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MPPT Control Strategy based on CVT and Pendant Combined with MPC

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Abstract

Under the background of how to make the system operate stably and efficiently when the external environment or load changes sharply in photovoltaic power generation. A maximum power point (MPPT) control strategy based on constant voltage method (CVT) and disturbance observation method (MPC) combined with model predictive control (MPC) is proposed. The photovoltaic array is quickly tracked to the maximum power point (MPP) by using CVT, and then the steady-state accuracy of the system is guaranteed by pendant. The action of the switch tube at the next time is given through the prediction of MPC, and the power curve is output. The simulation results show that compared with the conventional control strategy, the proposed control strategy can track the maximum power point more quickly, improve the steady-state accuracy, and improve the photoelectric conversion efficiency of the system.

Keywords

Photovoltaic Array; Photovoltaic System; Maximum Power Point Tracking; Constant Voltage Method; Disturbance Observation Method; Model Predictive Control.

1. Introduction

The photoelectric conversion efficiency of photovoltaic system is easily affected by irradiance and temperature. In order to make the system operate efficiently, it is necessary to add MPPT control strategy into the system. There are many kinds of control strategies of MPPT, and conductance increment method (INC), P&O [3] and CVT [4] are often used in practical application. Its control strategy is simple and efficient, but it has some defects such as slow tracking speed, low power achievement rate and weak anti-interference ability. A sliding mode MPPT control method is proposed in reference [5]. Choosing the appropriate control rate can achieve the balance between tracking speed and steady-state accuracy, but the inappropriate control rate can not be MPPT, and it is excessively dependent on the choice of control rate, which has great limitations in practical application. In reference [6], a variable step size incremental P&O algorithm is proposed, which determines the optimal operating point of the maximum power point (MPP) by disturbing the duty cycle, introduces an automatic adjustment mechanism to adjust the proportion factor M, increases the step size and responds quickly, and quickly reduces the step size when approaching the new MPP. The system can be flat in rapidity and stability. However, the algorithm is complex and difficult to use in practical applications. In reference [7], a variable step size conductance increment method is proposed to realize MPPT. Making use of the difference of the absolute value of slope on both sides of MPP, two proportional coefficients are set around MPP, and the fast tracking is realized by variable step size. The dynamic performance is better than that of conventional INC and is easy to implement. However, it is highly dependent on the selection of proportion coefficient. In reference [8], a control algorithm combining adaptive P&O and adaptive MPC algorithm is proposed. the maximum output power is close to the ideal value, fast response time and good steady-state accuracy, but the above algorithms have some limitations.

Based on the analysis of control strategy in reference [2-8], a MPPT control strategy based on the combination of CVT, Populo and MPC is proposed. In the case of drastic changes in environmental factors or load, the rapidity of CVT is used to track to the MPP point, and then the Pruno algorithm is switched to track. The combination of MPC algorithm, CVT algorithm and Pruno algorithm has a good performance in stability and rapidity.

2. Mathematical Model of Photovoltaic Cell

The external characteristic model of the solar cell can be regarded as a parallel circuit of a constant current and a forward diode. The equivalent model is shown in fig. 1.

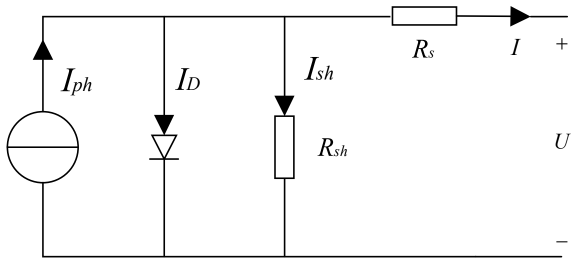

Fig. 1 equivalent model of photovoltaic cell

$$I = I_{sc} - I_0\left(e^{q(\frac{U+IRs}{nKT})} - 1\right) - U + I\frac{R_s}{R_{sh}} \tag{1}$$

Where I is the current output value of the photovoltaic array, I_{ph} generates the current for the photovoltaic array, the short circuit current of the photovoltaic array is set to I_{sc}, I_0 is the diode reverse saturation current, I and U are the photovoltaic side output current and voltage, R_{sh} is the equivalent parallel resistance of the photovoltaic array, R_s is the equivalent series resistance of the photovoltaic array K is the Boltzmann constant, n is the ideal factor of the diode, q is the charge of the electron, T is the ambient temperature. In the face of practical application, the parallel resistance R_{sh} and series resistance R_s are idealized [9], The open circuit voltage of the photovoltaic array Set to U_{oc}, The voltage and current at the maximum power are set to U_m and I_m.

