

The Maximum Power Point Tracking Method Based on Lagrange Multiplier

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Abstract: Grid photovoltaic system (PV) is a nonlinear system, PV is easily affected by the grid work and the meteorological factors, and power output is volatile. Aiming at misjudging and tracking slow the problem of incremental conductance method, PV array model was built using MATLAB\ Simulink; the Lagrange multiplier algorithm was improved and optimized by using tracking differentiator based on Lagrange multipliers method in analysis. The simulation results showed that the Lagrange multiplier algorithm could rapidly and accurately tracking photovoltaic system maximum power using tracking differentiator after transformation, it could effectively inhibit various disturbances and reduce the misjudgment rate, the dynamic performance and stability of the system were better than the conventional incremental conductance method, thereby improving the robustness of the system. *Copyright © 2013 IFSA.*

Keywords: Lagrange multiplier algorithm, Photovoltaic system, Tracking differentiator, Maximum power point tracking.

1. Introduction

Maximum power point tracking (MPPT) is an important control strategy of direct-current (DC) side of photovoltaic power generation system, it could ensure the tracking accuracy in both the premise to improve the tracking speed through the extreme value of function optimization control algorithm, the control objective is to reduce the MPPT misjudgment rate. It is an important problem to be solved in a photovoltaic system how to use the new tracking algorithm to improve the anti disturbance ability of the system. The literature [1] used the Newton-Rapson method to quickly calculate the PV array output power voltage differential values based on the

research on the characteristic curve of PV arrays dP/dU , further work to form a PV array at the maximum power point voltage reference value. Literature [2-8] proposed a fixed voltage start and variable step perturbation and observation method. It made photovoltaic cells and ultimately achieves the maximum power point by comparing the size of around twice the power to determine the direction of the photovoltaic cell voltage disturbance. Literature [9-11] he used an improved variable step incremental conductance method, it can quickly and accurately track the maximum power point occurs at a significant change in light intensity. Literature [12] proposed a method using hysteresis comparator and the optimal gradient combination of maximum power

point tracking method. Literature [13] using particle swarm optimization fuzzy membership function of real-time control to adjust tracking step length, in order to ensure that the system had a faster dynamic response and high stability precision of light intensity and temperature changes. The maximum power point tracking method had numerous outstanding performances in the steady state control accuracy and dynamic response, misjudgment correct side; tracking could be achieved better results in an ideal working environment. However, the actual working environment of photovoltaic systems there was a temperature, light intensity changes brought about by internal disturbances and superimposed on the external disturbances on electrical quantities, the above methods had the shortcoming of anti-interference performance, low tracking accuracy, judgment could occur even wrongly phenomenon, and it was likely to cause power loss.

Therefore, given the traditional MPPT algorithm anti-interference performance is weak, PV systems work will result in a non-maximum power point, and it directly affects the photoelectric conversion efficiency. This paper analyzed the operating characteristics of PV systems, Lagrange algorithm was proposed maximum power point tracking of PV systems, at the same time using tracking differentiator to improve the method of Lagrange multiplier, to improve anti-jamming capability and MPPT tracking accuracy, it achieved a Lagrange multiplier and tracking differentiator design using MATLAB S function, the simulation results verify the correctness of the theory.

2. Method

2.1. Mathematical Model of Photovoltaic Array

According to the principle of the photoelectric conversion, PV cell is equivalent to a current of the constant current source I_{ph} and a diode connected in parallel, the mathematical model is formula 1 considering the temperature and light intensity of two main factors.

$$I = I_{sc} \times \frac{S}{1000} + C_T \times (T - T_{ref}) - I_0 \left[e^{\frac{q(U+IR_s)}{AKT}} - 1 \right] - \frac{U+IR_s}{R_{sh}} \quad (1)$$

Formula 1: the load current is I , the load voltage is U , light intensity is S (W/M²), battery temperature is T (K), ambient temperature is T_{ref} , diode reverse current is I_0 , Series resistance is R_s , R_{sh} is a shunt resistor, C_T is the temperature compensation coefficient, K is Boltzmann constant (1.38e-23J/K), q is the electronic quantity (1.6e-19C), A is a P-N node coefficient of semiconductor devices in the photovoltaic cell, I_{sc} is a photovoltaic battery short circuit current. According to the mathematical model of the PV array using MATLAB simulation, the U - I ,

U - P waveforms were shown in Fig. 1 and Fig. 2, light intensity and temperature on the output of the PV array had a greater impact.

