SIMULATION RESEARCH ON THE GRID CONNECTED GENERATION SYSTEM OF SOLAR THERMAL POWER GENERATION

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Abstract: *Objective: To improve the conversion efficiency of photovoltaic power generation system, improve the power quality, and promote the optimization and development of solar thermal power generation. Methods: In this study, firstly, voltage feedback, power feedback, disturbance observation and conductance increment are used to track the maximum power of photovoltaic cells. After that, the problems and shortcomings of incremental conductance method are further optimized and improved. Then, the control of maximum power point tracking (MPPT) is expanded. Finally, in the Matlab software, the simulation model of power generation system is built. Results: The synchronization time of voltage and current is less than 0.1s. The current voltage and grid current voltage have the same frequency and phase. In the case of reactive power, the power factor of the system is close to 1. There is a certain relationship between the wave form of the active power and the illumination, and the illumination change will be found. The active power will also change with it, and the changing waveform is very similar to the light waveform, or even close to it. Conclusion: The simulation experiment shows that the optimized power generation system has great advantages and effectiveness, its dynamic response ability is very strong, and the output waveform of the power generation system can change with the sun light, which can effectively prevent the interference from the environment.*

Key words: *solar energy; power generation; grid connection; simulation; control*

1. Introduction

Energy is an important material basis, which is not only related to the development of national economy, but also necessary for people's life. In the primitive society, the era of wood for fire developed to the modern era of fossil resources, and then to the modern era of new energy such as solar energy and water energy. The development of energy in each era is closely related to the development of social productivity, and the development of productivity must rely on the supply of energy [2, 3]. In the face of the rapid development of social productivity, the increasing demand for energy, the lack of fossil energy to provide social development, and the rapid depletion of fossil energy, countries have increased the use of new energy research. The demand for energy has become an important indicator of a country's economic development and national living standards [4]. Electric energy is the most important primary energy, which is mainly composed of thermal power, hydropower and nuclear power [5]. Among them, thermal power generation still accounts for a high proportion in China, and the coal combustion as the main body of thermal power generation has caused serious irreversible pollution to the earth's environment [6]. At the same time, the emission of greenhouse gases makes the environment temperature rise constantly, the melting of glaciers at the north and south poles causes the sea level to rise, and the land area of human life is threatened [7]. Although hydropower will not cause too much environmental pollution, it still has a potential threat to the ecological environment, limited by the region. Moreover, the development of hydroelectric power in China has come to an end [8]. Nuclear energy is a relatively clean energy. However, if there is a nuclear leak, it will cause unimaginable disaster. Moreover, the waste after nuclear power generation is not easy to deal with.

In 2020, the total consumption of coal should be controlled under 2.72 billion tons of standard coal. The proportion of coal consumption will decrease by 57.3%, and the proportion of non fossil energy will increase to 15.2%. By 2050, global clean energy accounting for 80% of primary energy is to be achieved. Not only the emissions of harmful gases and greenhouse gases are to be reduced, but also the temperature rise is to be controlled within two degrees Celsius [9]. In view of the above situation, China's State Grid proposes the concept of global energy interconnection, connecting "one pole one equator", and developing the Arctic wind energy and solar energy near the equator [10]. Therefore, the development and utilization of wind energy and solar energy is the main direction of future development. In fact, any form of energy comes from solar energy, and solar power generation has unique advantages, such as large reserves, wide distribution, clean energy, and relatively simple construction, no noise. However, it also has many disadvantages, such as low power generation efficiency, high cost, easy to be affected by the environment, unable to output good waveform, and low power quality.

In this study, a new tracking strategy and control algorithm are proposed by optimizing the grid connected generation system. In view of the shortcomings of the incremental conductance method, an improvement is made. The improved incremental conductance method is applied to the tracking of the maximum power of the system, which can improve the output stability of the power generation system. With the maximum power point tracking (MPPT) control system, the voltage of the system is feedforward controlled. By using this method, the stability, anti-interference ability and dynamic response ability of power generation system can be improved. This simulation experiment is of great significance to the optimization and application of photovoltaic power grid connection.

