

# Maximum Power Point Optimization of Photo-voltaic System using Active Disturbance Rejection Control

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**ABSTRACT:** Photovoltaic technology based power generation system is the growing form of energy conversion generating system resulting in electrical power output. It is susceptible to the impact of solar radiation, external temperature and seasonal changes. There are many indecisions. Active Disturbance Rejection Control (ADRC) technology if applied to solar PV systems to control of DC-DC Converter can help in performance improvement. In the system model, uncertainties and external disturbances are unified to effect the system with unknown interference. An observer is used for dynamic observation of the disturbances. The nonlinear state error feedback the control strategies are used to compensate the system. So, it doesn't affect the parameters within the system and unknown disturbance. It will simplify the process of the control system. Simulation results show that the design of ADRC can achieve the desired control effect, and has good stability and robustness.

**KEYWORDS:** ADRC, Solar PV, DC-DC Transform

## I. INTRODUCTION

When radiation and temperature are given, the power that photovoltaic cell output is closely related to its terminal voltage. Due to the high cost of the photovoltaic power generation system, it is necessary to constantly adjust the terminal voltage of the photovoltaic cell to stabilize its operating point at the maximum power point neighbourhood to improve the utilization of solar energy, which makes the maximum power tracking technology become a very important control strategy in photovoltaic power generation system [1]. At present, the most used methods of the maximum power point tracking (MPPT) algorithm are: perturb and observe, incremental conductance and other methods derive from them. These derived algorithms include the variable step perturb and observe method and the gradient variable step length incremental conductance method [2-3].

The environmental factors that affect the output characteristics of photovoltaic cells are mainly radiation and temperature. Since the temperature has little effect on the output characteristics of photovoltaic cells and the temperature cannot change suddenly, existing MPPT algorithms only consider the impact that abrupt change of light intensity to the maximum power point tracking. In this paper, an improved MPPT algorithm based on incremental conductance method and active disturbance rejection controller is proposed, which has faster dynamic response speed and better stable performance when comparing to the conventional incremental conductance method. Finally, the proposed algorithm is validated by simulation with MATLAB/Simulink.

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## II. SOLAR PV SYSTEM MODEL

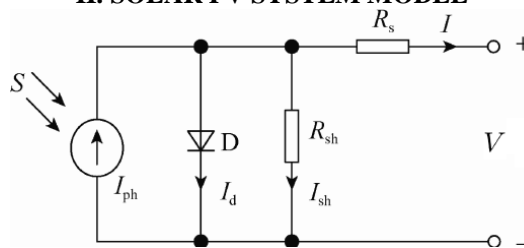


Fig1 - Solar PV Equivalent Circuit

PV equivalent circuit is shown in the figure below. Many literature study shows the characteristics of photovoltaic cells, under higher light intensity, that the greater the solar cell output current, higher output power, and open circuit voltage is slightly increased, which if the higher the temperature of solar cells, that the smaller the output voltage, output power of more low, but the short circuit current is a slight increased. According to the Kirchhoff laws, the I-V equation for photovoltaic cell is given by:

$$I = I_L - I_0 \left[ \exp \left[ \frac{q(V + R_s I)}{AKT} \right] - 1 \right] - \frac{V + IR_s}{R_{sh}}$$

Where  $I_{ph}$  is the current of light-sensitive diode D,  $I_d$  is the current through p-n junction, V is the photovoltaic cell output voltage, I for the photovoltaic cell output current,  $R_{sh}$  represents the parallel resistance, and it is inversely proportional to the current that the battery leakage to the ground,  $R_s$  is the series resistance of the cell, T is the thermodynamic temperature of the battery, n is the diode quality factor, q is the electrical charge of electron,  $q = 1.602 \times 10^{-19} \text{ C}$ , k is the Boltzmann constant,  $k = 1.381 \times 10^{-23} \text{ J/K}$  and  $N_s$  is the number of series PV units.  $I_{sat}$  is the inverse saturation current and it could be calculated by:

$$I_{sat} = I_0 \times \left( \frac{T}{T_0} \right)^{\frac{3}{n}} \times \exp \left[ \frac{qE_{gap}}{nk} \left( \frac{1}{T_0} - \frac{1}{T} \right) \right]$$

Where,  $T_0$  is the reference temperature of cell,  $I_0$  is the inverse saturation current of PV cell in  $T_0$  and  $E_{gap}$  is the air-gap voltage of p-n junction in PV array.

