average generation power of the conventional control method and the proposed control method is analyzed. We can conclude that the efficiency of solar photo-voltaic power generation can be improved through effective control. In order to clearly analyze the efficiency of power generation control of solar photo-voltaic power generation system. The ratio of actual power generation to theoretical power generation is adopted to quantify the generation power control efficiency of the solar photo-voltaic power generation system, as shown in formula (5):

$$C = \frac{S'}{S} \times 100\% \tag{5}$$

Where, C represents the generation power control efficiency of solar photo-voltaic power generation system; S' represents the actual generating power, the unit is W; S stands for theoretical generation power, the unit is W.

The theoretical power generation used in the experiment is 150W. According to the variation table of average power generation of conventional control method and proposed control method, the following conclusions can be drawn:

Under the environment with sufficient average effective illumination time (sunny day), the proposed power tracking optimization control method for solar photo-voltaic power generation system and the conventional power control method for solar photo-voltaic power generation system both have high power control efficiency;

Under the environment where the average effective illumination time is insufficient (evening and early morning), the proposed optimization control method has an effective power generation control rate, which is 17.31% higher than the conventional power generation control rate.

When affected by the interfered environment, the proposed power tracking optimization control method for solar photo-voltaic power generation system is more efficient than the conventional power control method for solar photo-voltaic power generation system.

The integrated power generation control efficiency of the proposed optimization control method is 13.97% higher than that of the conventional control method;

4. Conclusion

This paper proposes a study on the optimal control of solar photo-voltaic power generation system. Based on the optimal calculation of the solar photo-voltaic power tracking system, the driving optimization of the solar photo-voltaicpower tracking control, and the optimization program design of the solar photo-voltaic power tracking control, the research purpose of this paper is realized. Experimental data show that the proposed method is highly effective. It is hoped that the research in this paper can provide theoretical basis for the optimal control of power tracking of solar photo-voltaic power generation system.

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