When the irradiance is 1000w/m2 and the ambient temperature is 25 degrees, the formula 1 is abbreviated as:

$$\begin{aligned} I &= I_{sc} - C_1 I_{sc} e^{(\frac{U}{C_2 U_{oc}})-1} \\ C1 &= (1-\frac{I_m}{I_{sc}})e^{-\frac{U_m}{C_2 U_{oc}}} \\ C2 &= (\frac{U_m}{U_{oc}})\ln(1-\frac{I_m}{I_{sc}})-1 \end{aligned} \tag{2}$$

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3. MPPT Control Strategy

3.1 Overall System Structure

Fig. 2 is the topology diagram of the MPPT control system based on the combination of Playo and CVT with MPC, which is composed of photovoltaic array (PV), BOOST circuit, CVT and pendant module, MPC module and load.

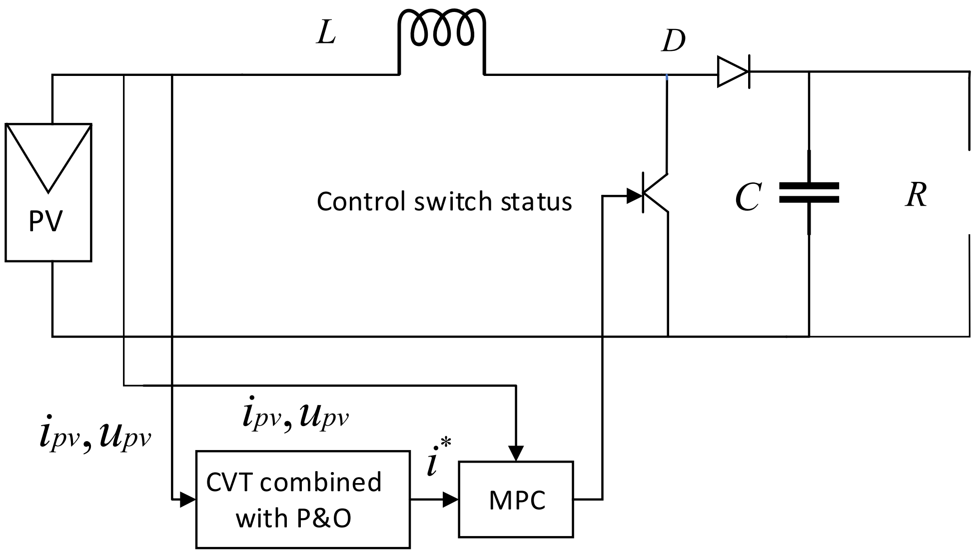

Fig. 2 MPPT control block diagram based on CVT and P&O combined with MPC

i_{pv} and u_{pv} are the input current and voltage of the photovoltaic side. After the calculation of CVT and P&O algorithm, the reference current i^* is obtained as the reference input model predictive controller, and the output state quantity is used to control the switch after the calculation of the model predictive controller.

3.2 Control Strategy based on the Combination of CVT and P&O

CVT refers to the photovoltaic array output maximum power, the output voltage is fixed to a value, according to practical experience, the operating voltage is usually adjusted to 78% of the open-circuit voltage ocU [10]. Due to the output characteristics of photovoltaic array, photovoltaic power generation is easily affected by environmental factors. CVT can quickly track to the maximum power point, but the ability of CVT to adapt and control the environmental change is poor. The phenomenon of peak shift will occur and lead to local optimization of the algorithm [11], which leads to the reduction of work efficiency. Combine the advantages and disadvantages of the two algorithms [12] The control strategy adopted is as follows: at the beginning of the 2nd Journal of Jilin Institute of Chemical Technology, CVT is used to quickly track to the vicinity of MPP, and the P&O algorithm is switched in 0.2s for steady-state optimization. The strategy of controlling the duty cycle is adopted, that is, changing the disturbance step Δd. According to the analysis of the characteristics of the two algorithms, the CVT algorithm can only make the PV fluctuate near the MPP. According to the characteristics of the P&O algorithm, the steady-state optimization is carried out when it is close to the small step size of the MPP switching algorithm.