## III. MPPT CONTROL ALGORITHM

The weather and load changes cause the operation of a PV system to vary almost all the times. A dynamic tracking technique is important to ensure maximum power is obtained from the photovoltaic arrays. The following algorithms are the most fundamental MPPT algorithms, and they can be developed using micro controllers. The MPPT algorithm operates based on the truth that the derivative of the output power (P) with respect to the panel voltage (V) is equal to zero at the maximum power point. In the literature, various MPP algorithms are available in order to improve the performance of photovoltaic system by effectively tracking the MPP. However, most widely used MPPT algorithms are considered here, they are:

1. Perturb and Observe (P&O)
2. Incremental Conductance (InCond)
3. Constant Voltage Method.

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### a) Perturb and Observe (P &O)

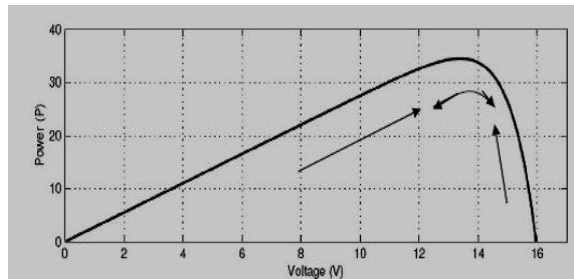


Fig-2 Graph Power versus Voltage for Perturb and Observe Algorithm

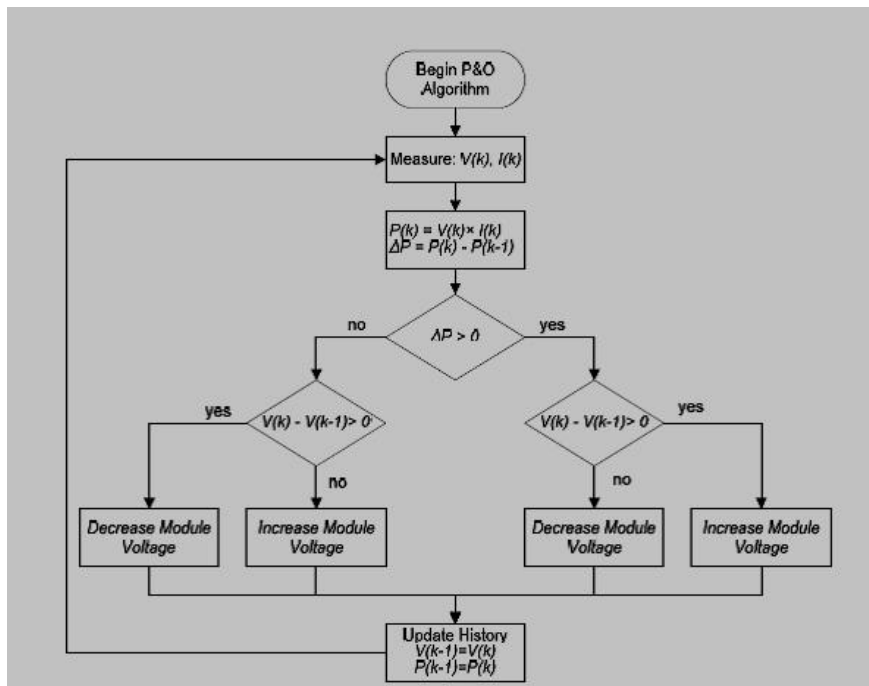


Figure 3. P&O Algorithm

The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the module voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle. In this algorithm a slight perturbation is introduced to the system. This perturbation causes the power of the solar module to vary. If the power increases due to the perturbation then the perturbation is continued in the same direction. After the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses as shown in Figures 2 and 3. When the stable condition is arrived the algorithm oscillates around the peak power point. In order to maintain the power variation small the perturbation size is kept very small. The technique is advanced in such a style that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts to transfer the operating point of the module to that particular voltage level. It is observed that some power loss occurs due to

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this perturbation also the fails to track the maximum power under fast changing atmospheric conditions. But remain this technique is very popular and simple.