2. Method

2.1. Maximum power tracking

In the process of output, photovoltaic cells are very unstable and vulnerable to external environment, such as solar radiation intensity and panel temperature [11]. If the output of the battery and its inverter cannot be properly matched, or the maximum power of the photovoltaic cell cannot be grasped, a lot of energy will be lost. Therefore, it is necessary to use appropriate control methods to control photovoltaic cells and control circuits, such as the MPPT method proposed in this study. Using this method, the maximum power point tracking of inverter can be promoted timely and quickly.

2.1.1 Voltage feedback

The simple, effective and practical maximum power tracking method used in the study is shown in the Fig. 1 and Fig. 2. By using this method, the voltage of the battery board can be effectively adjusted to be equal to the test voltage of the maximum power, so as to further achieve the purpose of tracking the maximum power point. In this process, the voltage corresponding to the maximum power point of the solar panel can be tested in advance. However, once it is greatly affected by the external environment, the system cannot track the maximum power point, which will eventually lead to a large error.

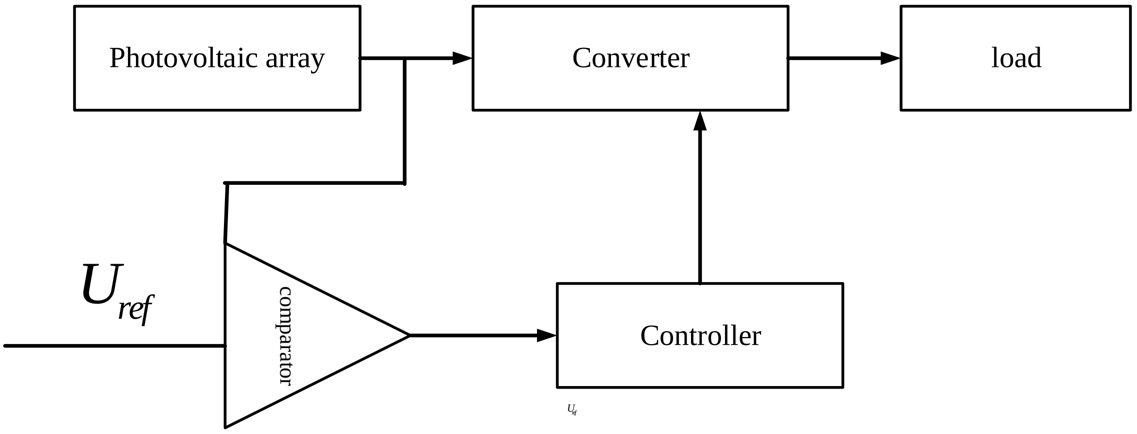

Figure 1 Block diagram of fixed reference voltage method

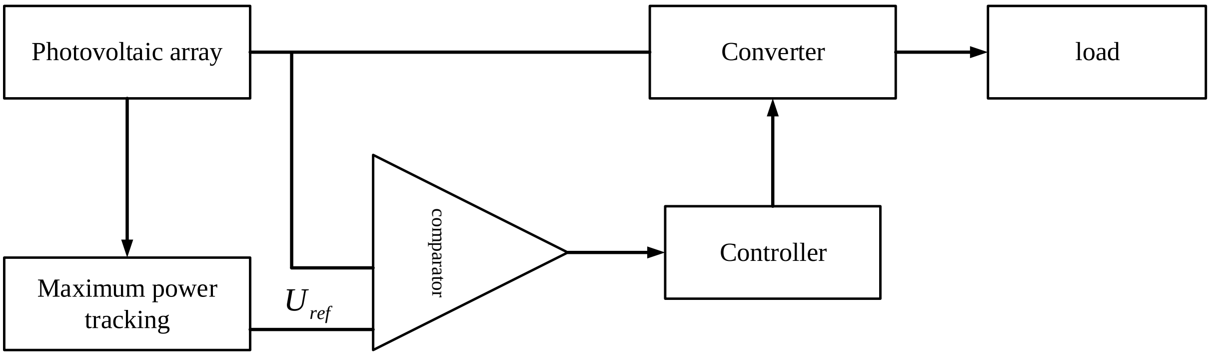

Figure 2 Block diagram of variable reference voltage method

2.1.2 Power feedback

Another method of maximum power point tracking in this study, power feedback method, is shown in the Fig. 3 below. The voltage regression method has some defects. Once the environment changes, it will not adapt to the situation, and ultimately cannot complete the purpose of tracking the maximum power point. Therefore, a certain logic judgment is added to the power regression method. After joining, it will not be affected by any weather environment, and can track the maximum power point in any weather environment. Although this method is relatively large and complex, it has great advantages, can effectively save the energy loss of the circuit, and can improve the overall effect of the system operation.

