Study on Energy Coordination Mechanism of Micro Photovoltaic Grid Connected Inverter

Enmu Zhang¹ *, Yong Shen¹, Wenbin Wang¹, Peilei Feng² a, Tianqi Xu¹

¹Yunnan Minzu University, Kunming, Yunnan China
²Anhui Jinzhai Pumped Storage Power Company Limited, Lu'an, Anhui, China

*Corresponding author e-mail: zhangghg@126.com, a243653648@qq.com

Abstract. In this paper, the non isolated grid connected inverter control strategy is adopted. The simulation model of photovoltaic grid connected inverter is built in MATLAB. Realize the same frequency and phase of grid connected current and grid voltage, the sine degree of grid connected current waveform is better, and realize the islanding detection function. In the experiment platform, the control idea is further verified, and the simulation is proved to be correct.

1. Introduction
In recent years, the energy problem has attracted extensive attention in various fields, and a lot of research has been carried out by scientific research institutions at all levels and colleges and universities. As a potential, inexhaustible and inexhaustible green energy, solar energy has irreplaceable advantages over other fossil fuels. At present, photovoltaic grid connected power generation system has gradually become the mainstream power generation mode, small and medium-sized photovoltaic power generation system is more and more used in daily life. Reference [1-3] introduces the common control mode and topology structure in photovoltaic grid connected power generation system. In this paper, PV + boost + inverter structure is adopted, and the control goal is low power, high efficiency, cascade and easy to realize MPPT control of maximum power point is realized by conductance increment method, which has the advantages of high control accuracy and fast maximum power point tracking [1-3].

2. Control principle block diagram
2.1. Mathematical model of photovoltaic cell
The equivalent circuit of photovoltaic cell is similar to a PN junction, as shown in Figure 1. Iph is the ideal current source; Id is the equivalent diode current; R1, R2 is the internal parallel and series resistance, RL is the load resistance. The output power of photovoltaic cell is:

\[ P = U_0 I = I^2 R_L = [I_{ph} - I_d - \frac{U_0 + IR_d}{R_L}]^2 R_L \] (1)

When the parameters of fixed light intensity and normal temperature are s = 1000W/m², t = 25°C, a fixed maximum power point can be obtained. When the light intensity and ambient temperature change,
in order to improve the energy conversion efficiency, a new mathematical model should be established to calculate the new maximum power point.

$I_{SC}$ is the short-circuit current of photovoltaic cell, $V_{OC}$ is the open circuit voltage, the voltage and current at the maximum power point are $V_{PVM}$ and $I_{PVM}$ respectively, the output voltage of photovoltaic cell is $V_{PV}$, and the output current is $I_{PV}$.

Neglecting the influence of parallel resistance, the expression of input and output of photovoltaic module can be obtained when considering the temperature and light change [4-5]:

\[
I_{PV} = I_{SC} \left( 1 - A_1 \left( e^{(V_{PV}/A_2 \cdot V_{OC})} - 1 \right) \right) + \Delta I \tag{2}
\]

\[
A_1 = \left(1 - I_{PVM} / I_{SC}\right) \cdot e^{(-V_{PVM}/A_2 \cdot V_{OC})} \tag{3}
\]

\[
A_2 = \left(V_{PVM} / V_{OC} - 1\right) / \ln(1 - I_{PVM}) \tag{4}
\]

\[
\Delta I = \alpha \left(S / S_{REF}\right) \cdot \Delta T + \left(S / S_{REF} - 1\right) \cdot I_{SC} \tag{5}
\]

In the MATLAB/Simulink environment, the simulation model parameters of photovoltaic cells are shown in Figure 2, which can be easily adjusted. Figure 3 and Figure 4 respectively show the current voltage waveform and power voltage waveform of the photovoltaic module. After comparison, the waveform conforms to the actual situation and the model is correct.

![Figure 1](image)

**Figure 1.** Equivalent circuit of photovoltaic
Figure 2. Photovoltaic module simulation

Figure 3. Current voltage curve

Figure 4. Power voltage curve
2.2. System control block diagram
The system control block diagram is shown in Figure 5. PV + boost + inverter structure is adopted in
the system, taking into account efficiency and hierarchical control. The maximum power control (MPPT)
of photovoltaic module is realized by controlling MOSFET, and the current grid connected control
(inverter-pll) with the same frequency and phase with the grid is realized by inverting circuit.

2.3. MPPT control
Due to the influence of solar radiation and ambient temperature, the output characteristics of
photovoltaic modules are variable and nonlinear. It can be seen from Figure 4 that under certain external
environment, the output power of photovoltaic module will have a maximum value Pmax, which is
called the maximum power point. In the process of photovoltaic grid connection, the photovoltaic
module is always expected to work at the maximum power point, so the energy conversion efficiency is
the largest. At present, the most commonly used methods of maximum power point tracking are:
disturbance and observe, incremental conductivity, constant voltage tracking, hysteresis comparison and
other improved algorithms
In general, each algorithm has its own advantages and disadvantages. In this paper, the conductance
increment method is chosen to calculate the maximum power point of photovoltaic module from the
perspective of easy implementation. As shown in Figure 6:

![Block diagram of photovoltaic grid connected control system](image)

