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PV modeling and Maximum power extraction using Voltage Control Algorithm

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Abstract: ***In this paper a Voltage Control Algorithm (VCA) is implemented for maximum power point tracking (MPPT) from solar photovoltaic (PV) system with less complexity. In addition, single diode model is designed and applied for solar PV modelling without applying any approximation conditions. In modelling, PV manufacturer's provides limited parameters in datasheet at standard test condition (STC). The information given in the manufacturer's datasheet is not enough in identification of the characteristic curves of solar PV panel under different climatic conditions. In single diode model has five parameters namely, photo current (I_{ph}), diode current (I_d), series resistance (Rs), shunt resistance (R_p) and ideality factor (A). These parameters are extracted using gauss seidal method with the help of manufacturer's information. The suggested proposed MPPT algorithm is implemented in the DC-DC boost converter and simulation results are compared with existing P&O MPPT technique. Finally the proposed algorithm is able to track maximum power for given solar PV system with less oscillation and less complexity.***

Keywords: Gauss seidal method, Single diode model, solar PV system, Voltage control algorithm.

I. INTRODUCTION

In the recent years, solar energy is one of the fastest growing resources of renewable energy and implantation is steadily increasing in both rural and urban areas. Solar is more prominent and generating electricity simple manner. Naturally the input of solar like temperature(T) and irradiance(G) are nonlinear in nature in order to the output of solar panel also nonlinear [1-2]. The PV system can convert solar energy into electricity directly without any intermediate controller [3]. Further, the advantage of solar is free, clean energy and maintenance is very less owing to absence of rotating machine. But the drawback is the conversion efficiency quite low around 20-30%. In order to substitute for the lack of efficiency due to oscillations, MPPT algorithm can be employed. In literature many publications are developed MPPT algorithms for improving solar panel efficiency [4-7]. The characteristics of a PV system can be modeled using V-I and P-V characteristic curves. The behavior of PV is changing with respect of solar irradiance and temperature in nature. For modelling purpose single diode and two diode model are used. Initially, the selection of equivalent circuit model and methodology of finding optimal value for unknown parameters is most important part [8-9].

Among circuits, single diode with parallel resister model circuit is accurate and simple. Two diode model is more accurate but more complicity due to presence of seven unknown parameters and two exponential equations [10-11]. Past two decades more MPPT techniques are made by researchers among that the simplest method is short circuit current(SCC) is used to find the maximum current from solar PV system[12]. Open circuit voltage technique(OCV) is used to find the maximum voltage from solar PV system[13-14]. But the drawbacks of these conventional techniques in both methods are failed to extract maximum power from solar PV system. Perturb and Observe (P&O) is introduced and popular method because of simplicity as well as tracking response also this method called as Hill climbing (HC). The main drawback of this method is more oscillations and the efficiency of solar quite low under shading conditions[15-18]. Then Incremental conductance(IC) method is next version of P&O method which is track maximum power from solar PV system however it fails to track maximum power [19]. The main drawback of this method low efficiency because of oscillations present in MPP and little complicated due to using both voltage and current sensors [20-21]. Hence, to overcome these drawbacks the voltage control algorithm is proposed for tracking maximum power from solar PV system. In normal conditions both Perturb & Observe (PO) and Incremental Conductance (IC) works well but need two sensors for maintain the power at maximum. Using two sensors make quite complicate as well as storage burden [22-24]. The paper presents an iterative method to obtain the accurate parameters of a solar PV system to obtain I-V and P-V characteristics. Voltage Control MPPT algorithm is proposed to obtain maximum power with less oscillation.

This proposed paper is contributed as follows: The fundamental concept of PV model as well as characteristic of solar PV system is explained in Section 2, Parameter extraction with iterative technique is depicted in Section 3, Evaluation of proposed MPPT algorithm with simulation results using MATLAB/SIMULINK is presented in Section 4 and remarkable directions and conclusion are delivered in Section 5.

II. MODELING OF PV PANEL

Modelling of solar PV system is finding the behaviour of solar PV system under different environmental conditions.

