COMPARATIVE STUDY OF PERTURB & OBSERVE AND FUZZY LOGIC CONTROL BASED MPPT ALGORITHMS

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ABSTRACT
Maximum Power Point Tracking (MPPT) is a process which tracks one maximum power point from photo voltaic (PV) array input, by varying the ratio between the voltage and current delivered to extract the maximum power. Presently, there are so many MPPT algorithms have been developed by the researchers to have an increase in efficiency. Among that, the classical and very easy implementable MPPT algorithm is perturb and observe (P&O) algorithm. Similarly the robust and intelligent way of control the MPPT for the PV is Fuzzy logic algorithm. In this paper, the basic operation and the design steps of the above two algorithms is presented with Matlab/Simulink simulation and its performance results will be compared at different solar radiation and temperature.

KEYWORDS: *PV Array, MPPT, Perturb and Observe Algorithm, Fuzzy Logic, Simulink*

I. INTRODUCTION

After the energy crisis and environmental issues such as global warming and pollution, a great attention has been achieved by the solar photo voltaic (PV) systems in research. Currently more research works has been focused on how to extract more power effectively from the PV cells to increase the efficiency of the solar photo voltaic systems. The main drawback of the solar PV systems is the variation in output voltage with the changes in solar irradiation and temperature. Maximum Power Point Tracking (MPPT) is a process which tracks one maximum power point (MPP) from photo voltaic (PV) array input. The main challenge by MPPT techniques is to automatically find the voltage V_{MPP} or current I_{MPP} at which a PV array should operate to obtain the maximum power output P_{MPP} under a given temperature and irradiance. It is noted that under partial shading conditions, the P-V characteristics of the PV array get more complex and bear multiple peaks [1]. There are lot of MPPT tracking techniques are in practice and the comparison of most of the MPPT techniques with respect to the amount of energy extracted from the PV panel have been proposed in the literature [2-3]. The most popular MPPT algorithms are Perturb and Observe (P&O) and Incremental conductance (IC) algorithm [4]. But practically P & O control is very easy and feasible to implement [14-15]. In this paper, the basic characteristics of the PV cell and the simulation model of the circuit are developed with the help of Matlab/Simulink software in section II. The basic operation of P&O MPPT algorithm with its flow chart steps is discussed in section III. The section IV describes the design steps of implementing the fuzzy logic MPPT algorithm. The section V compares the simulation results of both P & O controller and Fuzzy logic MPPT controller.

II. MODELING OF PV SYSTEM

2.1 Equivalent Circuit of PV Cell

A solar PV cell is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater then the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation. To achieve higher voltage and current, multiple cells are used as needed. The PV cell can be represented by a simple equivalent circuit shown in figure 1. The series resistance R_s represents the internal losses due to the current flow, whereas the shunt resistance R_{sh} corresponds to the leakage current to the ground and it is normally ignored.

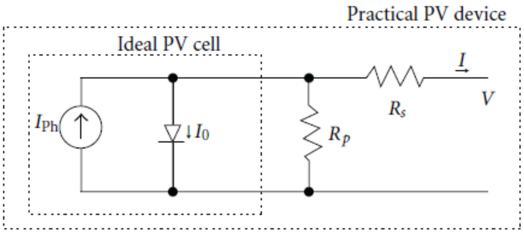

Fig.1 Equivalent circuit of PV cell

The output current is a function of solar radiation, temperature, wind speed and coefficients that are particular to the cell technology. The authors [5-6] present a detailed analysis of solar cell and its electrical equivalent model is created in Matlab /Simulink. The net current equation of the PV cell (eqn.1) is the difference between the photocurrent I_{ph} and the normal diode current I_D.

$$I = I_{ph} - I_D = I_{ph} - I_o\left(\exp\frac{e(V + IR_s)}{mkT_c} - 1\right) \qquad \text{Eqn.1}$$

Where:
m - Idealizing factor
k - Boltzmann's gas constant
T_c -The absolute temperature of the cell
e- Electronic charge
V-The voltage impose across the cell
I_o -The dark saturation current

2.2 Characteristics of Solar Cell

PV modules have unique current v/s voltage (I-V) characteristics. From the P-V and I-V characteristics, as shown in figure 2, it is clear that the PV systems must be operated at a maximum power point (MPP) of specific current and voltage values so as to increase the PV efficiency. The voltage that corresponds to the module maximum power varies with temperature and insolation variations, so a MPP tracking system is needed to ensure that we stay as close as possible to the maximum power point.