**Figure 5.** Block diagram of photovoltaic grid connected control system

```
start

U(K), I(K)

\[ dU = U(K) - U(K-1) \]
\[ dI = I(K) - I(K-1) \]
\[ dP = P(k) - P(k-1) \]

= 0

\[ dU = \begin{cases} 
0 & dI/dU > I/I \ 
U = U + \Delta U & dI/dU \leq I/I \ 
U = U - \Delta U & dI/dU < 0 \ 
U = U + \Delta U & dI/dU = 0 
\end{cases} \]

end
```

**Figure 6.** Flow chart of incremental conductance method
2.4. Grid connection control

The grid connection control idea is shown in Figure 7. The voltage and current generated by the photovoltaic module are calculated through a series of operations. Combined with PLL, the reference current of grid connected inverter is generated in the early stage. After comparing with the actual current output by grid connected inverter, it is sent to PID module to generate the reference voltage controlled by grid connected inverter. After comparing with the grid voltage, it is sent to PWM module to generate the inverter control pulse, so as to achieve the purpose that the output is in the same frequency and phase with the grid [6-7].

![Figure 7. Grid connection control flow chart](image)

3. Analysis of simulation results

As shown in Fig. 8 and Fig. 9, the voltage generated by the photovoltaic module boosts the bus voltage $V_{bus}$ to about 450V through boost circuit, and the ambient temperature is 25°C at 0.2S; When the light intensity changes from 1200W/m² to 1000W/m², $V_{bus}$ changes to 420V. Meanwhile, the grid connection current $I_{out}$ changes from 4A to 3A. In the whole process, the voltage $V_{bus}$ of DC bus keeps stable, the waveform of grid current is good, and the frequency and phase of grid current and grid voltage are the same. At 0.4s, when the power grid is powered off, the control system can cut off the trigger pulse quickly, and the grid connection current is output to 0 from 0.4s later, which shows that the control system has achieved the expected purpose [8-9].

![Figure 8. DC bus voltage](image)
4. Experimental verification
In order to further verify the feasibility of simulation, an experimental test platform for grid connected inverter is built on the basis of STM32F103RBT6 development board. Based on the zero crossing detection, the reference signal with the same frequency and phase with the grid voltage is obtained. On this basis, the sinusoidal current waveform with the same frequency and phase with the reference signal is generated through the STM32F103RBT6 development board experimental platform. As shown in Figure 10, blue is the voltage waveform with the grid, and yellow is the current waveform generated by the grid connected inverter. It can be seen that the grid connected current waveform has fewer ripples and better sinusoidal degree, meeting the grid connection requirements [10].

5. Conclusion
In this paper, the photovoltaic grid connected inverter control system is built in MATLAB. Through the simulation results, under the function of boost circuit, the DC bus voltage is stable, the grid connected inverter current waveform and grid voltage are in the same frequency and phase, and the sine degree is good. It is verified in the experimental platform, which provides a reference for further study of photovoltaic system.
Acknowledgments
Fund Project: Yunnan applied basic research program youth fund project (2017FD120)

References
[1] Yang Yulin, Gong Yueling, Zhang Ling. Photovoltaic inverter simulation study [J]. Electronic Design Engineering, 2011, 19(20): 22-26.
[2] Liu Jichuan, Liu Wubin, Deng Jiakang, et al. Research on simulation of photovoltaic power generation system based on MPPT algorithm. New Energy, 2018, 72-76.
[3] Zhao Gang, He Jun, Jiang Hui. Simulation Analysis of Household Single-phase Grid-connected PV Power System. East China Electric Power, 2012, 40(8), 1375-1378.
[4] Li Xing, Liu Zhengying. Simulation of Operation Control of Single-Phase Photovoltaic Grid-Connected Control. Journal of Chongqing University of Technology (Natural Science), 2014, 28(5), 115-119.
[5] Wang Xiaoming, Lv Jinheng, Qiang, Minghui. Simulation research on single-phase grid-connected photovoltaic system based on MATLAB. Electronic Design Engineering, 2014, 22(17), 59-62.
[6] Gao Xiaoling, Li Tao, He Zhenzhong. Simulation and Design of Single-Phase Photovoltaic Grid Connected system Based on MATLAB. SCIENCE & TECHNOLOGY INFORMATION, 2013, 3, 36-37.
[7] Chen Jun, Jiang Tianbo, Yang Shuang, et al. Simulation study of single-phase grid connected photovoltaic system based on MPPT. Power and Technology, 2014, 38(12), 2405-2407.
[8] Dai Xunjiang, Chao, Qin. Current control constant hysteresis band for single photovoltaic grid-connected inverter. Power System Protection and Control, 2009, 37(20), 12-17.
[9] Yang Haizhu, Liu Jie. Research on Maximum Power Point Tracking Control Based on the Low Power Photovoltaic Grid-connected Inverter. IPEMC2009, 2165-2169.
[10] Hao Zhou, Chaonan Tong, Meiqin, Mao, et al. Development of Single-phase Photovoltaic Grid-connected Inverter Based on DSP Control. 2010 2nd IEEE International Symposium on Power Electronics for Distributed Generation Systems, 650-653.