### b) Incremental Conductance (IC)

The perturb oscillation around peak power point of perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by IC method. The Incremental Conductance can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between  $dI/dV$  and  $-I/V$ . This relationship is derived from the truth that  $dP/dV$  is negative when the MPPT is to the right side curve of the MPP and positive when it is to the left side curve of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher precision than perturb and observe. The disadvantage of this algorithm is the increased complexity.

### c) Constant Voltage Method

The Constant Voltage method (CV), also in some literature called Open voltage Ratio method, uses the fact that the MPP voltage at different irradiance is approximately equal.

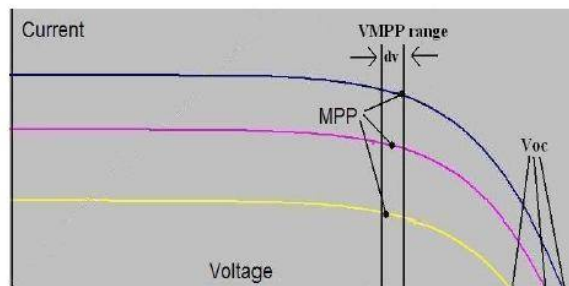


Figure 4. Constant Voltage Method in V-I curve

VOC represented the open circuit voltage of the PV panel. VOC depends on the property of the solar cells. A commonly used VOC/VMPP value is 76%. This relationship can be described by equation below:

$$V_{MPP} = k * V_{OC}$$

where  $k \approx 0.76$  in this case.

The solar panels are always disconnected from the converter circuit for a short duration of time for VOC measurement. The operating voltage of the MPP is then set to 76% of the measured VOC. The major advantage of this method is that the MPP may be located very quickly. However at the same time this method suffers from low accuracy, because the VOC is also affected by the temperature of the solar cells which may change the VOC/VMPP ratio significantly. Any small deviation of the VOC after the sampling can cause large difference in tracking the MPP during that sampling period. Moreover, power is lost during the short sampling time, further reducing the efficiency of constant voltage method.

## IV. PROPOSED METHODOLOGY FOR MPPT OPTIMISATION

It can be seen in the traditional incremental conductance method, approximation  $\Delta I / \Delta V$  will inevitably loses a certain degree of accuracy. Therefore, a reasonable access to differential signals so as to improve the accuracy of the system is very important. For a system which is described by  $y = f(x)$ . And suppose that we do not know its concrete expression, we can only get the input and output signal in real time, so we cannot get the derivative  $dy/dx$ ,

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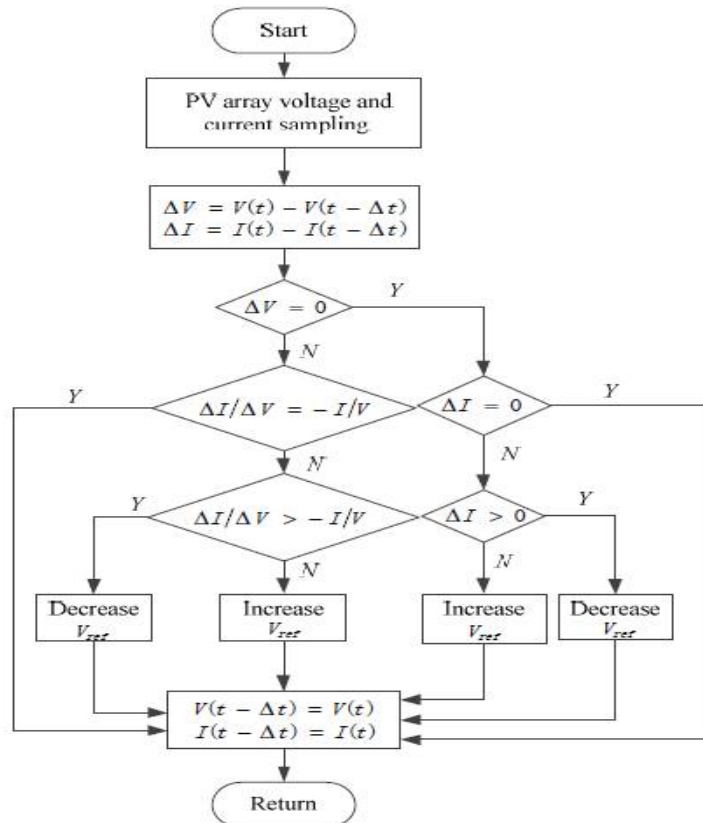