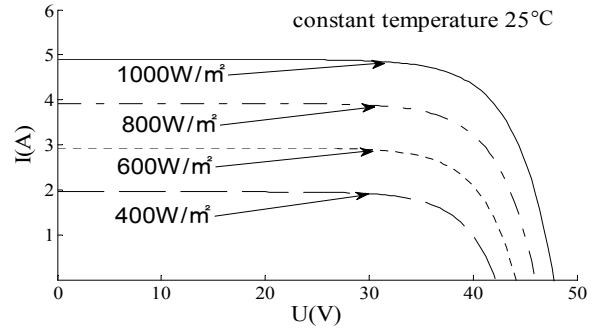


Fig. 1. Temperature constant illumination changes U - I curve.

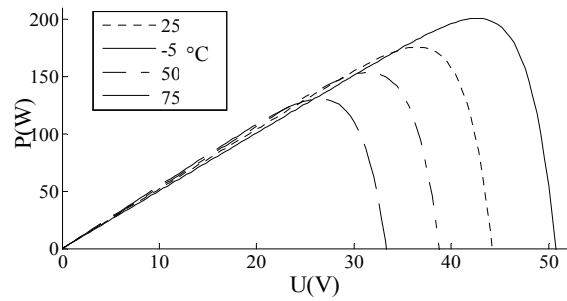


Fig. 2. Light constant temperature change curve of U - P .

2.2. Lagrange Multiplier Algorithm

Lagrange multiplier method could be used to solve with equality and inequality constrained nonlinear programming problems, the basic idea was that by introducing Lagrange multiplier, there would be equality constrained optimization problem into unconstrained optimization problems, thus by unconstrained multivariable function optimization methods to strike the objective function extremum, set the target function to the formula 2.

$$L(x, u) = L(x_1, x_2, \lambda) \quad (2)$$

To satisfy the constraint equation of the objective function was formula 3.

$$\begin{aligned} f_1(x_1, x_2, \lambda) &= 0 \\ f_2(x_1, x_2, \lambda) &= 0 \end{aligned} \quad (3)$$

Conditional constraint equations made slight changes in the conditions of extreme points, objective function fully differential dL and f_1 , f_2 were zero. It could be seen that by introducing a Lagrange multiplier λ , the extremum problem of function could be obtained under the condition of equality constraint

into without seeking Lagrange function under the constraint of the stagnation problem. The objective functions of f_1 , f_2 fully differential as showed in a formula 4.

$$J_0 = \begin{bmatrix} \frac{\partial f_1}{\partial x_1} & \frac{\partial f_1}{\partial x_2} \\ \frac{\partial f_2}{\partial x_1} & \frac{\partial f_2}{\partial x_2} \end{bmatrix} \neq 0 \quad (4)$$

dx_1 and dx_2 could be calculated using formula 4. Formula 5 could be obtained to formula 3 and 4 into formula 1.

$$\frac{\partial L}{\partial \lambda} - \left[\frac{\partial L}{\partial x_1} \frac{\partial f_1}{\partial \lambda} \frac{\partial f_1}{\partial x_2} + \frac{\partial L}{\partial x_2} \frac{\partial f_1}{\partial \lambda} \frac{\partial f_2}{\partial x_1} \frac{\partial f_2}{\partial x_2} \right] / J_0 = 0 \quad (5)$$

Formula 5 was suitable for the optimization of multi variable function; Lagrange multiplier λ was the goal function L with constraints of small changes in rates [14].

3. The Control Principle of Nonlinear Tracking Differentiator

3.1. Composition of the Tracking Differentiator

Tracking differentiator structure was shown in Fig. 3. A set of nonlinear signal processing functions into two paths of signals through nonlinear tracking differentiator according to the working characteristic of the controlled target.



Fig. 3. Tracking differentiator structure diagram.

$R(t)$ was the input signal in Fig. 3, $X1(t)$ signal was a tracking signal from $R(t)$ after processing functions, $X2(t)$ was the differential signal tracking signal [15].

3.2. Extraction of Differential Signal

Mathematics for differential expression was the formula $y=(v(t)-v(t-\tau))/\tau$, the method had amplification effect in the actual working

environment for noise. It was seriously affecting the quality of the output signal. Differential expression using approximate formula was $y=(v(t-\tau_1)-v(t-\tau_2))/(\tau_2-\tau_1)$, this formula was a second-order dynamic differential expression, in order to reduce the noise amplification effect, tracking differentiator series closed-loop dynamic system was a formula 6 [16-17].

$$\begin{cases} \dot{x}_1 = x_2 \\ \dot{x}_2 = -r \operatorname{sign}(x_1 - v(t) + \frac{x_2 |x_2|}{2r}) \end{cases} \quad (6)$$