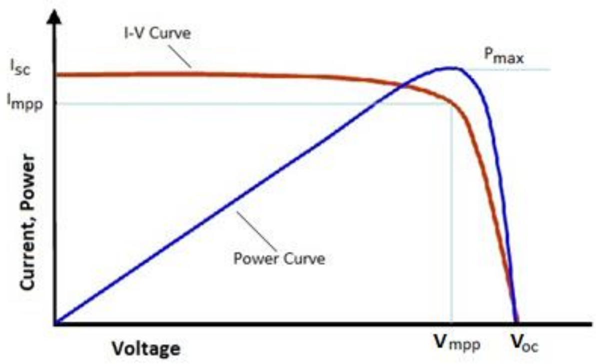

Fig.2 PV-IV curves of Solar Cell

III. P&O MPPT ALGORITHM

3.1 Algorithm

This algorithm is an iterative technique and very simple one. It measures the panel operating voltage and current periodically and calculates the instantaneous power. This instantaneous power compares with the previous output power, then the operating voltage is determined and changed by changing the duty ratio of the converter. The sign of change of output power is also observed to track the MPP. If the output power increases by increasing the operating voltage, then the operating voltage is further perturbed in the same direction until it reaches the point of MPP or dp/dv=0. If the output power decreases by increasing the operating voltage, i.e the operating point is in the negative slope region of the PV curve. Then the operating voltage is perturbed in the reverse direction to track the MPP.

3.2 Flow Chart

The flow chart of the P&O algorithm [7] is shown in the figure 3**.**

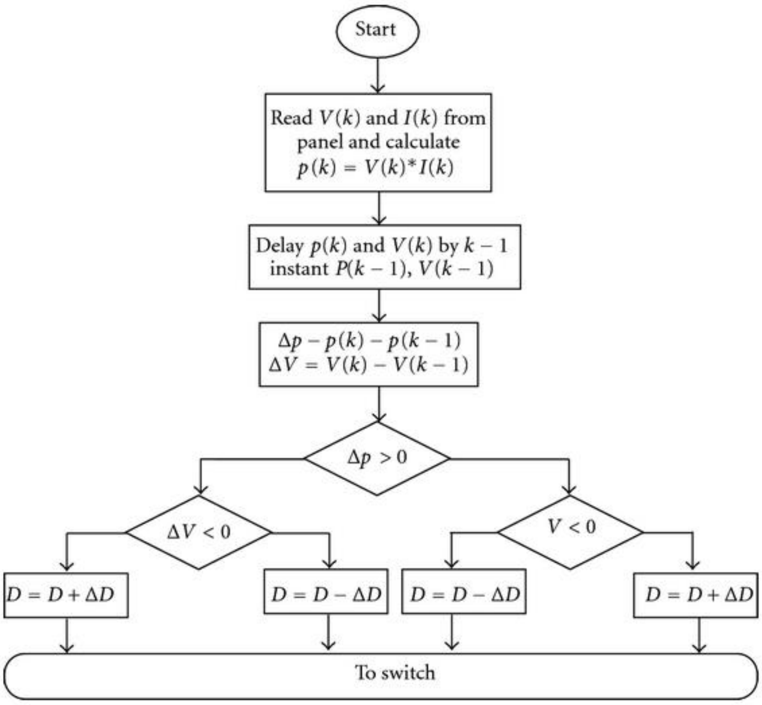

Fig. 3 Flow chart of P & O Algorithm

The main advantage of this technique is very simple and easily implemented [16]. But the disadvantage is the operating point is highly oscillated around the MPP point and not fixed on the exact MPP. The literature review reveals that if we increase the step size of the algorithm, the oscillations around the MPP will be more and dynamic. If we reduce the step size, the convergence speed will be very less and cannot able to track the MPP at various atmospheric conditions. Several researchers [8-9] in the review suggested or modified the P&O algorithm to have better efficiency compare to the conventional.