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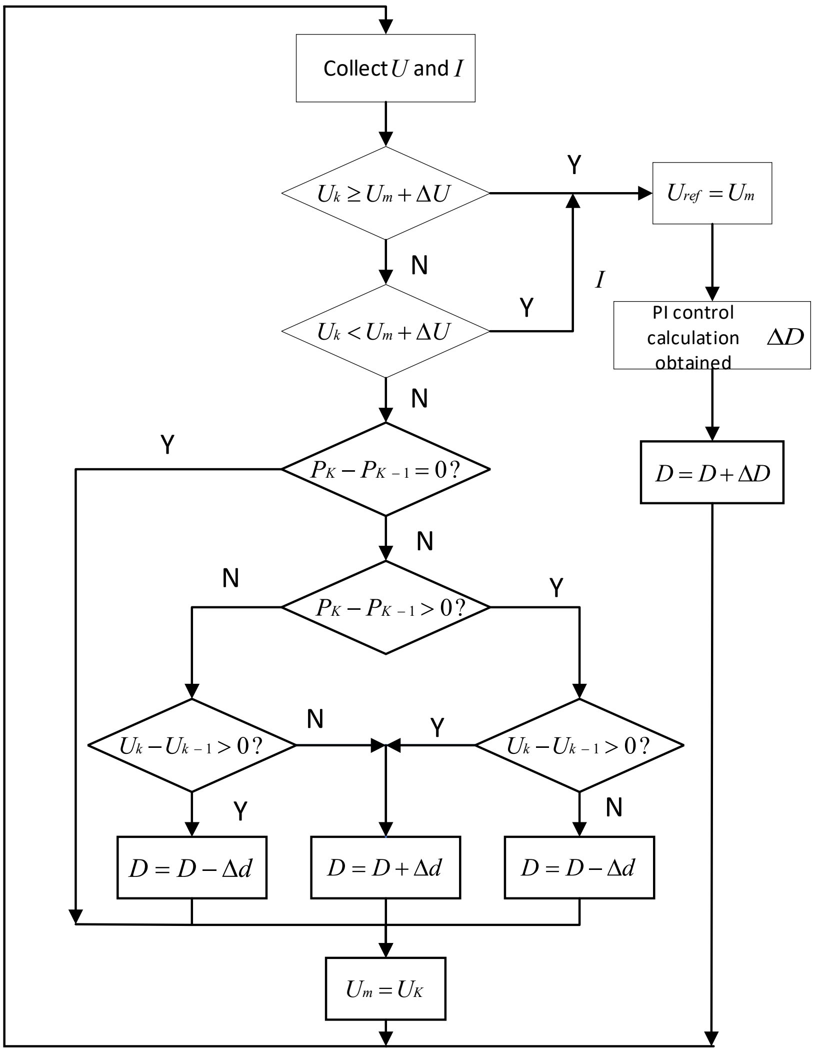

Fig. 3 MPPT control flow chart based on CVT combined with P&O

The output voltage of the photovoltaic array is tracked by the P&O algorithm with small step size, and the CVT algorithm is used to track the output voltage of the photovoltaic array if the variation range is outside the $\pm\Delta U$ receiver. According to the fact that there is $U_m = 0.78U_{oc}$ [10] between the working voltage and the open circuit voltage, the step size change of the output voltage stable at the U_m is calculated by PI control, that is ΔD, and the MPP in each cycle can be obtained.