Tracking speed factor was r in the formula 6, $v(t)$ was the output signal, x_1 was the input signal $v(t)$ to fast track the output signal in the tracking speed factor r , x_2 was $v(t)$ of the differential output signal, the discrete expression of 6 formula were formula 7.

$$\begin{cases} x_1(k+1) = x_1(k) + T x_2(k) \\ x_2(k+1) = x_2(k) + T f_{st}(x_1(k), x_2(k), v(k), r, h) \end{cases} \quad (7)$$

T was the sampling period in formula 7, $v(k)$ was the input signal of K moment, the $x_1(k)$ was the filtering signal of $v(k)$, $x_2(k)$ was the differential output signals of $x_1(k)$, r was tracking speed factor, h was the filter factor, the tuning of h parameters determine the filtering effect. The function f_{st} were the formula of 8~10.

$$\delta = rh, \delta_0 = \delta h, y = x_1 - v + h x_2, a_0 = \sqrt{\delta^2 + 8r|y|} \quad (8)$$

$$a = \begin{cases} x_2 + y/h, & |y| \leq \delta_0 \\ x_2 + 0.5(a_0 - \delta) \operatorname{sign}(y), & |y| > \delta_0 \end{cases} \quad (9)$$

$$f_{st} = \begin{cases} -ra/\delta, & |a| \leq \delta \\ -r \operatorname{sign}(a), & |a| > \delta \end{cases} \quad (10)$$

Input signal was v the in the formula of 8~10, δ , δ_0 , a , a_0 and y were the tracking differentiator intermediate variable control parameters, by adjusting the speed factor r and the size of the filter factor h could be tracked on the differential value of the signal extraction, At the same time could overshoot of system stability of the closed-loop system was improved [18-20].

4. Design of MPPT Optimal Control

The output signal tracking differentiator meet Lagrange for photovoltaic system maximum power operating mechanism according to the working principle of tracking differentiator multiplier method, the use of tracking differentiator to realize the Lagrange multiplier algorithm MPPT simulation model was shown in Fig. 4.

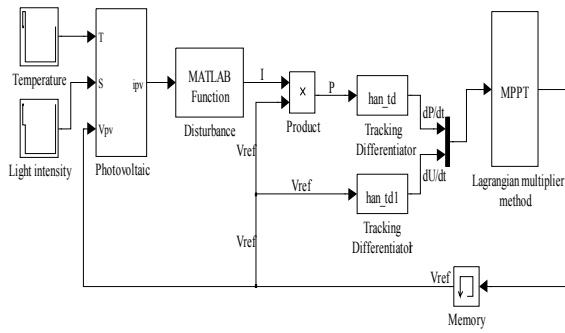


Fig. 4. Diagram of the MPPT using tracking differentiator.

Using tracking differentiator to realize Lagrange multiplier method MPPT was composed of three parts, first, the PV array, second, the differential input signal-tracking, third, using the Lagrange multiplier method for MPPT. The differential tracking for the Lagrange multiplier method improvement mainly had the following three:

Tracking differentiator for input power P could be filtered control, it could effectively filter out the current I and the voltage U carry noise, to improve the accuracy of MPPT judgment.

Tracking differentiator used differential expression $y=(v(t-\tau_1)-v(t-\tau_2))/(\tau_2-\tau_1)$, It was used for the differential P and U values of the input signal, Compared with the traditional method using $y=(v(t)-v(t-\tau))/\tau$ for differential value, it could reduce the overshoot to improve the system dynamic performance. Incremental conductance method was the finite difference method in the implementation of MPPT judgment, the method had great limitations, the signal read interval time could not be too small if the signal data contained the perturbation, the signal read interval was too small to value increases the error range of the read signal over, this was the same sampling law draw further apart, namely multi data acquisition volume but not accurate results. However, in the implementation of tracking differentiator filtering and calculated the differential P and U input signal values of dP and dU , therefore, the improved method of Lagrange multipliers simply judge dP and dU symbols, it could achieve the MPPT greatly improves the response speed of the system only using logic judgments.

5. Results

System simulation model was established based on MATLAB/ Simulink simulation software platform, set the same simulation parameters were compared with the results verified.

MPPT simulation parameters of PV array were followed: $V_{oc}=44.2$ V, $V_m=35.2$ V, $I_{sc}=4.9$ A, $I_m=4.5$ A, $r=400$, $h=0.01$, $T=0.01$. The temperature from 45°C to -19°C in 0.01 seconds, photovoltaic array initial light intensity was 500 w/m^2 , light intensity rose from 500 w/m^2 to 1000 w/m^2 in

0.1 seconds, light intensity from 1000 w/m^2 to 700 w/m^2 in 0.5 seconds, light intensity rose from 700 w/m^2 to 1200 w/m^2 in a second time. In the PV array output current I was applied perturbation $y=x+0.2*(\text{rand}(1, \text{length}(x))-0.5)$, the simulation waveform shown in Fig. 5, Fig. 6 and Fig. 7.

