Research on photovoltaic power generation system based on power electronics

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Abstract. This paper introduces the DC power obtained from photovoltaic power generation, and then boosts it by the boost chopper circuit. Finally, it is inverted by a single-phase full-bridge inverter circuit into 220V, 50Hz single-phase AC power that meets the normal working requirements of household appliances. Give the load. Among them, the inverter is the most important part, which can convert direct current into alternating current. Before this, it is necessary to increase the DC voltage through a boost chopper circuit and then invert it.

1. Introduction
Chinese solar photovoltaic power generation capacity has exceeded the kilowatt level and is at the forefront of the world. China’s solar cells on artificial earth satellites have already achieved success. Although there is a certain gap between China and some foreign countries, the gap between China and foreign countries is shrinking due to the existence of a sustainable development strategy.[1-3] Especially the people living in poverty-stricken areas in western China are in a period of poverty and backwardness. Most of the residents living on the islands have no electricity and cannot achieve basic living. However, they are sunny and can use renewable energy such as solar power to provide electricity to these areas to enable them to achieve a normal and normal life.

2. Components of a photovoltaic system
The photovoltaic power generation system is composed of a solar battery pack, a boosting portion, an inverter, an energy storage portion, and a load. As shown in Figure 1:
The main circuit of this paper consists of a boost chopper circuit and a single-phase full-bridge inverter circuit. The boost chopper circuit raises the DC voltage generated by the solar energy to a certain amplitude, so that it reaches the voltage required for the next inverter. Then, this voltage will enter the next step of the inverter, and the inverter circuit will be converted into a voltage that meets the normal working condition of the household appliance, so that it can work normally. The resulting single-phase electric power supply is supplied.

3. Selection of IGBT
After the existing research, we determined that the IGBT in the inverter circuit is subjected to a voltage of 0 in the first half of the cycle and a voltage of $u_d$ in the second half of the cycle. Therefore, the voltage at both ends of the IGBT is effective. The value is:

$$u_{VT} = \frac{\int_{0}^{\pi} u_d d(\omega t)}{2\pi} = \frac{u_d}{\sqrt{2}}$$

(1)

Therefore, the maximum voltage that the IGBT is subjected to is $u_d$.

Since the margin needs to be considered, the IGBT with a rated voltage of 2 to 3 times the maximum value should be selected. Therefore, the calculated rated voltage is:

$$U_{VT} = (2 \sim 3) u_d$$

(2)

$$U_{VT} = (2 \sim 3) u_d = (488.8 \sim 733.2)V$$

(3)

This paper decided to choose a rated voltage of 500V. Because the effective voltage across the resistor in the circuit is 220V, the maximum value is 311V and the resistance is 10 ohms. Therefore, the maximum current is 31.1A. Considering the 1.5~2 times margin, the rated current is 50A. Therefore, an IGBT with a rated voltage of 500V and a rated current of 50A is selected.

4. DC-AC inverter circuit
After analyzing the characteristics of the DC-DC converter circuit, it was decided to use the boost chopper circuit to adjust the DC voltage. Then, this paper will introduce the DC to AC conversion circuit and select two schemes. The working process of the solution and decide which circuit type to use as the inverter circuit.
Option 1: Single-phase half-bridge inverter circuit. as shown in picture 2. The voltage-type inverter of the single-phase half-bridge is mainly composed of two bridge arms composed of controllable power electronic devices and diodes. And the controllable power electronic device is connected in parallel with the diode, wherein the diode is connected in reverse parallel to the controllable power electronic device. In addition, a capacitor needs to be connected in parallel at both ends of the DC power supply for the purpose of isolating the DC. In addition, the inductor is connected in parallel on the AC side. Its function is:

(a). It is possible to reduce the degree of floating of the last generated current;
(b). Eliminate the higher frequency current generated at the end and protect the household appliance from damage;
(c). Because of this inductance, the voltage and current will not change easily. In addition, the PWM modulation makes the controllable power electronic device regularly turn on and off, which can easily make the output voltage and current work normally. The standards are consistent.

![Figure 2. Single-phase half-bridge inverter circuit](image)

If the value of the capacitor is assumed to be infinite. If the trigger currents of the two controllable power electronic devices are each turned on for half of the time in one complete duty cycle, the other half of the cycle is in the off state. If the load is inductive, the resulting AC voltage is rectangular and the size is half of the DC voltage, and the current generated is related to the load carried by the circuit. Suppose that the first controllable power electronic device is in the on state before the time, the second controllable power electronic device is in the off state, and the first controllable power electronic device is immediately turned off at the moment. State, in the moment the second controllable power electronics are in an on state. Although the trigger current can start or end in an instant, due to the presence of the energy storage component of the inductor, the current in the circuit does not change immediately, but will hinder the occurrence of this change, and the current will continue to follow the previous direction. When the flow is carried out, the diode we mentioned above starts to play its role. The diode will now direct the residual current from the inductor to the DC-blocking capacitor connected in parallel on both sides of the DC power supply, and absorb it. This kind of reactive power, so this diode has a name, called a freewheeling diode, because its role is to enable the current to continue to flow during this period, so that the current will not be interrupted continuously. When the current in the inductor is exhausted at the moment, the second controllable power electronic device starts to be in the on state, and the current in the circuit is in the reverse flow state, thus completing a work cycle.