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The models presented in literature are namely, ideal, single, two, three and modified diode models [25-27]. Among these models, the accurate, simple and most important is single diode model. Even though two diode model is the most accurate but not used more due to complexity. Therefore, single diode model is presented in this paper [25-26]

A. Single diode model

Single diode model consists a current source in parallel with diode. The advantage of this model is accurate and less complicated than two diode model. In single diode model five parameters are presented. These parameter values are not presented in manufacturer's datasheet. So, making precise single diode model is difficult task. In order to identify the unknown values using iterative method [27]. Equivalent circuit of single diode model diagram shown in Fig.1

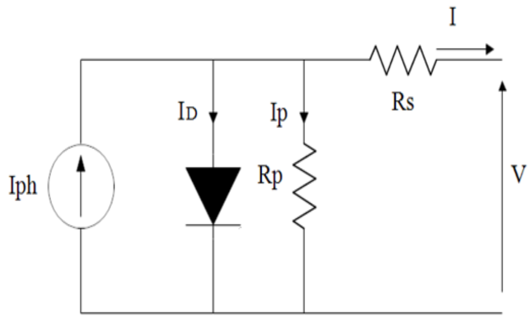

Fig.1. Equivalent circuit of single diode model

The equation of output current can be written as,

$$I = I_{ph} - I_0\left[\exp\left(\frac{(v+Rs.I)}{V_T}\right) - 1\right] - \left(\frac{v+Rs.I}{R_p}\right) \qquad (1)$$

Where, I is the average output current, V is the average output voltage, I_{ph} is the photocurrent, I_0 is the diode current, V_T is the thermal voltage, Rs is the series resistance, R_p is the shunt resistance.

The thermal voltage can be written as,

$$V_T = \frac{KTA}{q} \qquad (2)$$

Where, K represents Boltzman's constant, T is the operating temperature, A is the diode ideality factor and q is the charge of electron.

$$I_{ph} = [I_{STC} + K_i\,(T - T_{STC})].\left(\frac{G}{G_{STC}}\right) \qquad (3)$$

B. Mathematical description of single diode model

The accuracy of simulation for PV modules of single diode model depends on five parameters namely, photo current (I_{ph}), diode current (I_d), series resistance (Rs), shunt resistance (R_p) and ideality factor (A). These parameters values are not mentioned in the manufacturers' datasheet and needs to be identified using iterative method.

At open circuit condition, $(V_{oc}, 0)$

$$0 = I_{ph} - I_0\left[\exp\left(\frac{(V_{oc})}{n.Vt}\right) - 1\right] - \left(\frac{V_{oc}}{R_p}\right) \qquad (4)$$

At short circuit condition, $(0, I_{sc})$

$$I_{sc} = I_{ph} - I_0\left[\exp\left(\frac{(Rs.I_{sc})}{n.Vt}\right) - 1\right] - \left(\frac{Rs.I_{sc}}{R_p}\right) \qquad (5)$$

At maximum voltage condition, (V_{mpp}, I_{mpp})

$$I_{mpp} = I_{ph} - I_0\left[\exp\left(\frac{(V_{mpp}+Rs.I_{mpp})}{n.Vt}\right) - 1\right] - \left(\frac{V_{mpp}+Rs.I_{mpp}}{R_p}\right) \qquad (6)$$

Since, there are five unknown variables so five equations are need. To obtain the other two equations derivative has to be calculated. The derivative of the power with respect to the voltage at the MPP is zero.

$$\frac{dP}{dV}\Big|_{\substack{V=V_{mpp} \\ I=I_{mpp}}} = 0 \qquad (7)$$

Derivative of the current with respect to the voltage at short circuit condition,

$$\frac{dI}{dV}\Big|_{I=I_{sc}} = -\left(\frac{1}{R_p}\right) \qquad (8)$$

C. Parameter extraction

The main objective of this paper is parameter extraction from single diode PV model using iterative method.