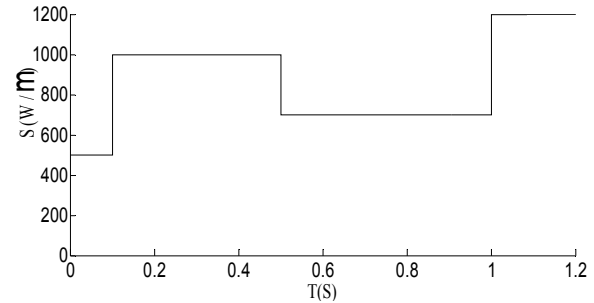


Fig. 5. Variation curves of light intensity.

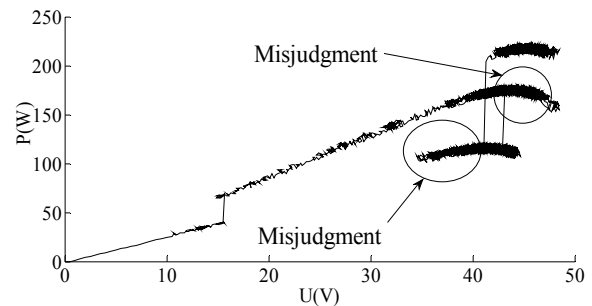


Fig. 6. Incremental conductance method for U-P curve of the maximum power point tracking.

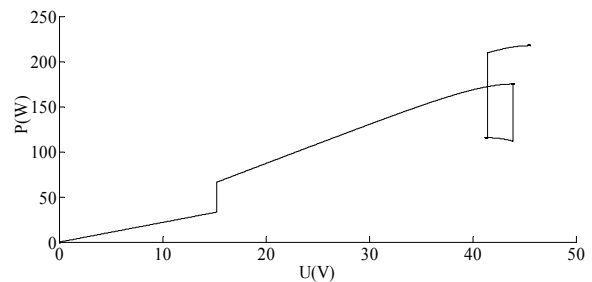


Fig. 7. The Lagrange multiplier method for U-P curve of the maximum power point tracking.

6. Discussion

In order to verify tracking differentiator Lagrange improved multiplier method could be quickly, accurately tracking the maximum power point, light intensity changes according to swells and dips shown in Fig. 5, to judge two algorithms on the maximum power tracking were good or bad. The maximum power of incremental conductance method to add disturbance tracking curves in Fig. 6, the maximum power of traditional incremental conductance method to track the emergence of local turbulence in the

perturbation effect, it did not accurately track the maximum power point of the power loss occurred in magnitude, it appeared erroneous judgment and tracking speed was reduced, the tracking accuracy decrease in light intensity changes. Fig. 7 simulation of the tracking differentiator to add noise disturbance optimized Lagrange method to get maximum power curve, it was compared with the traditional incremental conductance method error reduction of nearly 90 %, and it could according to the changes of light intensity accurately tracking the maximum power value and power loss. Lagrange multiplier tracking differentiator optimized in the filter and second-order differential under the action of high tracking precision. Smooth curve did not appear the phenomenon of misjudgment. Synchronize two curves were better at the early stage, incremental conductance method had obvious mistakes in the voltage were 40 volts, analysis incremental conductance occurs mainly due to a judgment. First, the traditional incremental conductance method by repeated disturbance of the judgment MPPT wasted a lot of machine cycles, it lead to the tracking speed drop; Second, the external perturbations lead to the traditional incremental conductance disturbances in the internal – Errors in judgment could not accurately track the extreme point and illumination changes resulting power loss.

7. Conclusion

In this paper, photovoltaic system maximum power point tracking used to the Lagrange multiplier method, the use of tracking differentiator to signal filtering and differential extraction, it was the foundation of improvement and optimization over the Lagrange multiplier method to the core algorithm, it put forward a new Lagrange multiplier method for obtaining maximum power point tracking technology new tools.

1) Using tracking differentiator filtering effectively filter the PV array output current noise contained;

2) Tracking differentiator extracted the input differential signals of the Lagrange multiplier method and optimized control strategy;

3) Realization of second-order differential tracking differentiator precisely tracked the maximum power values in the case of adding internal and external disturbances. It reduced the chance of false positives and misjudged the speed and accuracy while tracking had increased substantially. Simulation results showed that the method was correct and feasible.

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