IV. FUZZY LOGIC BASED MPPT

4.1 Fuzzy Logic

The Fuzzy logic controller uses the fuzzy logics to make the decisions and to control the output of the controller. The main components in fuzzy logic based MPPT controller are fuzzification, rule-base, inference and defuzzification [13] as shown in figure 4.

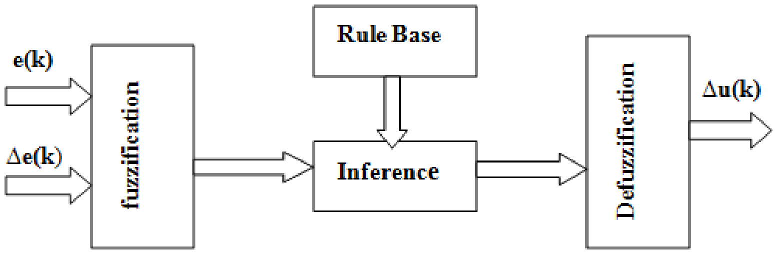

Fig. 4 Fuzzy logic block diagram

There are two inputs to the controller – error e(k) and change in error Δe(k). The Fuzzification block converts the crisp inputs to fuzzy inputs. The rules are formed in rule base and are applied in inference block. The defuzzification converts the fuzzy output to the crisp output. The fuzzy inference is carried out by using Mamdani's method, and the defuzzification uses the centre of gravity to compute the output of this FLC which is the change in duty cycle.

The inputs to the Fuzzy controller are change in PV array Power (ΔP_{PV}) and change in PV array current (ΔI_{PV}) corresponding to the two sampling time instants [11-12]. The two inputs are processed by the Fuzzy controller and the output of the Fuzzy controller is the incremental reference current (ΔI_{ref}). This output is given to the Dc-Dc power converter. The first input variable (ΔP_{pv}) for the fuzzy logic controller is divided into seven Fuzzy sets: PB (Positive Big), PM (Positive Medium), PS (Positive Small), ZZ (Zero), NS (Negative Small), NM (Negative Medium) and NB (Negative Big). The second input variable (ΔI_{pv}) for the fuzzy logic controller is divided into 3 Fuzzy sets: N (Negative), Z (Zero) and P (Positive). The only one output variable (ΔI_{ref}) is divided into 7 Fuzzy sets: PB (Positive Big), PM (Positive Medium), PS (Positive Small), ZZ (Zero), NB (Negative Big), NM (Negative Medium) and NS (Negative Small). The rules [10] are formed as shown in table 1.

Table.1 Rule Base

ΔP_{pv} / ΔI_{pv}	PB	PM	PS	ZZ	NS	NM	NB
P	PB	PM	PS	PS	NS	NM	NB
Z	PB	PM	PS	ZZ	NS	NM	NB
N	NB	NM	NS	NS	PS	PM	PB

The input, output membership functions are shown in figures 5, 6 & 7 respectively