$$I = I_{ph} - I_0\left[\exp\left(\frac{(v+Rs.I)}{n.Vt}\right) - 1\right] - \left(\frac{v+Rs.I}{R_p}\right) \qquad (9)$$

$$I_{ph} = [I_{STC} + K_i\,(T - T_{STC})].\left(\frac{G}{G_{STC}}\right) \qquad (10)$$

$$I_o = \left[I_{0,STC}\left(\frac{T_{STC}}{T}\right)^3 \exp\left[\frac{E_{g0}q}{KA}\left(\frac{1}{T_{STC}} - \frac{1}{T}\right)\right]\right] \qquad (11)$$

By applying numerical iterative method, unknown parameters of single diode model are determined. The flowchart of implementation of gauss siedel method is given in Fig.2. For maximum current the series resistance should be less and the shunt resistance should be high. The value of series resistance is taken close to zero and shunt resistance is taken in high. Since gauss siedel method is applied, if the assumed value of resistance is not proper, the equation doesn't converge. In case, where the equation doesn't converge different values of shunt and series resistance are to be assumed and the iterative method to be implemented until the equation converges.

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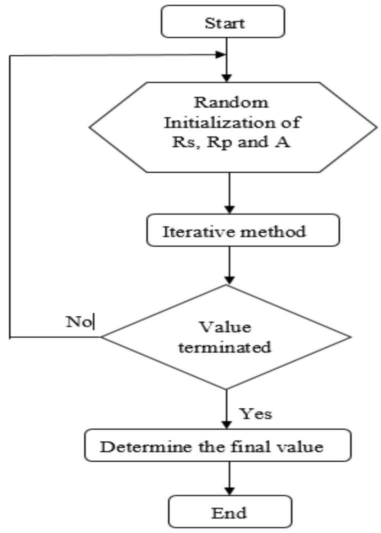

Fig.2.Flowchat of parameter determination of iterative process

The initial values are assumed with the help of ELDORA 250 poly-crystalline solar PV module data sheet given in Table.1. After implementing the iterative method, the values obtained are shown in Table.2.

Table.1. The specification of ELDORA 250 poly crystalline solar PV module

Electrical characteristic of solar panel at STC	From datasheet I-V curve
Open circuit voltage(V_{oc})	37.80
Short circuit current(I_{sc})	8.80
Maximum power voltage(V_{mpp})	30.60
Maximum power current(I_{mpp})	8.20
Maximum power(P_m)	250
Temperature co efficient of V_{oc}	-0.32
Temperature co efficient of I_{sc}	0.42
No. of cells in series (n_s)	60

Table. 2. Estimated value for single diode PV module

Parameter	Estimated value
Series resistance(R_s)	0.1713
Parallel resistance(R_p)	1000.3
Diode ideality factor(A)	1.3
Photo current(I_{ph})	8.4578
Reverse saturation current(I_o)	2.227

III. SIMULATION RESULTS OF SOLAR PV MODELING

The input irradiance and temperature are taken under standard test conditions for making modelling for given solar PV model. The output of solar panel is evaluated to obtain the P-V and I-V characteristics. These characteristics are obtained for different values of temperature and irradiance to study the change based on irradiance and temperature. Fig.3 and Fig.4 depict the I-V and P-V characteristics respectively at different irradiance levels with constant temperature. Fig.5 and Fig.6 depict the I-V and P-V characteristics respectively at different temperature levels with constant irradiance. In manufacturers datasheet provides the performance of solar PV system only for STC conditions. The simulation results of proposed solar PV modelling depict the performance of given PV model under different irradiance and temperature conditions. Because of high installation cost these performances analysis is very useful for consumers and solar panel designers for analyzing the panel at any environmental conditions.

