MPPT Using Improved Variable Step Size INC

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Abstract

In order to make full utilization of energyin photovoltaic(PV) cells,among all the maximum power point tracking (MPPT) techniques, the incremental conductance (INC) method is widely used due to the high tracking accuracy at steady and good adaptability to the rapidly changing atmospheric conditions. So, this paper based on dynamic impedance matching presents a new improve variable step size INC methodfor MPPT.There are many problems in the traditional INC method,such as track the MPP point too slow , maximum power oscillation is too large , in order to make a good solution , this paper use INC combine with constant voltage method ,and take voltage mode control variable step strategy. The experimental results show that propose MPPT algorithm has good steady-state and dynamic performance.

Keywords

Impedance Matching, MPPT, PV Cells, INC, Energy

I. Introduction

Recently, energy generated from clean,efficient and environmentally-friendly sources has become one of the major challenges for engineers and scientists.Among all renewable energy sources, PV cells generation systems are one of these sources which attract more attention because they provide excellent opportunity to generate electric energy. However, the output power of PV cells depending on atmospheric conditions, such as temperature and solar irradiation. The MPPT technology improves the effective use of solar energy and the efficiency of PV power generation system [1].

So far, several kinds of MPPT algorithm has been proposed to improve the energy utilization ratio, the common method such as Hill Climbing method, P&O method, INC method, the Artificial Fuzzy algorithm and so on. The fuzzy algorithm can solve the problem very well, but the question is the algorithm is too complex, and its cost too much,so in normal situation it's not a good choice. And the other algorithm has their own advantages and disadvantages. Based on this, this paper presents a new way to solve the contradiction between oscillation and tracking speed.It according to the output characteristics of the solar panel, firstly it track near to MPP point, then use INC method, makes the system accurate to MPP , and maintain the stability[2].

This paper is organized as follows. The modeling of the solar panel is described in Section II. And in this section explains how to achieve the dynamic impedance matching from PV cells to the load by MPPT controller, this is the core of MPPT process. Next,the improvement algorithm is described in the Section III, The section IV and V is analysis of simulation results and make a conclusion.

II. Description of The MPPT

A. PV Model

As the paper [3]shows that the PV equivalent model can describe as Fig 1. In the figure is the PV cell short current, Its size depends on the size of the light intensity, a stronger light irradiation and it cause a much higher; is the dark current, refers to the PV cells in the absence of light, by the way the current flowing through the external applied voltage within a PN junction; I is the output current; is parallel resistance; is the series resistance. When the illumination is constant, does not change with the working state and the change of PV cells, at this time the equivalent circuit can be regard the Structure as a current of constant current source and a forward diode D in parallel.

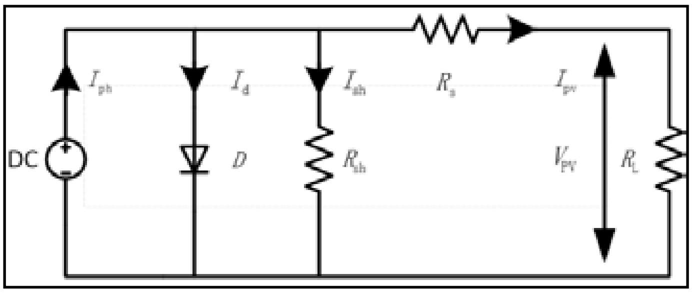

Fig.1 : Electrical equivalent circuit of solar cell

If the terminal voltage of the diode Dis U_d, then, the output current can describe as follows:

$$I_{pv} = I_{ph} - I_d - U_d/R_{sh} \quad (1)$$

Dark current:

$$I_d = I_o * \left(\exp\left(\frac{q*U_d}{AKT}\right) - 1\right)(2)$$

By the formula (1) and (2) can be obtained:

$$I_{pv} = I_{sh} = I_0 * \left(exp\,\frac{q*U_d}{AKT} - 1\right) - \frac{U_d}{R_{sh}}(3)$$

In the formula (3):I_0 is saturation current; q is the electron charge, in number it is equals to 1.6* $10^{-19}C$, K is Boltzmann constant, 0.86* $10^{-4}eV/K$; T and A is absolute temperature and PN junction ideality factor. According to the characteristics described above, can be easily in the Maltab-Simulink get output characteristic curve of solar cell. It shows in the Fig.2 and Fig.3 [4].

