



# Research of Single-Phase Photovoltaic Grid-Connected System Based on MATLAB

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**Abstract.** Based on the analysis of structure and common control scheme of photovoltaic grid-connected system, a solar photovoltaic (PV) cell simulation model is built according to the internal structure and output characteristics of PV cell. A control method of photovoltaic MPPT which can track photovoltaic points and the maximum power of photovoltaic cells is expounded. This method can be used to improve the efficiency of photovoltaic cells to the greatest extent. Finally, the principle and control strategy of the photovoltaic grid-connected system are analyzed in detail. According to the instantaneous value control method of grid-connected inverter, some requirements of grid connection with low THD and high power factor are achieved.

**Keywords:** Photovoltaic grid-connected system · PV cell · MPPT control · Instantaneous value control

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## 1 Introduction

Energy is indispensability for the development of the world economy. However, because of the depletion of traditional energy sources such as coal, oil, and natural gas and increasing of the world population, the energy problem has appeared more or less in many countries all over the world, and the energy crisis has become a difficult problem to be solved all over the world. The emergence of new renewable energy has greatly alleviated the energy crisis, especially the utilization of solar energy. As a new type of renewable energy, solar energy has attracted more and more attention in recent years due to its advantages of green environment and inexhaustible energy [1].

One of the most common utilization of solar energy is grid-connected photovoltaic power generation. First, a solar array is used to collect solar energy, and converts the heat energy of solar into DC power and then outputs to the inverter. The DC energy is converted into sinusoidal alternating current energy which will be incorporated into the AC network, thus an active inverter system is formed [2].

## 2 Composition of Photovoltaic Grid System

MPPT two-stage mode is the common structure of photovoltaic grid system, which is generally composed of PV array, DC–DC chopper circuit, DC–AC inverter circuit, active filter circuit, and so on, as shown in Fig. 1. The DC–DC converter is used to track and control the maximum power point of photovoltaic. The DC–AC inverter is used to turn the DC inverse of the solar cell into alternating current and sends to AC network, and controls its phase be same with the grid, so that the power factor is close to 1 [3]. The active power filter is used to filter the high harmonics contained in alternating current power before the grid is connected, so that it is closer to an ideal AC sine signal.

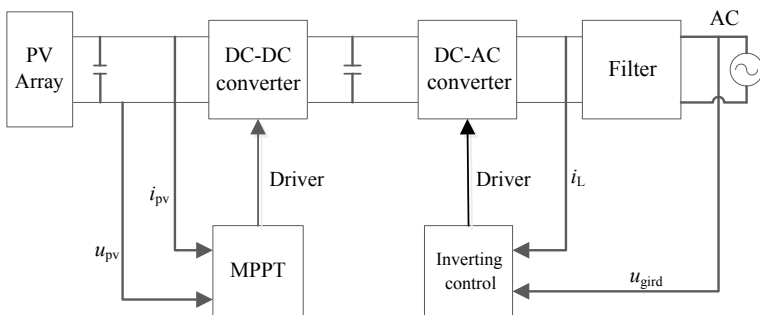


Fig. 1. Two-stage grid-connected structure mode

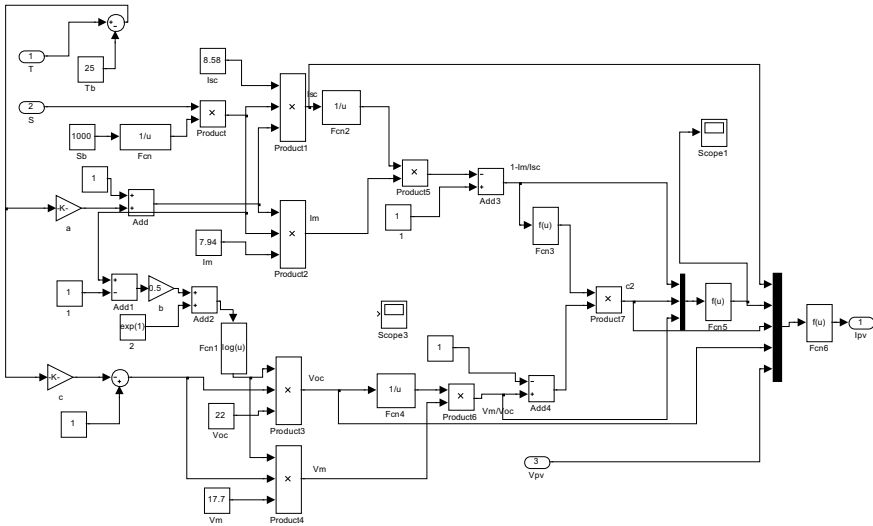
## 3 PV Cell Modeling and MPPT Control Method