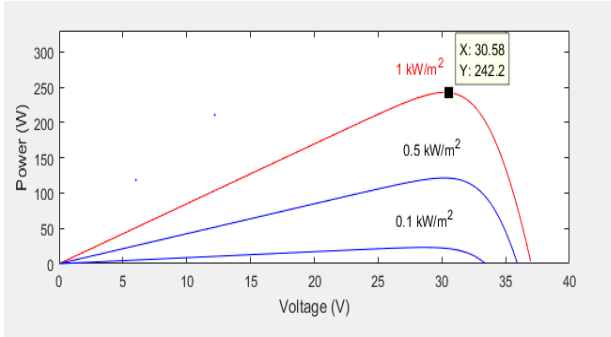

Fig.3. P-V curve with different irradiations

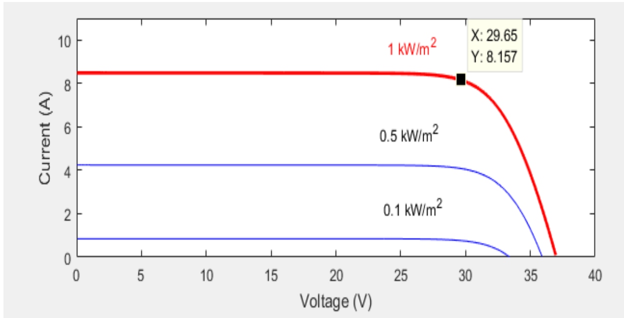

Fig.4. I-V curve with different irradiations

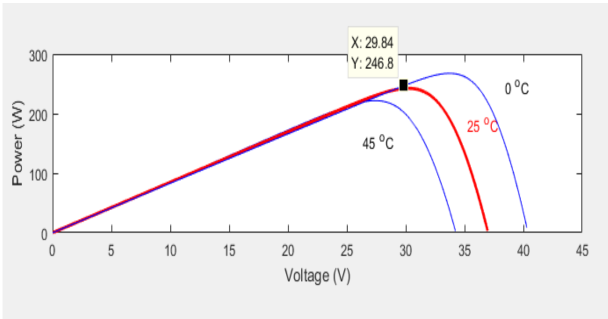

Fig.5. P-V curve with different temperature

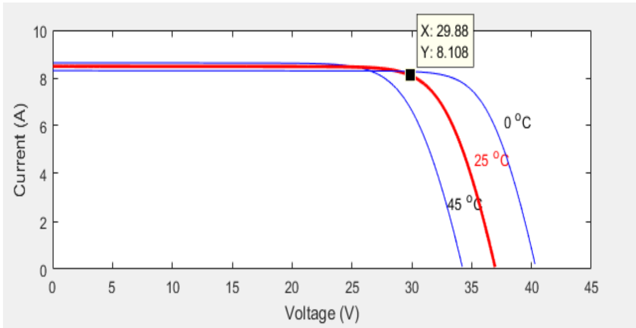

Fig.6. I-V curve with different temperature

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IV. VOLTAGE CONTROL ALGORITHM FOR MPPT

Generally, the solar cells have low efficiency due to manufacturing process which around 20 to 30%. In order to increase their efficiency, MPPT methods are to be undertaken to match the source and the load properly. This technique is used to obtain the maximum possible power from a given solar PV system. In PV system the I-V and P-V curves are in non-linear, thereby making it difficult to be used to power a certain load. This is done by utilizing a boost converter which duty cycle is varied by using a MPPT algorithm. There are various methods to track the maximum power point of a solar PV system. The methods used prominently are perturb and observe method, incremental conductance method, parasitic capacitance method, constant voltage method and constant current method and etc. In this paper, a single sensor voltage based MPPT algorithm has been developed. From the P-V and I-V characteristics of the PV cell, obtain the maximum voltage output for a particular voltage condition using the algorithm shown in Fig.6. The reference voltage is compared with actual panel voltage and getting some error signal.