3.3 Research on the Control Strategy of MPC

MPC controls the circuit by controlling the state of the switch tube in the BOOST circuit. The voltage U_{pv} and current I_{pv} of the photovoltaic side are obtained by the P&O algorithm, and the current input value is used as the output value of the next moment to provide a reference. The performance index is calculated under different switching states, the required objective function is designed, the performance index is compared and the optimal solution is obtained, thus the state of the switch tube in the next cycle is determined. Then the predictive control is realized, in which the switch tube has two states of opening and closing (f=1 is open, f=0 is closed). Its working status is shown in figures 4 and 5.

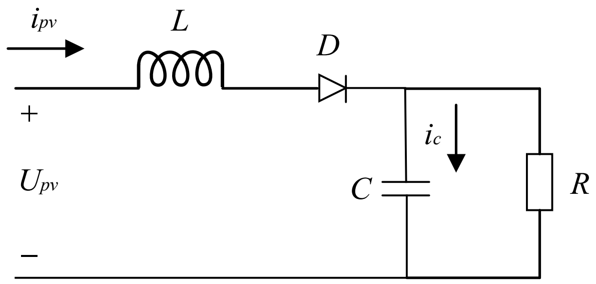

Fig. 4 the state of the off-tube disconnection

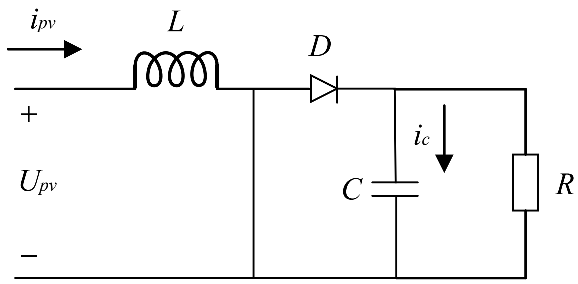

Fig. 5 closed state of shut-off tube

When the switch tube is closed, there is a formula 3.

$$\frac{di_{pv}}{dt}=\frac{1}{L}*v_{pv} \tag{3}$$

When the switch tube is disconnected, there is type 4.

$$\frac{di_{pv}}{dt}=\frac{1}{L}*v_{pv}-\frac{1}{L}*v_c \tag{4}$$

If the working cycle of the switch tube is set to T, formula 5 can be obtained by discretization.

$$i_{pv}(k+1)=\frac{T}{L}*v_{pv}(k)-S\frac{T}{L}*v_c(k)+i_{pv}(k) \tag{5}$$

In this system, the predictive control of the output current is carried out. In order to make the accurate predictive control of the current at the next moment, the working state of the next moment needs to be analyzed. Its core is through the cost function:

$$\min J_{s=n,m}^{n=0,1\&m=0,1}=|\,i_{pv,\,s\,=\,m(k+2)}-i^*\,|+|\,i_{pv,\,s\,=\,n(k+1)}-i^*\,| \tag{6}$$

Among them, i^* is the expected value, and J function restricts it. The two-step model predictive control will output the reference current of the next two sampling periods. Through the values of four cost functions J_{11}、J_{12}、J_{21}、J_{22}, and select preferably, the action of the switch tube of the BOOST circuit at the next time can be determined.

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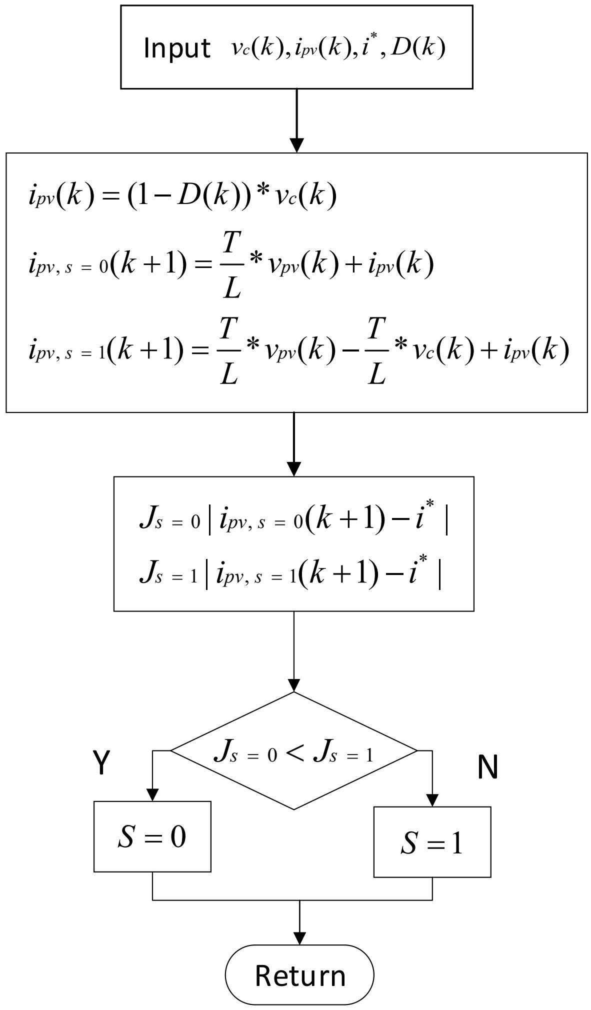


