The Research on Three-phase Photovoltaic Grid-connected Inverters Control Strategy Based on MPPT

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Abstract. This paper develops successfully SVPWM voltage vector tracking current control model for three-phase grid-connected inverter and a novel current scheme under two phase synchronous rotating frame is presented, which is using grid feed forward controller. Considering the efficiency of photovoltaic modules, using an improved maximum power tracking algorithm. The simulation results show that the inverter has high output power factor and photovoltaic system has good dynamic performance and tracking result.

Introduction

The key technology of Photovoltaic (pv) grid power generation system researched mainly the utilization of photovoltaic arrays and the control strategy of grid inverter, which the control system directly affected the whole system performance. Firstly, it generally needed to adopt MPPT algorithm to improve the utilization efficiency of pv, the variable step-size perturbation observation method had better tracking speed and accuracy than traditional perturbation observation method. Secondly, output voltage waveform quality was an important indicator of a inverter. The voltage vector tracking current control of fixed switching frequency SVPWM is studied. Compared with the SPWM control [1,2], which the voltage utilization of DC side is higher and dynamic performance is better. At the same time, it is convenient to eliminate the steady-state error of AC in the rotating coordinate system. As the emergence of high-speed digital signal processor (DSP), for the pv inverter digital control provided a convenient, proposing a three-phase SVPWM inverter based on double closed-loop control.

The Mathematical Model of PV Grid Inverter

The topology of three Phase Grid-Connected inverter, as shown in Fig. 1. Using the Kirchhoff’s law, we could get the model of each phase voltage loop of the inverter in three-phase stationary coordinate system[3]. As shown in equation (1).

\[
\begin{align*}
\frac{di_a}{dt} &= -\frac{R}{L}i_a + \frac{1}{L}u_a - \frac{1}{L}e_a \\
\frac{di_b}{dt} &= -\frac{R}{L}i_b + \frac{1}{L}u_b - \frac{1}{L}e_b \\
\frac{di_c}{dt} &= -\frac{R}{L}i_c + \frac{1}{L}u_c - \frac{1}{L}e_c
\end{align*}
\] (1)
In the formula, \(i_a, i_b, i_c\) — inverter output current, \(u_a, u_b, u_c\) — inverter output voltage, \(e_a, e_b, e_c\) — Grid phase voltage, \(L\) — output filter inductance, \(R\) — internal resistance.

The first, converting to \((\alpha, \beta)\) of two-phase stationary coordinate system, then converting to \((d, q)\) of two-phase synchronous rotating coordinate system, Equation 2 is obtained that thinking out the three-phase balance and according to the principle of constant power.

\[
\begin{bmatrix}
u_d \\
u_q
\end{bmatrix} = \begin{bmatrix}
\cos \theta & \sin \theta \\
-\sin \theta & \cos \theta
\end{bmatrix} \begin{bmatrix}
1 & 0 \\
1/\sqrt{3} & 2/\sqrt{3}
\end{bmatrix} \begin{bmatrix}
u_a \\
u_b
\end{bmatrix}
\]

Equation 3 is obtained that substituting Equation 2 into Equation 1 and neglecting \(R\).

\[
\begin{align*}
L \frac{di_d}{dt} &= L \omega_i q + u_d - e_d \\
L \frac{di_q}{dt} &= L \omega_i d + u_q - e_q
\end{align*}
\]

The Control Strategy of Grid Operation

In the system steady state, the \(i_d\) and \(i_q\) of the rotating coordinate system are DC, in order to control the intermediate DC bus voltage and network side current at a given value, supposing \(e_q = 0\). This system used voltage vector tracking current control strategy based on the PI regulator in the synchronous rotating coordinate system\[4\], as shown in Fig. 2.