Through the above we can easily know that the PV cells with the change of the light intensity has a greater fluctuation to the output characteristic, but the changes of the open circuit voltage is very small. The more important is MPP point voltage and the relative changes of point is also very small. This is very important in the application of improve algorithm.

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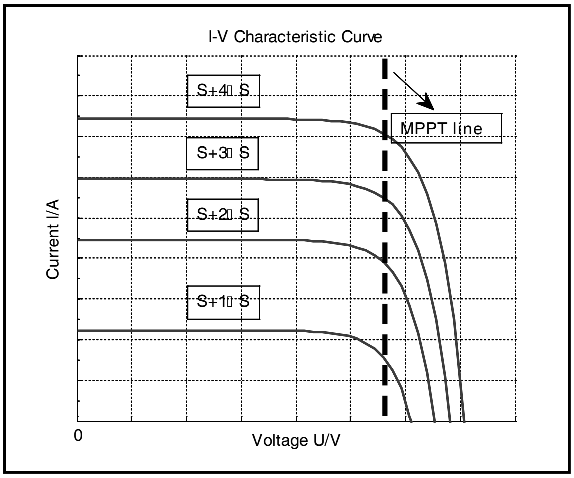

Fig.2 : I-V characteristics of PV cells systems under various levels of solar insolation.

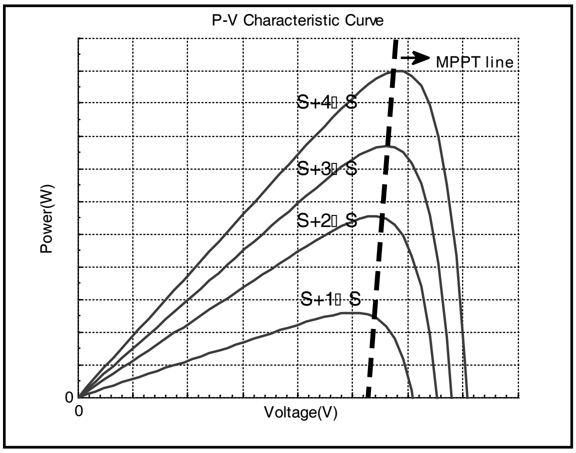

Fig.3 : P-V characteristics of PV cells system under various levels of solar insolation

B. MPPT Algorithm Based On Impedance Matching

Because the internal impedance of the PV cells is dynamic and nonlinear [5]. According to what we already know, when the PV cells internal impedance equals to the external one of the PV system. Then we can get the maximum output power. The typical circuit equivalent topology with MPPT controller shows in Figure 4.

The output voltage, current to PV cells are respectively as $U_{pv}I_{pv}$. Boost circuit output voltage .

And current is I_o and U_c . Therefore, the input power $P_{pv}=U_{pv}*I_{pv}$, the output power $P_o=U_c*I_o$, If the conversion efficiency is λ, then:

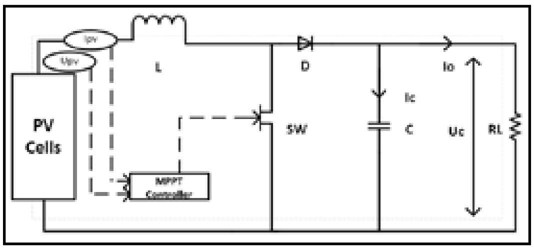

Fig. 4 : The boost circuit topology with MPPT controller

$$P_o=\lambda*P_{pv}(4)$$

Duty cycle is defined by D, then:

$$U_c=\frac{1}{1-D}U_{PV}(5)$$

$$I_o=\lambda(1-D)I_{PV}(6)$$

When the circuit works in continuous current mode, the lowest after flow inductance is:

$$L_{min}=\frac{R_L D(1-D)^2}{2f_s}(7)$$

Then the equivalent impedance is:

$$R(k)=\frac{U_{pv}(K)}{I_{pv}(K)}=\lambda(1-D)^2\frac{U_c(K)}{I_o(K)}$$
$$=\lambda(1-D)^2R_L(8)$$