Fig. 6 Model Predictive Control flow chart

4. Simulation Analysis

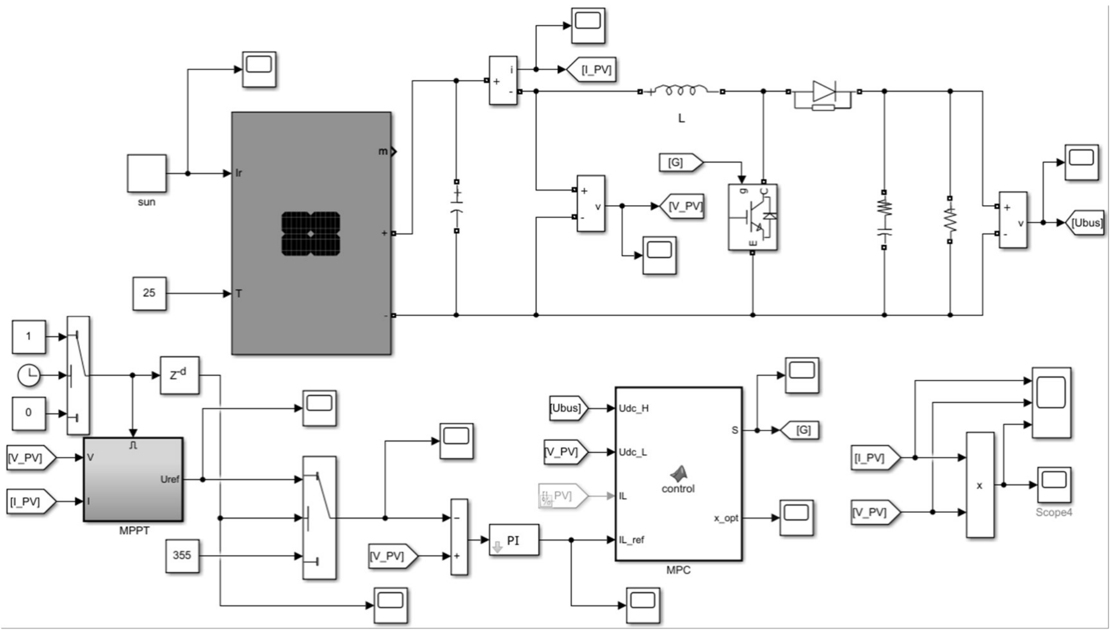
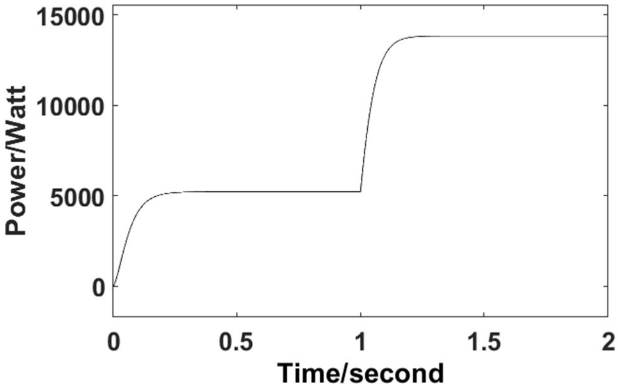
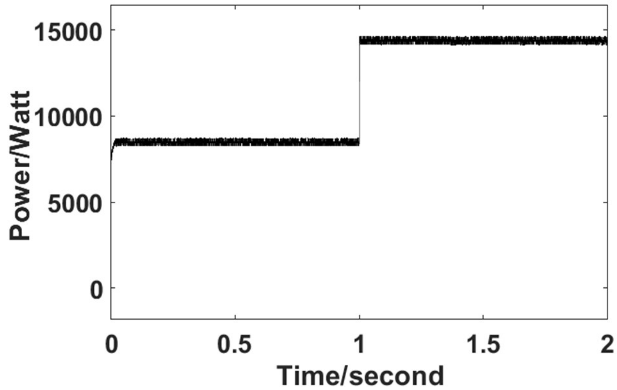