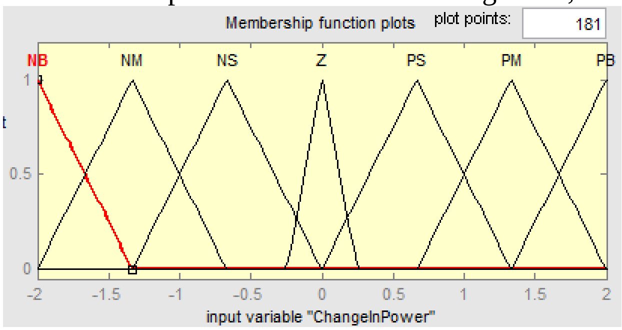

Fig. 5 Membership functions of "change in Power" input

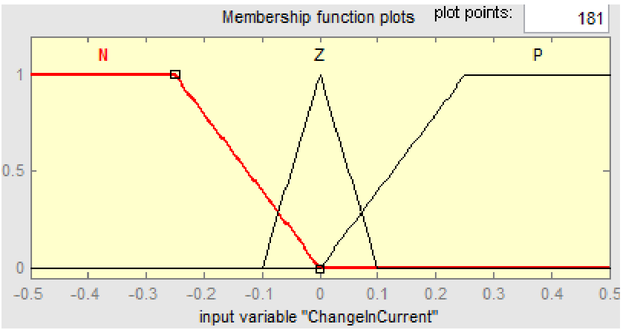

Fig. 6 Membership functions of "change in current" input

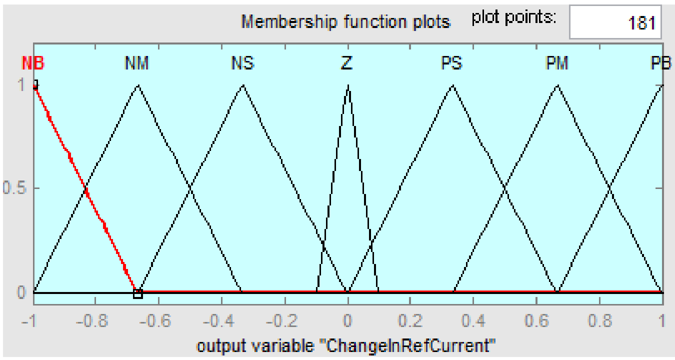

Fig. 7 Membership functions of "change in Reference current" output

V. Simulation Results

The P& O MPPT controller and Fuzzy logic MPPT controllers are designed modelled and implemented in the Matlab/Simulink software as shown in the figure 8 and 9. The simulation setup is arranged such that initially having a constant temperature of 25ºC with the slow increase of insolation from 500 watts/m^2 to 1300 watts/m^2. Then at the same condition, the insolation will be decreased from 500 watts/m^2 to 1300 watts/m^2. Then the tests can be conducted for the constant insolation, with rapid increase or decrease the temperature from 25ºC to 50ºC. The specification of the PV module used in this simulation is tabulated in table 2.

Table.2 PV- Module specifications

Short Circuit Current	13.5 A
Open Circuit Voltage	48 V
Current at P_{max}	11.2 A
Voltage at P_{max}	35.6 V