Therefore, by the formula above,The Boost circuit can be adjusted by the switch duty cycle, an equivalent impedance into another equivalent impedance, the impedance matching and PV cells, so as to achieve the maximum power point tracking.

III. MPPT Algorithm Analysis

A. MPPT Control Principle

A solar system can regular the voltage or current of the solar panel using a dc-dc converter interfaced with an MPPT control to deliver the maximum allowable power. Fig. 3 shows the integration of such a system where a boost converter is utilized to deliver optimal power to load. Depending on the application, other power converter topologies may be used in place of the boost converter. In boost converter system shows in Fig.3, the MPPT controller senses the voltage and current of the solar panel and yields the duty cycle D to the switching transistor SW. However, according to the analysis of the last part we know change the D can affect the relationship between the input and output impedance matching. Now the question is turn to control the direction of D, we set a disturbance to the D, if after disturbance the power have increased, we could thought the disturbance of the direction of the D is correct, otherwise, we should take the another sides. In the part B. we will describe the principle of how to judge the disturbance direction of D.

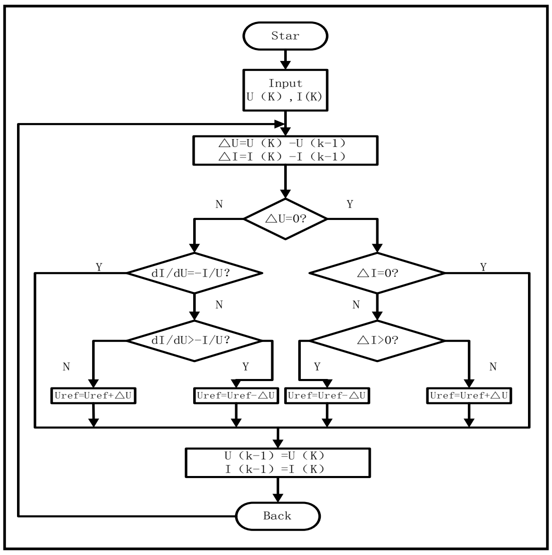

Fig.5 : Traditional INC Method

B. INCMethod

According to the characteristics of U-I curves of PV cells, at the MPP point slope of the curve is zero. Because P=UI, derivative to the U [6]:

dP / dU = I + UdI / dU (9)

The INC method is through a change in the set value, to determine the current PV cells in which side of the point MPP. In the MPP

point to the right, change the value is negative; in the MPP point to the left, the change value of the positive direction. And from one steady state to another state, make the right judgment according to the change of output current, stabilized in MPP neighborhood. The traditional INC method flow chart as shown in Fig.5.
Traditional incremental conductance method is judge on the base physical characteristics of the PV cells component itself, so it will not be influenced by the external environment to track the maximum power point can have very stable output. But at the MPP point the oscillation and the track time is can't be solved by traditional method. So a new method to be proposed base on the traditional method [7].

C. Proposed MPPT Algorithm

We propose a method makes it divided into two parts. Because of traditional method has lots of shortcomings, so we need to utilize variable step size strategy.As it shown in output characteristic of solar cell, in most regions before reaching the MPP point, are showing a linear growth curve, the curve changes very quickly, the MPP voltage and open circuit voltage is a relatively stable proportion, The voltage of MPP is about 0.8 times of open circuit voltage. When the system start work, we don't hope it cost too many time in this region. So, in the first part, we use constant voltage method, the PV cells working point fast set to near MPP point. Then, we can easily find the voltage range between the left area and right area of the MPP point is about 4:1 for the power change. If the working point is in the right, is as step-size, on the contrary, the are as step-size in order to further improve the dynamic performance. In this strategy, the proposed algorithm can get a better performance in tracing time. Fig.6 shows the control method of initial stage [8].