### 3.1 PV Cell

There are many factors in nature which can affect the efficiency of PV cell, such as light intensity, temperature and so on. The output of the PV cell will appear nonlinear due to PN junction parameters and external environmental factors. The relationship between output voltage and output current is shown in Eq. (1) [4, 5].

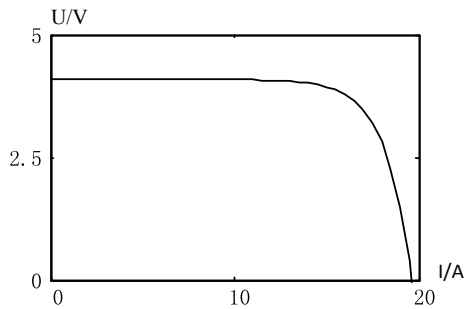
$$I = I_{ph} - I_o \{ \exp[q(U + IR_s)/AKT] - 1 \} - (U + IR_s)/R_{sh} \quad (1)$$

Thereinto,  $U$  is the output voltage of PV Cell;  $I$  is the output current of PV cell;  $I_{ph}$  is the photocurrent current of PV cell;  $I_o$  is the reverse saturation current of diode.  $R_s$  is the series equivalent resistance;  $R_{sh}$  is the parallel equivalent resistance;  $K$  is Karl Seidman constant;  $T$  is the absolute temperature of PV cell;  $A$  is a dimensionless curve fitting constant with value range of  $1 \leq A \leq 2$ . According to the engineering mathematical model, the PV cell simulation model is built in Simulink, as shown in Fig. 2.



**Fig. 2.** PV cell simulation model

When the light intensity is  $1000 \text{ W/m}^2$  and the ambient temperature is  $25 \text{ }^\circ\text{C}$ , the I-V and P-V characteristic curves of PV cells are shown in Figs. 3 and 4. With the increasing of PV cell output current, the output voltage gradually decreases, and the PV cell output power will increase gradually with the increasing of PV cell output voltage. After the maximum power point, the output power decreases sharply as the output voltage continues to increase.



**Fig. 3.** I-V output characteristic curve

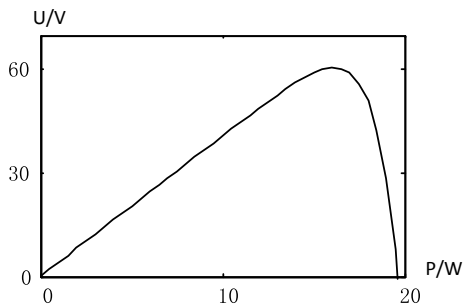


Fig. 4. P-V output characteristic curve

### 3.2 MPPT Control Method

MPPT control can effectively solve instability of system working points caused by the nonlinear output voltage of PV cell, so that the maximum power can be output under any conditions, therefore, MPPT control is widely used in the field of PV grid system. There are some methods of MPPT control, such as CVT, P&O or IC<sup>3</sup> and so on. In this paper, the disturbance observation method is used to control the output voltage. Because the Boost circuit has the advantages of the simple driving circuit and always working in the continuous current state, this circuit is usually used to achieve maximum power point tracking. The MPPT simulation model built in the Simulink toolbox is shown as Fig. 5, in which  $L = 10^{-3}$  H,  $R_1 = 30 \Omega$ ,  $C = 3 * 10^{-3}$  F.