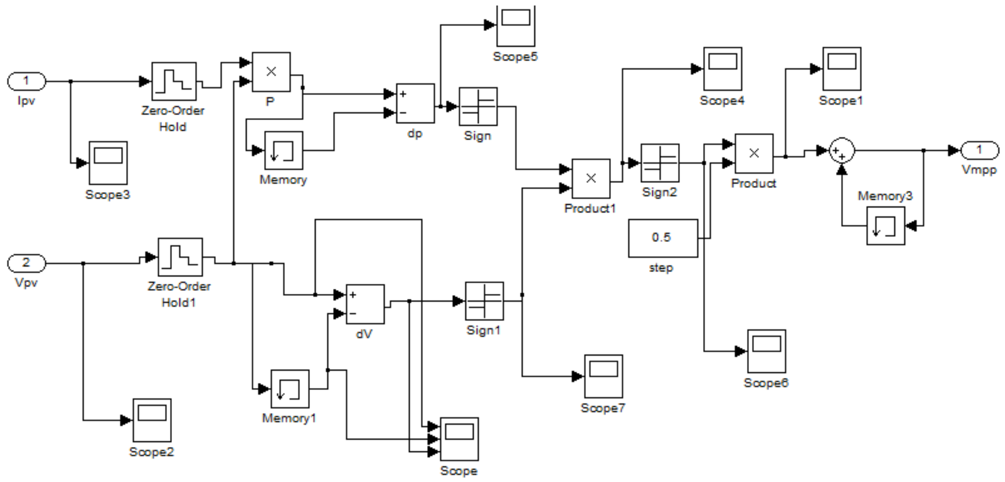

Fig.8 P & O Algorithm based MPPT

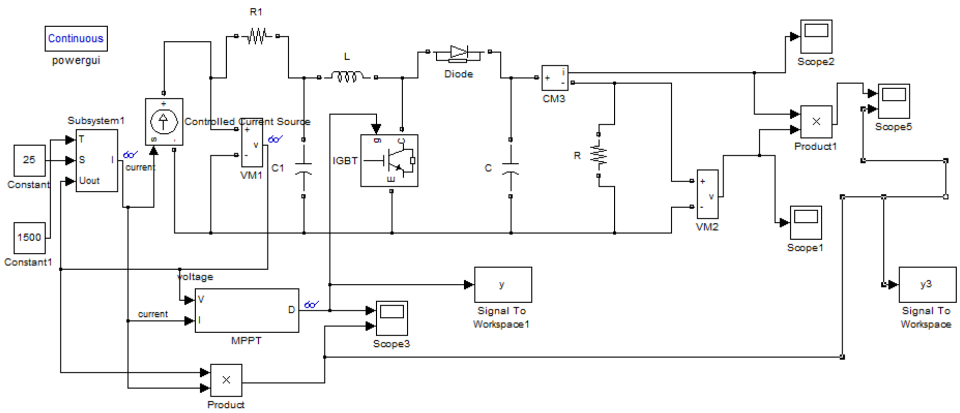

Fig.9 Fuzzy logic control based MPPT

Fig.10 and Fig.11 shows the results of the fuzzy logic controller PWM output and the output power of the PV Module with the irradiation of 500, 800, 1000 and 1300 watts/m^2. The fig.11 shows the performance of the PV system using Fuzzy logic controller under fast changing of irradiance. It is clear that energy gained by the proposed fuzzy logic technique is giving better efficiency compare to the conventional technique P&O technique.

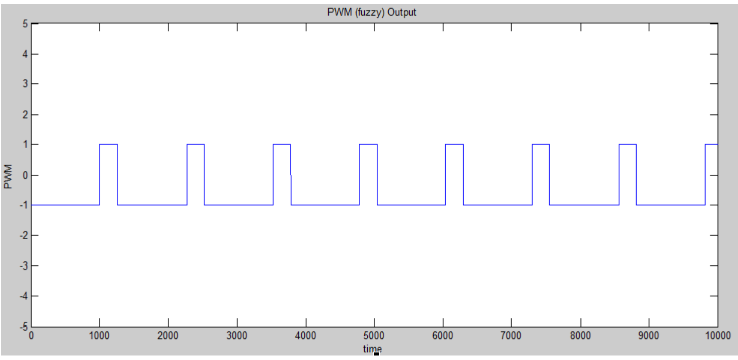

Fig. 10 Proposed fuzzy logic control PWM output

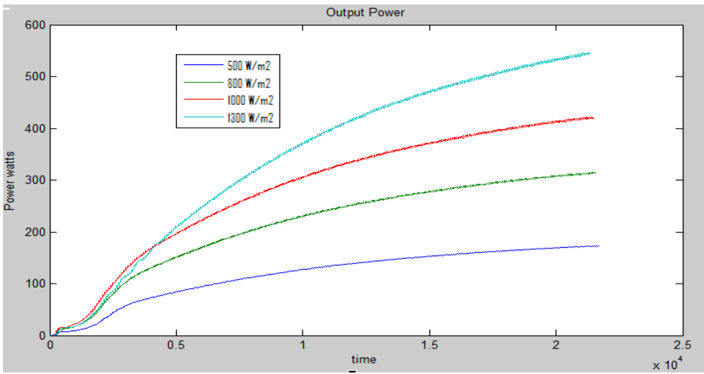

Fig.11 Output Power at different irradiations

VI. Conclusion

In this paper, the basic characteristics and equivalent circuit of the solar module is discussed. To have a maximum extraction of power from the solar source, P&O MPPT algorithm and fuzzy logic algorithm are also reviewed, modelled and implemented in the matlab/simulink software. The output power of both the MPPT algorithms are compared and analysed at different solar irradiation conditions. From this comparative study, fuzzy logic MPPT controller is giving better results of extracting more power than the classic P&O MPPT.

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