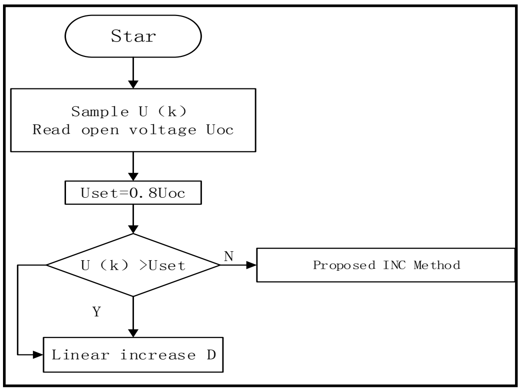

Fig.6 : Constant Voltage Starting Method

In the second part, the proposed aimed to solve the oscillation characteristics, the variable step size adopted for this algorithm is given by the following equation:

$$D(K) = D(K-1) \pm N * \frac{|\Delta P|}{|\Delta V|} \quad (10)$$

$$D(K) = D(K-1) \pm N * \frac{|P(K)-P(K-1)|}{|V(K)-V(K-1)|} \quad (11)$$

Where:
P(K),V(K):output power and voltage of the PV array at the K, the sample of time.
P(K-l), V(K-l): output power and voltage of the PV array at the K-l, the sample of time.
N: Scaling factor for adjusting the step size.
D(k): Duty cycle at the (k) the sample of time.
When the operation points is far from the MPP point, the step size is large, in this case, the algorithm tends to tracing the MPP point more faster [9]. And when the system working is on the MPP point, it is known that is almost at its lowest value around the PV MPP. To ensure the convergence of the MPPT update rule, the variable step rule must obey the following:

$$N * \frac{|\Delta P|}{|\Delta V|} < \Delta D_{max} (12)$$

The scaling factor should be obtained as

$$N < \Delta D_{max} / \frac{|\Delta P|}{|\Delta V|} (13)$$

If (12) cannot be satisfied, the working step size will lager than, so it will damage the stability. Equation(12) provides a simple step size INC MPPT algorithm. In the case of equation 6, lager N will get a faster response than a small N.

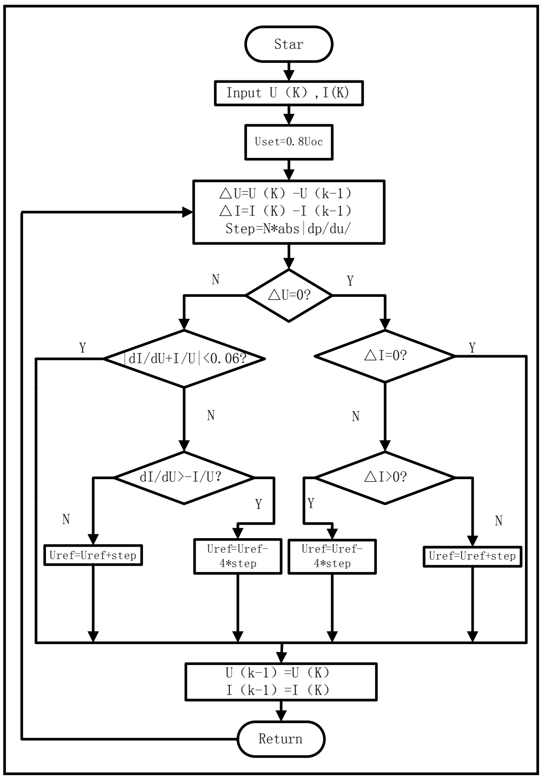

Fig.7 : Flowchart of the proposed INCmethod.