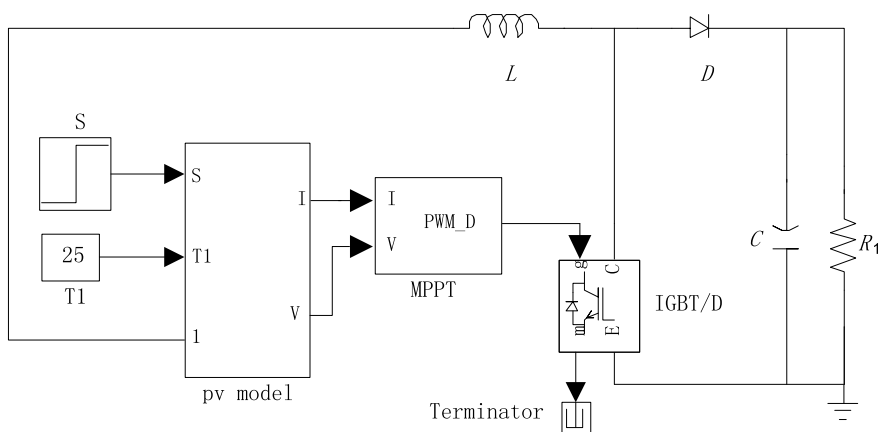
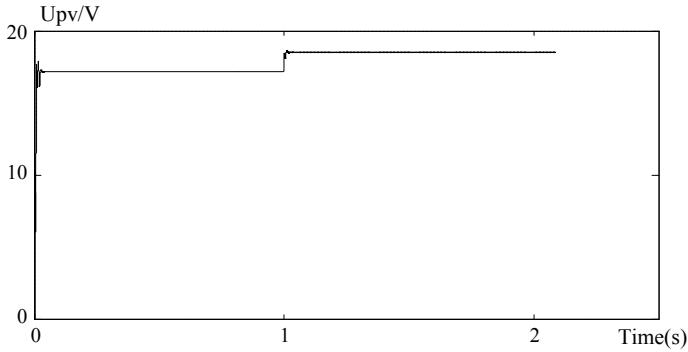


Fig. 5. MPPT simulation model

When the light intensity changes from 600 to 1000 W/m<sup>2</sup>, the output voltage waveform of the simulation model is shown as Fig. 6.

It can be seen from the waveform in Fig. 6 that the P&O control has a good dynamic response and can track the maximum power point of PV cell well. The control

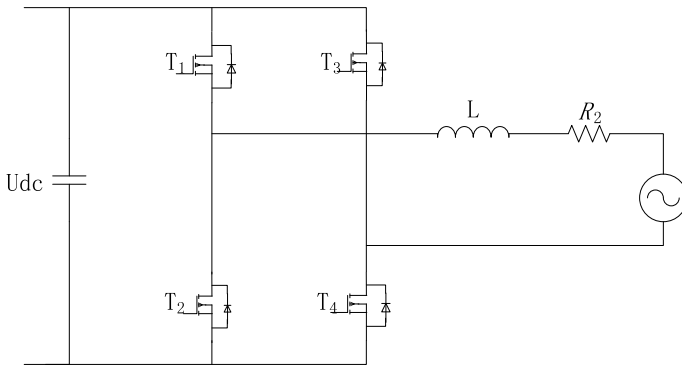


**Fig. 6.** MPPT voltage output waveform

scheme is simple and easy to be realized, and the control precision is more accurate than CVT. However, there are some disadvantages of this control scheme that the output voltage will be slightly oscillating near the maximum power point, and the control precision is greatly influenced by the disturbance step.

#### 4 Control Strategy of Two-Stage Photovoltaic Inverter

The two-stage type PV inverter circuit is a voltage type full control bridge inverter circuit as shown in Fig. 7, where  $U_{dc}$  is the steady voltage of PV array after Boosting and control,  $U_o$  is the output voltage of inverter,  $U_{grid}$  is the grid voltage,  $R_2$  is the equivalent resistance of the line (generally small, assuming that is  $0.01 \Omega$ ),  $L$  is the filter inductance which is  $6 * 10^{-3} \text{ H}$  and is used to filter out the higher harmonics in output voltage, at the same time, to balance the voltage difference between the output voltage and the grid voltage [6].



**Fig. 7.** Voltage type full control bridge inverter circuit

There are four switch tubes of the full bridge inverter circuit that are divided into two groups T1, T4 and T2, T3 which are connected alternately, using SPWM driving mode. After inverting, the AC voltage signal is filtered out of the high harmonic through the filter inductor; after adjusting the voltage phase, the AC voltage signal becomes AC sinusoidal signal with less harmonic content and the same frequency as the voltage of the power grid, which is incorporated into AC network.

There are many methods to control the inverter circuit. In this paper, the instantaneous value control method which has a better dynamic response is used. This control method has been widely used in the field of active inverter because of its advantages such as fast dynamic response speed, simple control and less harmonic content in the output voltage waveform. The control logic schematic diagram of SPWM instantaneous current is shown in Fig. 8 [7].