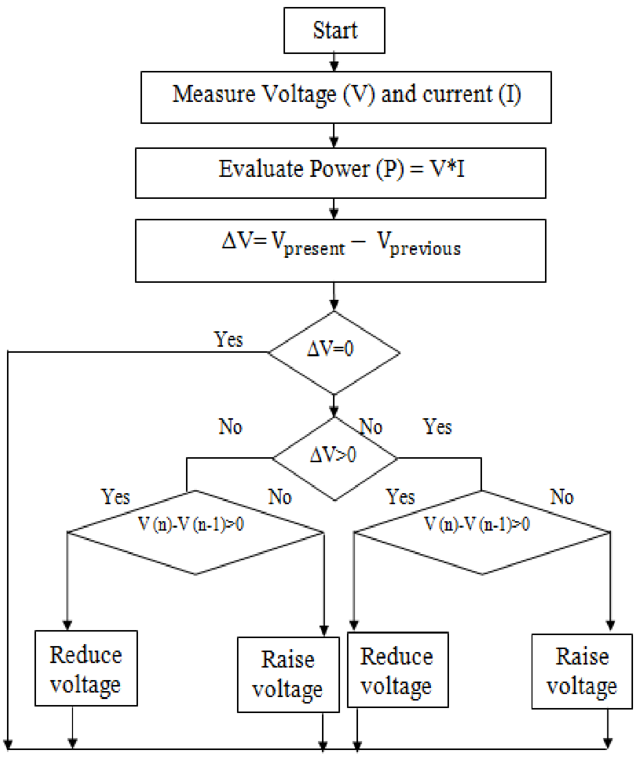

Fig.7. flowchart of Voltage control algorithm

The generating pulse which is made by error signal and used for making switch as turn on and turn off process and controllable from the proposed MPPT algorithm through the matlab function block of MATLAB/SIMULINK software. The proposed technique outputs are more reliable and high efficiency. The proposed algorithm is evaluated and verified with given ELDORA 250 poly-crystalline solar PV module. The response of proposed technique is quite effective with less oscillation.

V. RESULTS AND DISCUSSION

To evaluate the performance of proposed MPPT technique, its overall performances are compared with conventional P&O method. For simulation purpose, the values taken for single diode model of solar PV system at STC condition are selected as P_{max} =250 Watts, V_{oc} =37.80V, I_{sc} =8.80A, V_{mp} =30.60V and I_{mp} =8.20A. For boost converter the specification parameter values taken as capacitor = 0.01F and 4.7µF, Inductor=1.5mH, with load R=100Ω. The proposed method of maximum power tracking is effectively verified with help of most available software MATLAB/SIMULINK. The proposed technique consists 250watt module which has made by connecting more solar cells connected in series and parallel connection. This generated power is feed to a DC-DC boost converter. By getting pulse from the error of solar voltage and reference voltage is matched with PV module power thereby maximum available power from given module is extracted. The results are observed the time period of 0 to 1 sec in order to measures the power, voltage and current of both existing and proposed methods. The results which are getting through simulations are high efficiency with low oscillations. The power, voltage and current waveforms are shown in below simulation results Fig.8, Fig.9 and Fig.10 with both proposed technique and conventional method. The performance assessment of proposed technique with other conventional MPPT methods is also investigated through in Table.3.

Table.3. performance assessment of proposed technique with conventional P&O MPPT method

Method	P&O	Proposed VCA
Rated Power	250	250
Voltage at MPP	30.4	31.11
Current at MPP	7.90	7.99
Power at MPP	240.16	248.56
Efficiency (%)	99.06	99.42

VI. CONCLUSION

In this paper voltage control algorithm has been discussed for effective maximum power extraction of solar PV systems. The parameters from single diode model of PV system have been successfully extracted from their respective non-linear I-V and P-V characteristics using iterative method. In addition, modelling capability of iterative method was analysed with different temperature and irradiation conditions. The simulation results have been confirmed for the effectiveness of the proposed system of tracking maximum from given ELDORA 250 poly-crystalline type of solar model. In further, the complexity of proposed technique is quite low for comparing conventional methods and it provides constant the constant duty cycle for getting constant power from non linear inputs. Finally the suggested solar panel modelling circuit with appropriate MPPT technique helps to improve the overall efficiency and maximum power extraction of solar PV system effectively.

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