But, as it says above, there is no absolute tends to zero, we only can find an approximate range, at this area, and we regard it working at MPP point [10]. A permitted error of 0.06 as show in Fig.7, is used in the proposed algorithm to eliminate the steady-state oscillation in the system after the MPP is reached. The 0.06 is chosen based on the duty cycle step size is 0.005.

$$\left| \frac{dI}{dV} + \frac{I}{V} \right| < 0.06 (14)$$

IV. Simulation Result

To verified the performance of the proposed modified variable step size INC MPPT algorithm, a Simulink model of the operate system show in Fig.4. The parameter of the solar cell module use in the simulation is listed in Table1.

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Table1 : PV module specifications

Maximum power	175W
Voltage at MPP	35.4V
Current at MPP	4.95A
Open circuit voltage	44.2V
Short circuit current	5.2A

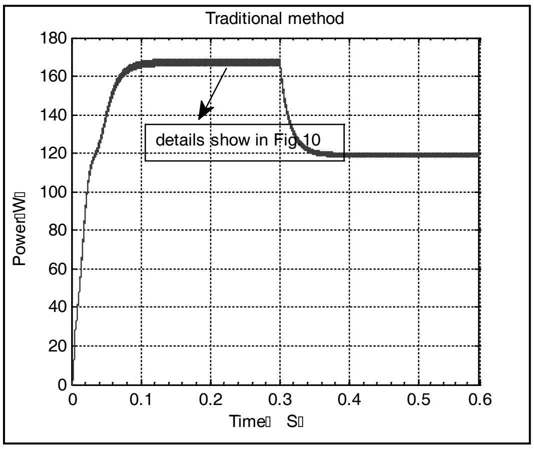

Fig.8 : Traditional method of INC

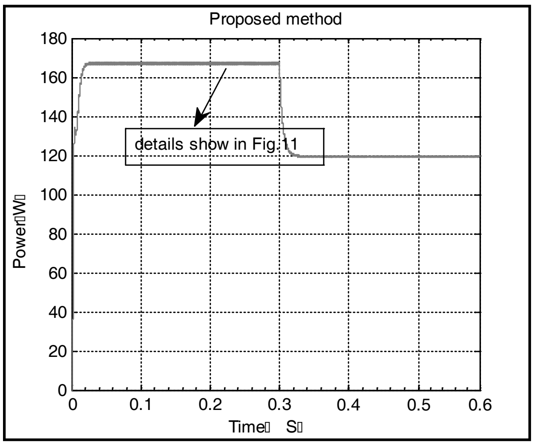

Fig.9 : Proposed method of INC

In order to simulate illumination changes, the irradiation set as a step signal, when the temperature T is equal to 25, we set the illumination jump from 1000 to 750 when 0.3s, and the traditional INC method and proposed method is show in Fig.8 and Fig.9. From the simulation figure shows above, we can easily know that the proposed method have a much better performance than the traditional method. And the following figure is the details about the time and the vibration characteristics.

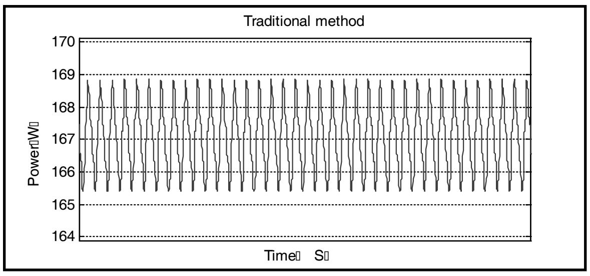

Fig.10 : Vibration details of traditional

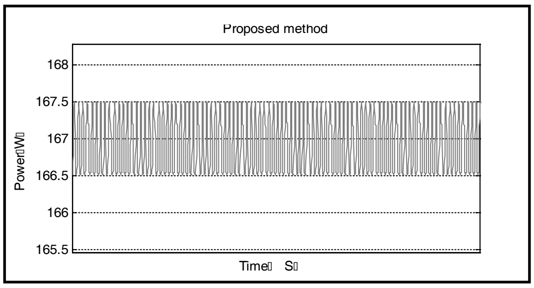

Fig.11 : Vibration details of proposed method

In this two figures 10 and 11, we can find, case the limited of the parameter N and the criterion $|\frac{dI}{dV}+\frac{I}{V}|<0.06$, the proposed algorithm have a great improvement the traditional one. Contrast the two figure dates, the first is changes from 165.5W~169W, but after changes, this numerical change is in order to 1W.