Fig 5- Flowchart of process

In the classical control theory, the differential signal for a given signal is obtained by the differential element that has a small time constant, but it has amplificatory effect on the noise, it is not suitable for obtaining the differential signal in engineering application. The fast tracking differentiator (TD)overcomes this drawback, which on the one hand can quickly track the input signal and on the other hand can give the differential signal of it, the general form of the tracking differentiator is given by:

$$\begin{aligned} \dot{x}_1 &= x_2 \\ \dot{x}_2 &= -r \operatorname{sgn}(x_1 - v(t) + \frac{x_2 |x_2|}{2r}) \end{aligned}$$

where  $v(t)$  is the input signal,  $x_1$  and  $x_2$  are tracking output and differential output, respectively,  $r$  determine the tracking speed. In this way, we can use two tracking differentiators to get differential signals of current and voltage, so that we can get  $dy/dx$ . With the above process,  $I/V$  and  $dI/dV$  are obtained, an error signal is generated given by:  $e = I/V + dI/dV$ .

At this point, if a controller is designed to ensure  $e$  is 0, then we can guarantee that the photovoltaic system works at the maximum power point. The active disturbance rejection controller (ADRC) has advantage that it doesn't need the detail mathematical model of the plant to be controlled and has strong interference rejection capacity. This paper uses linear active disturbance rejection controller (LADRC), because it has less parameters and easier to adjust. The linear active disturbance rejection controller is composed of three parts, which is: PD controller, extended state observer and dynamic compensation for disturbance. The structure of linear active disturbance rejection controller for second order system is shown in figure below.

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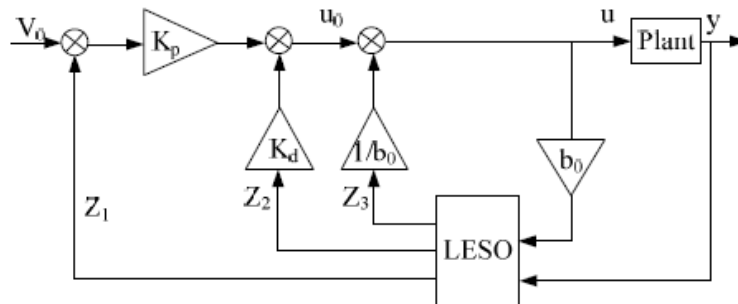


Fig 6- Structure of linear active disturbance rejection controller for second order system

## V. SIMULATION RESULTS

To investigate the performance of the proposed method, a whole photovoltaic power generation system is modeled in the Matlab/Simulink. The system is composed of a PV panel, a boost DC-DC converter, a MPPT controller and a load. The photovoltaic model which is used in this paper and its electrical characteristics in conditions that radiation is 1000 W/m<sup>2</sup> and temperature is 25°C are shown in Table 1 derived from NREL manual.