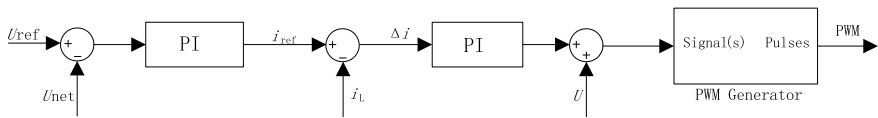


Fig. 8. Control logic of SPWM instantaneous current

The difference between the reference voltage and the output voltage of the sampling inverter is defined as the instantaneous error. The instantaneous error signal is adjusted by the PI signal regulator as the current reference signal  $i_{ref}$  which is compared with the instantaneous value  $i_L$  of the sampling inductor current to produce the error signal  $\Delta i$ . After the PI adjustment and the voltage feedforward compensation, the signal is compared with the triangle carrier, that is, the SPWM drive signal is produced which is used to control the power switch tube in the inverter circuit. According to the above control methods, a grid-connected control model is built in MATLAB, as shown in Fig. 9, where  $P = 0.01$ ;  $I = 100$ ;  $K = 1/400$ .

Figure 10 shows the simulation results of AC grid-connected power generation system under an illumination intensity of  $1000 \text{ W/m}^2$  and ambient temperature of  $25^\circ\text{C}$ .

Where  $i_L$  is the grid-connected current,  $U_{net}$  is the power grid voltage. After 0.06 s, the inverter output has the same frequency, same phase and with THD (the total harmonic base) of  $3.6\% \leq 5\%$ , which meet grid connection requirements.

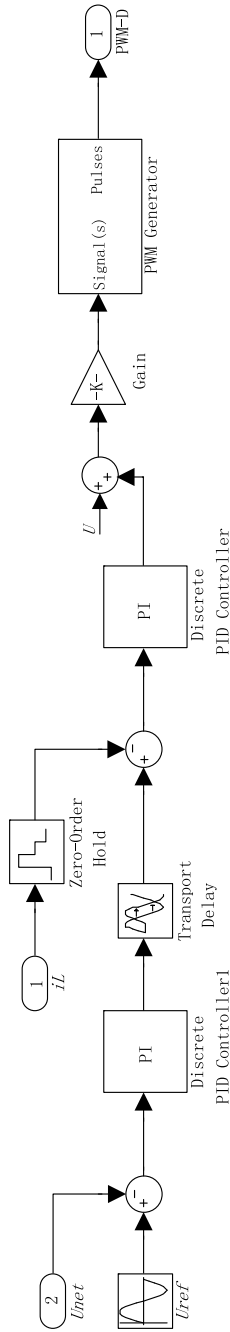


Fig. 9. Instantaneous current control model

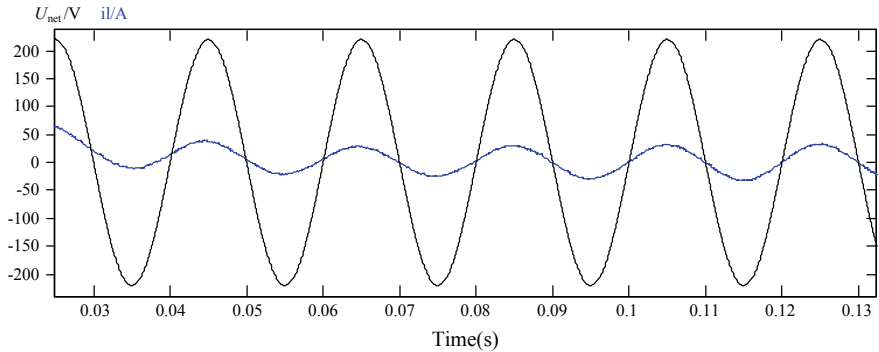


Fig. 10. Output waveform of grid-connected current and voltage

## 5 Conclusion

As shown in Fig. 10, the voltage-type full bridge inverter which is combined with P&O control method and current instantaneous value control method can make the output power of PV cell track the maximum power point well, and better achieve the demand of output voltage and grid. However, this control scheme still has some shortcomings, such as contradiction between disturbance step size and speed and control accuracy, which need further optimization.

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