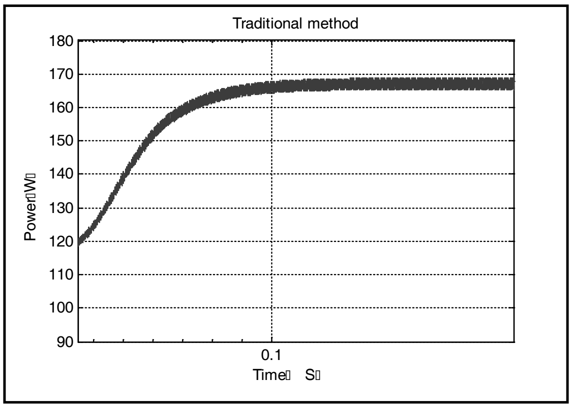

Fig.12 : Time details of traditional method

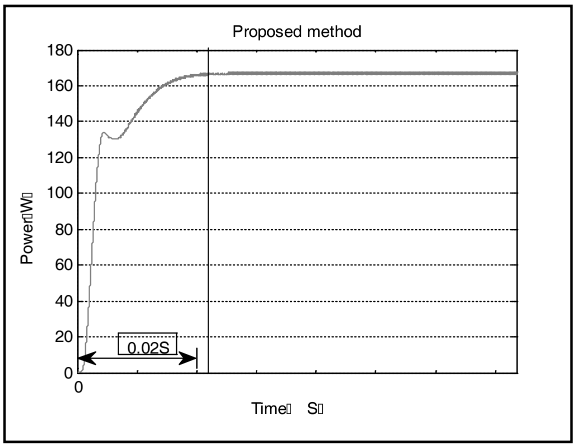

Fig.13. Time details of propose method

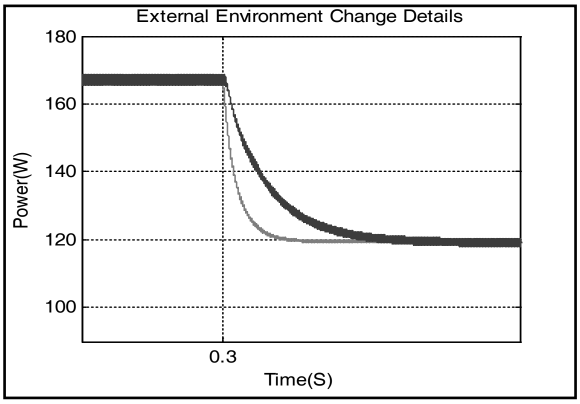

Fig.14 : External environment change details

As the show in the Fig12.and Fig13. The traditional method is get a balance when the time 0.1s, however in the after one, why the time much nearly but higher the 0.02s? The reason is at the beginning of the proposed algorithm, we set the star voltage is the 0.8 times of the open voltage. So when the star is zero, the same tracking environment, the tracking time is just 0.8 times of the proposed method. And the proposed algorithm set the limiting step of tracing process, this leads to why the time much nearly but higher the 0.02s. Change point of view, this also verifies the correctness of the simulation results from the other side.

At the end, we contrast the details when the external environment change, from the details shows above, whatever vibration or tracking speed, the proposed method is much better than the traditional method.

V. Conclusion

In this paper, an improved variable step size MPPT algorithm has been proposed,which is able to improve the dynamic and steady state performance of the PV system simultaneously. Furthermore, the proposed algorithm has a better stability when the external environment changes. A simple CVT start program is introduced to the proposed MPPT algorithm, which enables the smooth start process. The traditional method and the proposed method are simulated in the Maltab/Simulink system. The simulation results verity the feasibility and effectiveness of proposed method.

VI. AcknowledgEment

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