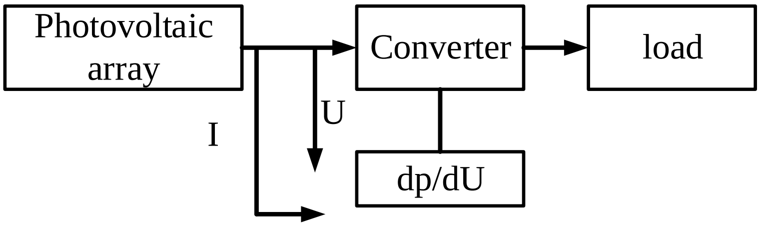

Figure 3 Power feedback method block diagram

2.1.3 Disturbance observation

The disturbance observation method is shown in the Fig. 4 below. The circuit structure of this method is relatively simple, and there are few real-time parameters that can be applied when observing the system. By changing the load periodically, the terminal voltage and output power of photovoltaic cell can be effectively changed. After the measurement of the output voltage and output power before and after the load change, it can be determined that whether to increase or decrease. If it is found that the output power increases, it is necessary to follow the steps in the previous direction. If the output power decreases, the direction of the previous step needs to be further changed. The main principle of disturbance observation method is to repeatedly disturb, observe and compare the situation, and finally achieve the purpose of maximizing the output power of photovoltaic array. When this method is near the MPP point, it will not stop, and may continue to disturb. Therefore, once the external environment conditions change dramatically, the maximum power point cannot be tracked in time and effectively, which will eventually cause the waveform to vibrate and energy loss.

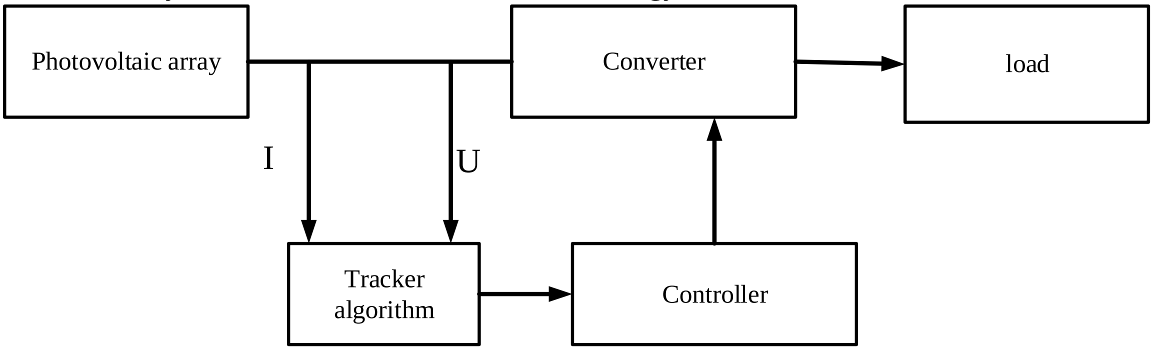

Figure 4 Block diagram of disturbance observation method

2.1.4 Incremental conductance

The incremental conductance method is one of the most widely used methods, as shown in Fig. 5. The main principle is to realize the function of MPPT by comparing the relationship between the instantaneous immittance and the variation of immittance. The output P-U curve and dP/dU variation characteristics of photovoltaic array are shown in Fig. 6. It can be seen from Fig. 6 that this curve has a first-order continuous differentiability. Among them, the dP/dU on both sides of the maximum power point is different and opposite. However, the dP/dU value at MPP is equal to zero. As shown in the Fig. 6 below, it can be seen that the basic principle and power feedback of this method are the same. The starting point is that dP/dU is equal to zero, which is the same as the logic judgment equation of power feedback. $dP/dU = 0$ can be further rewritten as Eq. 1.