TABLE I

ELECTRICAL CHARACTERISTICS OF USED MODEL

Parameter	Value
Maximum power (W)	305.226
Maximum power Point voltage (V)	54.7
Open circuit voltage (V)	64.2
Short circuit current (A)	5.96
Maximum power point current (A)	5.58
Light-sensitive current (A)	6.0092
Diode saturation current (A)	$6.3104 \times 10^{-12}$
Series resistance ( $\Omega$ )	0.37152
Shunt resistance ( $\Omega$ )	269.5934

The simulation is executed under two sets of conditions. The traditional incremental conductance method and the proposed MPPT method is implemented in both set. The simulation result under the condition that radiation is constrained at 1000W/m<sup>2</sup> and temperature change from 25°C to 50°C. The simulation result under the condition that temperature is constrained at 25°C and radiation change from 1000W/m<sup>2</sup> to 800W/m<sup>2</sup>.

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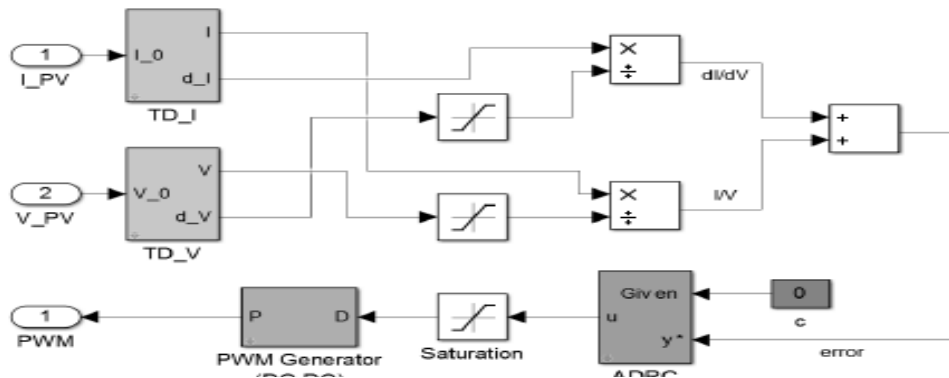


Fig 7- Model of the proposed MPPT method

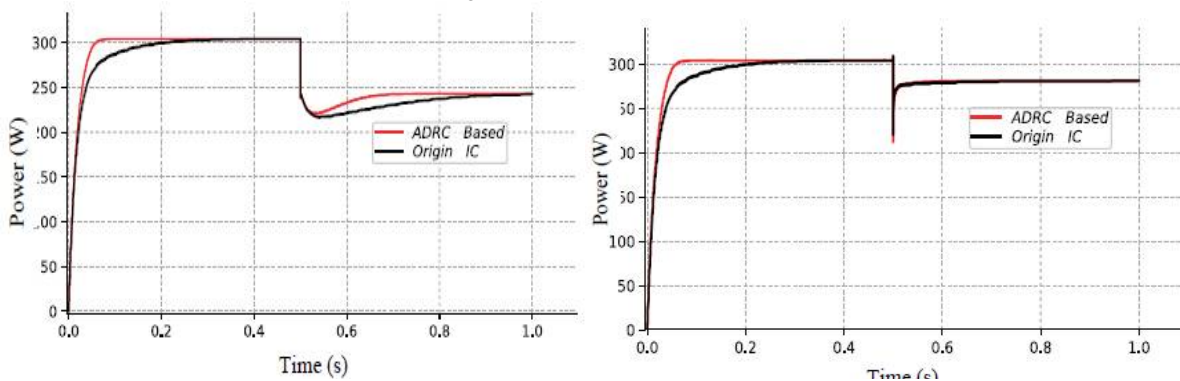


Fig 8- Simulation results under two sets of conditions: (a) fixed radiation and temperature changes (b) fixed temperature and radiation changes

## VI. CONCLUSIONS

ADRC can be used to solve the largest photovoltaic power power with the problem. Can effectively resist external interference, to improve the efficiency of solar power. Its greatest feature is that the system has strong internal and external interference suppression, showing a good robustness and adaptability. This paper, the disturbance rejection control introduced into the solar photovoltaic system, the load current and supply voltage from outside influence as a system of unknown factors such as interference and its dynamic compensation, eliminating the need for complex system testing MPPT optimization process has a strong real-time, simplifies the control process of the whole system. At the same time, the design parameters of ADRC parameters within the system. Parameter selection can be obtained in a larger context, the control system structure is relatively simple and easy to implement.

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