Option 2: Single-phase full-bridge inverter circuit. As shown in Figure 3. Compared with the two bridge arms of the half bridge, the full bridge has four bridge arms, which can also be equivalent to the combination of two half bridges, wherein the order of conduction is simultaneous on the diagonal, that is, the first controllable The power electronics are simultaneously turned on with the fourth controllable power electronics. The second controllable power electronic device is simultaneously
turned on with the third controllable power electronic device. The two groups are mutually conductive
and have a conduction angle of 180 degrees. The resulting voltage waveform is a rectangular wave
that is the same size as the DC power supply. Under the same load conditions, the generated current
waveforms are similar, the difference is that the size is twice that of the half bridge. When the
controllable power electronic devices are all in the off state, the workflow is the same as that of the
half bridge.

Figure 3. Single-phase full-bridge inverter circuit

By analyzing the two schemes, it can be known that the single-phase half-bridge inverter circuit
structure is simpler and has fewer components than the full-bridge inverter circuit. But we know that
the function of simple circuit implementation will certainly be less and unstable, so this paper decided
to use single-phase full-bridge inverter circuit to transform from DC to AC.

When the firing angle is 180 degrees, the generated voltage can be analyzed to be a Fourier series:

\[ u_a = \frac{4U_d}{\pi} (\sin \omega t + \frac{1}{3} \sin 3\omega t + \frac{1}{5} \sin 5\omega t + \ldots) \]  

(4)

The amplitude \( U_{o1m} \) and the effective value \( U_{o1} \) of the waveform of equation (4) are:

\[ U_{o1m} = \frac{4U_d}{\pi} = 1.27U_d \]  

(5)

\[ U_{o1} = \frac{2\sqrt{2}U_d}{\pi} = 0.9U_d \]  

(6)

Of course, we can also change the generated voltage by controlling the phase angle change,
although the trigger current of the above controllable power electronic device is complementary to the
trigger current of the controllable power electronic device below, but the trigger current difference of
the corner controllable power electronics is no longer a 180 degree angle, but is moved back by \( \theta \) (0
\(< \theta < 180^\circ \)). That is, the triggering of the latter controllable power electronic device is shifted by
\( 180^\circ - \theta \) forward than the previous controllable power electronic device trigger current. The following
article will analyze the process of its work.
If we give a trigger to the first controllable power electronics and the fourth controllable power electronics before \( t_1 \) time, let them both turn on, then they generate a voltage of \( U_d \) and arrive at \( t_1 \), the third controllable power electronic device is swapped with the trigger of the fourth controllable power electronic device, and the fourth controllable power electronic device stops working immediately, but due to the presence of inductance The current inside the circuit cannot disappear immediately, so even if the trigger is given, the third controllable power electronics can't work immediately, but it is in the on state with its anti-parallel freewheeling diode. At this time, only the first controllable power electronic device and the third diode are in operation, and thus the generated voltage value is zero. At \( t_2 \) time, the triggering of the first controllable power electronics is reversed with the trigger of the second controllable power electronics, at which point the first controllable power electronics ceases to operate immediately, and the presence of inductance, The second controllable power electronic device is rendered incapable, and a diode connected in parallel with the diode forms a loop with an output voltage of \(-U_d\). When the current in the circuit is zero, the reverse conduction begins. The second controllable power electronics and the third controllable power electronics begin to operate while the parallel diodes stop working. The voltage generated at this time is still \(-U_d\). At \( t_3 \) time, it is the same as \( t_1 \) time. The resulting voltage has a pulse width of \( \theta \). The voltage can be changed by changing the value of \( \theta \).

From the above analysis, we can know that if you want to get a 220V sine wave, its input DC voltage is:

\[
U_d = \frac{U_{in}}{0.9} = \frac{220}{0.9} = 244.4V
\]  

(7)

Therefore, the voltage input to the inverter circuit should be 244.4V.

5. MATLAB simulation

This simulation uses a number of components including the IGBT, oscilloscope, etc. in the Simulink library, and then constitutes two simulations of the boost chopper circuit and the single-phase full-bridge inverter circuit, and adjusts the internal devices. Show the final simulation results. Figure 4 is a circuit diagram of the boost chopper circuit:
Figure 4. Boost chopper circuit simulation diagram

When the voltage of DC 20V is input and the pulse trigger frequency is 100KHz, the voltage value obtained at the final output is 77V. As shown in Figure 5 below:

Figure 5. Boost chopper circuit simulation results

Figure 6 is a circuit diagram of a single-phase bridge inverter circuit:
When the input DC voltage value is 77V and the pulse trigger frequency is 50Hz, the output waveform is shown in Figure 7. The value is displayed in the digital display table, which is 311.8V, which is converted into an AC effective value of 220V.

Figure 6. Simulation diagram of single-phase bridge inverter circuit

Figure 7. Single-phase bridge inverter circuit simulation results
In summary, the simulation achieved the intended purpose and produced a voltage that was consistent with the normal operation of the household appliance.

6. Conclusion

Solar power generation can be divided into two types: independent photovoltaic power generation system and photovoltaic grid-connected power generation system according to application scenarios. This paper introduces a photovoltaic grid-connected power generation system that can deliver power to the grid and alleviate the pressure on the grid to power users. This paper mainly uses boost boost circuit and single-phase full-bridge inverter circuit, analyzes their working process and makes MATLAB simulation, and has achieved the expected results.

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