$$\frac{dP}{dU} = \frac{d(UI)}{dU} = I + U\frac{dI}{dU} = 0 \tag{1}$$

In Eq. 1, power is represented by P, current is represented by I, and voltage is represented by U. The Eq. 1 can be further sorted out to obtain Eq. 2:

$$\frac{dI}{dU} = -\frac{I}{U} \tag{2}$$

In Eq. 2, dI represents the current difference measured before and after increment, dU represents the voltage difference measured before and after increment. Therefore, in this study, it is only necessary to compare the value of dI / dU with I/U, and then the direction of the next value change and the size after the change can be obtained. If the incremental value and electric value can meet the requirements of the Eq. 2, the system power can reach the maximum power point.

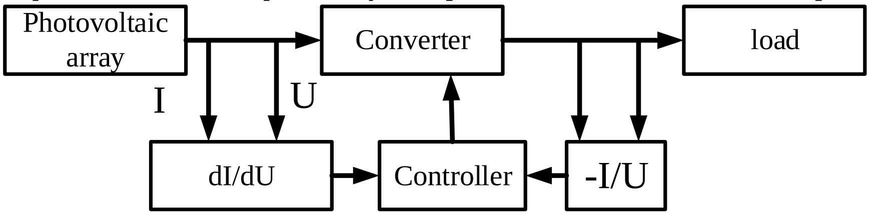

Figure 5 Conductivity increment

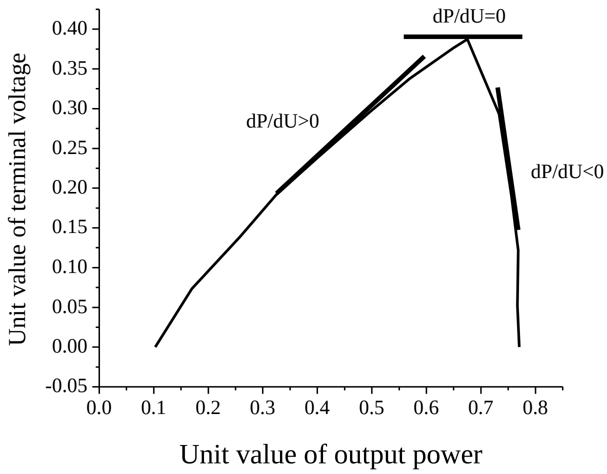

Figure 6 Output P-U curve and change characteristics of dP/dU of photovoltaic array

In order to ensure that the system can have the maximum output power, in this study, by using the method of increasing the working voltage, the working point of the photovoltaic cell moves in the right direction. This method can be used when dP / dV is greater than zero. On the contrary, if dP / dV is less than zero, the working point of the photovoltaic cell is moved to the right by applying the method of increasing the small voltage. If dP / dV is equal to zero, its voltage does not need to be adjusted. The method of regulating voltage can control accurately and adapt to the changes of the outside world. In addition, its vibration is relatively small, but if the measurement accuracy is not enough, there will be some errors. In Eq. 3,

$$\frac{dI}{dV} = -\frac{I}{V} \tag{3}$$

In this study, by adjusting the integral regulator, the value errors of dI / dV and (- I / V) are reduced to zero. At this time, the regulator output value is the compensation value of duty cycle.

2.2. MPPT control of two-stage grid connected photovoltaic inverter

The two-stage grid connected photovoltaic inverter used in this research is composed of the former DC / DC converter and the latter network test inverter. Among them, the photovoltaic array grid connected power generation process is as follows. First, it is necessary to realize the voltage of Boost boost circuit. After the step-up, the current is further output to the power frequency grid through the post inverter. After that, direct current bus is used to connect Boost converter and inverter. After that, the power between the converter and the inverter is transferred to each other.

2.2.1 MPPT control based on post stage grid connected inverter

In this study, in order to make the direct current bus voltage stable, the Boost converter is used to control the proportion of circuit switches to keep the voltage stable. Through this method, the energy between the front and back can be balanced. The later stage grid connected inverter can further realize the grid connected inverter control and MPPT control of the system circuit. The MPPT algorithm can get the output command of current variation amplitude ΔI_0. PI link can be used to further obtain the magnitude I_0 of current amplitude regulation.