![Figure 1. The Active Inverter Circuit Structure of Three Phase bridge Voltage Type.](image-url)
PV grid-connected control system consisted of DC voltage outer ring and current inner loop. Collecting the current and voltage from the grid, through the coordinate transformation, the actual voltage and current in rotating coordinate system were obtained. In the voltage outer loop, calculating the difference between the given value and the DC voltage obtained through the maximum power tracking, by the PI regulator it could realize the no-static-difference control of the DC voltage, and the output is $i_d^*$ as the current reference value of the d-axis. In the grid-connected inverter, \( i_d, u_{dc} = p = 3/2e_d i_d \), So through controlling active power to achieve the voltage control of DC side, reference value of the AC side outputting voltage were $u_d^*$ and $u_q^*$, current reference of the reactive current inner loop was $i_q^*$, according to the requirements of grid connection, Letting $i_q^* = 0$, then $q^* = 3/2e_d i_q^* = 0$ and supplying reactive power was zero. At last, obtaining the driving PWM signal of six IGBT by SVPWM controlling technique, and making the inverter output a constant sine wave voltage.

The Maximum Power Tracking Algorithm Realization

As the PV cells affected by the external environment, making the output voltage change and a wide fluctuations, the mppt is realized by the optimal control to get the input reference voltage of PV grid-connected system. At present, the main mppt control methods are constant voltage method (CVT), conductance increment method (IC), Perturbation observation method (P&O)[5-6].

In this paper, an improved perturbation observation method is adopted, in order to overcome the shock in the tracking process of the traditional perturbation observation method and improve the tracking effect, which has better performance, low cost, easy to implement and the core algorithm has universal universality. The core idea is that it changes the perturbation step in the process of disturbance, in order to obtain a higher response speed and steady-state tracking speed.
Since the sampling time is extremely short during the mppt, in this case \( \Delta P/\Delta V \) can be considered as the slope of the various operating points on the P-V curve, as shown in Fig.3. When the distance is away from the mpp, the slope is relatively large, so it can be disturbed for a large steps. When the distance is nearby from the mpp, The slope approaches zero and oscillation is small, so it can be disturbed for a small steps. According to this feature, it is possible to improve the tracking speed of the system and reduce the oscillation in the tracking process by adaptively adjusting the disturbance step length. The disturbance step is \( \Delta V = \alpha (dP/dV) \), where \( \alpha \) is a positive constant and a speed factor of the disturbance step. The flow chart of the improved perturbation observation method, as shown in Fig.4.

**The Simulation Result**

PV cell module type is XZSTII80-24/B, Peak power is peak power, maximum power operating point voltage is 36V, maximum operating current is 5A, open circuit voltage is 44.8V, short circuit current is 5.30A. 25kW PV array consists of 14 modules in series, 10 in parallel, PV array open circuit voltage is 627.2V and short circuit current is 53A. Under the conditions \( G = 1000W/m^2 \), \( T = 25^\circ C \), The PV array operates at the maximum power point voltage is 504V and current is 50A, the inverter input voltage is 700V, grid voltage is 380V, switching frequency of inverter is 10Hz and output phase current is 38A, fundamental frequency of grid - connected current is 50Hz, the PI regulator parameters of current loop are \( K_i = 20 \) and \( K_{ii} = 0.1 \), the PI regulator parameters of voltage loop are \( K_{vi} = 10 \) and \( K_{iv} = 0.1 \).
When the system is around 0.03s, the output voltage reaches a maximum of 504V and stability in the traditional perturbation observation method, as shown in Fig.5. When the system is around 0.02s, the output voltage reaches a maximum and stability, Compared with the traditional perturbation observation method the response speed is faster and the oscillation is also reduced, as shown in Fig.6. Fig.7 shows that the inverter output current and grid voltage in phase with the frequency, the power factor is 1. Compared with the simulation results in Fig. 8 can be seen that using SVPWM control of the inverter outputting voltage vector amplitude higher than using SPWM, with lower harmonic and higher voltage utilization.

Summary

The key technology of three-phase PV grid-connected system is studied by combining PV array mppt with SVPWM voltage vector tracking current control for grid-connected inverter, the simulation results show that the method has the fast tracking speed and high precision. Comparing with SPWM current control, it has higher voltage utilization of DC-side and lower higher harmonics, which improves the power quality.

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