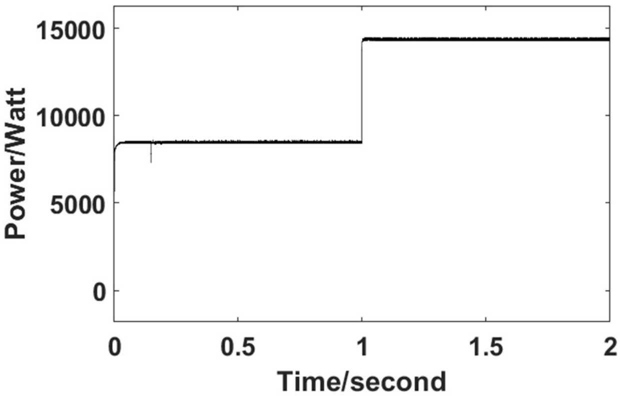
Fig. 7 P&O combined with MPPT simulation of MPC



(a) output curve of P&O algorithm



(b) The output curve of P&O combined with MPC algorithm



(c) The output curve of CVT and P&O combined with MPC algorithm

In order to verify the effectiveness of the algorithm, the simulation model is built in simulink as shown in fig. 7. The photovoltaic array is listed as A10Green Technology A10J-M60-240. short-circuit current I_{sc} = 8.66A, open-circuit voltage U_{oc} = 32V, maximum power point voltage U_m = 30V, maximum power point current I_m = 8.15A, simulation temperature T = 25 ℃. The irradiance jumps from 600 to 1000 in one second to simulate sudden changes in the environment. The parameters of BOOST circuit are C = 0.001F, L = 0.002H, R = 25Ω. The simulation verification is carried out on the algorithm of P&O, the algorithm of combining P&O with MPC and the algorithm of combining CVT with MPC, respectively. The output results are shown in (a), (b), (c) of fig. 7.

Through the simulation verification, P&O can be concluded that the tracking speed is a little faster, but when it reaches MPP, the steady-state accuracy is the best, and the utilization rate of photoelectric conversion efficiency is not as high as the other two. P&O combined with MPC algorithm has the advantages of fast tracking speed and small overshoot, and can quickly track near MPP in the face of sudden change, but the steady-state accuracy is slightly lower. The tracking speed of CVT and P&O

combined with MPC algorithm is the fastest, the tracking speed of environmental mutation is the fastest, and the curve is stable when it reaches MPP. Combined with simulation verification, the algorithm proposed in this paper plays a certain role in tracking speed, steady-state accuracy and environmental adaptability, and can improve the photoelectric conversion efficiency of photovoltaic array to a certain extent.

5. Conclusion

In this paper, the MPPT control strategy of P&O and P&O combined with MPC, and the MPPT control strategy of CVT and P&O combined with MPC are analyzed. Through the establishment of state simulation, a two-step cost function is designed to determine the working state of BOOST circuit switches at the next time. The simulation results show that the tracking speed of CVT and P&O combined with MPC at the maximum power point is faster, the accuracy is good when it reaches steady state, and the tracking speed is faster in the face of sudden change of environment, which has better performance than the other two algorithms, and then the photoelectric conversion efficiency can be improved to a certain extent. However, in the face of sudden changes in environmental factors and load at the same time, the applicable performance of the algorithm needs further research and demonstration.

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