Among them, multiplying the sinusoidal voltage signal of the grid synchronization unit and the magnitude I_0 of the current amplitude regulation can further achieve the current instantaneous value of the inverter output command, which is represented by i_{ref}. Then, the difference between i_{ref} and current instantaneous value I_0 is made, and the voltage is adjusted by the proportional regulator. Then, the control signal of MPPT can be obtained by comparing with the three-chord wave, and the control of MPPT can be further realized. In addition, the sinusoidal current of unit power factor should be effectively controlled.

2.2.2 MPPT control based on former stage grid connected inverter

In this method, the MPPT is controlled by using the former Boost converter. The stability of direct current bus voltage in the control system can be controlled by the later grid connected inverter, so as to keep it at a stable level, because the inverter can control the final output voltage of boost converter in the system. Therefore, in general, by adjusting the off-duty ratio of the converter, it will be found that the input current of the converter will also change correspondingly. Through this method, the voltage can be adjusted. After the detection of the current and voltage of the voltage output terminal, the voltage command can be further acquired and represented by U_{ref}. After that, the working point of the battery is adjusted. The voltage command and photovoltaic negligent voltage values are subtracted. The photovoltaic output voltage is represented by U_{PV}. Then, the input voltage of the converter is regulated by the regulator. Finally, the MPPT control photovoltaic cells are controlled. In the control of voltage outer loop and inner loop, the main application is the double loop control strategy, which is relatively mature. When the voltage of direct current bus is controlled, the main application is the principle of power balance to effectively control the voltage outer loop. Among them, the control of the current inner loop is mainly for the real-time tracking control of the network side current.

By comparing the MPPT control of the former stage grid connected inverter with the MPPT control of the latter stage grid connected inverter, it is found that the former stage has greater advantages and can precisely achieve the control purpose. Moreover, the coupling between the front stage and the latter stage is very small, which can effectively control the current and voltage fluctuation and maintain its stability.

3. Results

In this study, the simulation model of power generation system is established. Among them, the simulation time is 3 seconds, the temperature is set to 25°C, and the sampling time is set to 100us, $\triangle D = 0.0002$, $f_s = 2000Hz$. The load capacity is 11kva, the filter capacitance is 0.00062H, the inductance is 12000uf, and the given value of direct current bus voltage is 750V.

From the simulation curve of A-phase current and voltage in three-phase photovoltaic grid connected system, it can be seen that the time when the voltage and current can reach synchronization is not more than 0.1s. After that, the A-phase current is analyzed by FFT, as shown in the Fig. 7 below. Finally, the THD value is calculated to be 4.07%, which can effectively meet the grid connection requirements. According to the three-phase voltage waveform, it can be seen that the difference between the three phases of ABC is 120 degrees. Among them, the frequency is relatively large, 50 Hz. It can be concluded that the current voltage and grid current voltage have the same frequency and phase properties. Through the simulation experiment, it can be seen that the control strategy and the improved algorithm proposed in this study have certain advantages and effectiveness.

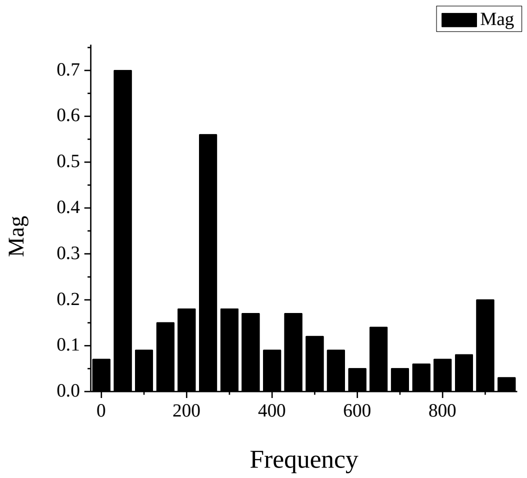

Figure 7 Harmonic analysis diagram

According to the waveform of direct current terminal voltage and regulation in MPPT, it can be seen that direct current bus can achieve the goal of balance within one cycle. Among them, the voltage at the direct current bus terminal will be in a relatively stable state at a given voltage value.

According to Fig. 8 below, there is a certain relationship between the waveform of the active power and the illumination. It will be found that the active power will change with the change of illumination, and the changing waveform is very similar to or even close to the illumination waveform. Once the illumination changes suddenly, the system can also accurately locate and track the maximum power point. In the case of reactive power, the system is almost in the state of zero. However, its power factor is close to 1, which shows that the control of this power generation system is very superior.

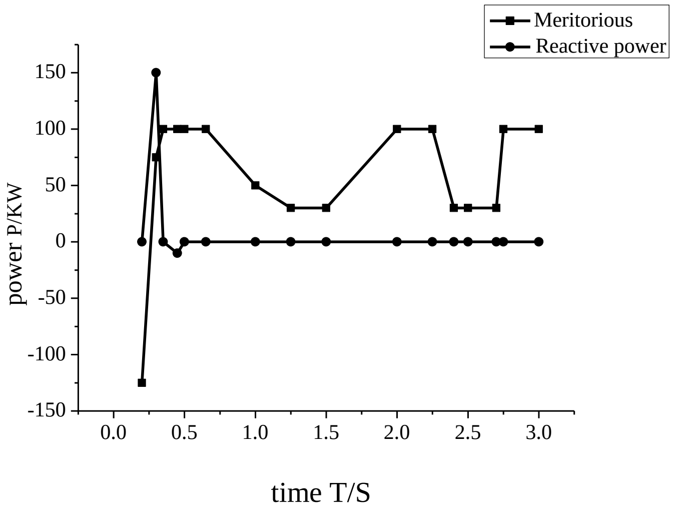

Figure 8 Reactive power and active power output

4. Discussion

China's coal production is second to none in the world. In recent years, with the continuous improvement of the economic level and people's living standards, the consumption rate and utilization rate of coal resources in China are higher and higher. The application of coal resources has promoted the development of China, not only the national economy, but also people's life style has been greatly changed [12, 13]. The safety, economic operation and clean combustion of coal-fired power generation are of great significance to the development of national economy, the improvement of people's life and the improvement of living environment [14, 15]. However, it inevitably causes great damage to the environment. Therefore, in view of the above situation, China proposes the concept of global energy interconnection. Wind and solar energy are developed for power generation. At present, the technology of solar power generation has become the main direction. It has wide distribution, clean energy and large reserves, but has some defects.

In this study, through the optimization design of grid connected power generation system, according to the unique output characteristics of photovoltaic grid connection, MPPT control algorithm and conductance increment algorithm are applied to the design of power generation system to track the maximum power of the system. Through the application of this method, it can effectively prevent the grid connected power generation system from being disturbed by the surrounding environment, can stabilize the output waveform, and reduce the impact of the external environment on the grid connected. The simulation model of power generation system is built in Matlab software, and the simulation experiment is carried out. The results show that the synchronization time of voltage and current is less than 0.1 seconds, and the current voltage and grid current voltage have the same frequency and phase properties. In the case of reactive power, the power factor of the system is close to 1. In the case of active work, changes in light will be found. The active power will also change with it, and the changing waveform is very similar to the light waveform, or even close to it. Direct current bus can achieve the goal of balance within one cycle. The voltage at the direct current bus terminal will be relatively stable at a given voltage value. This experimental research has achieved the expected results, and verified that the algorithm proposed in this study has good applicability and can be widely used in the photovoltaic power generation system, which is of great value to improve the stability of grid connection and conversion efficiency.

5. Conclusion

MPPT control algorithm and the improved conductance increment algorithm are applied to the grid connected power generation system to achieve the accurate tracking of the maximum power point of the grid connected output, which can well maintain the stability of the waveform and the system stability. The application of the control method of three-phase voltage source grid connected inverter can make the output and grid waveform in the same frequency state, and can effectively prevent the voltage fluctuation. In the process of power transmission, photovoltaic grid connected system may have a series of fault problems, such as grid overvoltage and strong voltage. Once this happens, the system should stop transmitting power, so it is very important to detect and identify it. However, in this study, there is no research on this point, which has certain limitations. Therefore, in the future research, it is necessary to consider more comprehensively.

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