Evaluation of P &O Method and FLC Method Based Maximum Power Point Tracking for PV System

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Abstract : Solar Photovoltaic (PV) exploitation is a significant renewable energy source. The energy converted directly from sunlight through PV panel is not steady due to different solar intensity. Maximum power point tracking (MPPT) is used extract maximum power from the solar panel, high-performance soft computing techniques can be used as a maximum power point tracking techniques. This paper proposes fuzzy logic controller (FLC) based MPPT method for the PV system under constant and varying climatic conditions. FLC-based MPPT is able to differ the PV operating voltage and seek for the maximum power that the PV panel can produce. The performance of fuzzy logic with various membership function (MF) is analyzed to optimize the MPPT. Simulation results demonstrate that the recital of FLC-based MPPT is better than unadventurous perturb and observe (P&O) MPPT

IndexTerms **- Photovoltaic system; Boost converter; Fuzzy logic controller Perturb & Observe Method.**

I. INTRODUCTION

Solar PV power generation is one of the burning research fields these days. Steep growth in the application of PV has been driven by growing concern about climate change, Government incentives and reduction in PV system costs. In order to cope with increased demand of energy, an efficient photo-voltaic (PV) power generation system with an effective maximum power point tracker needs to be developed. In a PV system, the conversion of solar energy to electricity is facilitated by means of a PV module and a power-electronic converter system with a control mechanism. The output power of a PV cell fluctuates to a large extent due to variation in solar irradiation and temperature. The current-voltage (I-V) and power-voltage (P-V) characteristics of PV cell are nonlinear. A PV module has an optimum operating point where power is maximum, known as maximum power point (MPP) which varies according to cell operating temperature and irradiation level [1]. PV modules have low energy conversion efficiency that can be increased only if a PV module can be operated at its MPP. When a direct connection is carried out between source and load, the output of PV module irregularly shifts away from maximum power point. The PV power can be made available for practical use by the help of an efficient device called maximum power point tracker which extracts the peak of the available PV power. This device must be constructed with a good MPPT algorithm and a controller with efficient control system [2]. MPPT uses DC-DC converters for regulating the solar input voltage to the maximum power point and providing impedance matching for the maximum power transfer to the load. Various methods of maximum power tracking in PV power applications have been reported in literature [3]. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, hardware required for the implementation or popularity.

Perturb and observe MPPT algorithm is simple and easy to implement but it suffers from drawbacks like slow convergence speed and oscillation of output around the MPP in steady state. When the system is operating near a region around the maximum power point, the P&O algorithm suggests an increase in duty cycle or decrease in duty cycle depending on the change in PV voltage. If the operating point is at left side of MPP then an increase in duty will results in shift of operating point to the right side of MPP. This causes an oscillation of system output around the maximum power point in the steady state. In order to avoid this oscillation and obtain a stable and steady output at the output of PV power generation system, a fuzzy logic based maximum power point tracking algorithm has been implemented. Fuzzy logic based MPPT can handle non-linearity and uncertainty associated with PV systems. Fuzzy logic based MPPT has several advantages like they do not require pre-knowledge of the exact model of the PV panel and provide better performance. This paper explores ways of improving maximum power point tracking using fuzzy logic. The control algorithm uses the excellent knowledge representation and deduction capabilities of fuzzy logic to address the drawbacks of conventional methods.

The main aim of this paper is to investigate the concept of conventional Perturb and Observe (P&O) algorithm and fuzzy MPPT (FMPPT) technique to produce an improved MPPT controller. An intelligent maximum power point tracking technique using fuzzy logic controller is presented to track the MPP of the PV module. Performance analysis and comparison of results of P&O MPPT and FMPPT in a PV power generation system are evaluated using MATLAB/Simulink Software

II. PV CELL MODELINGS

The operation of a PV solar cell is similar to that of a positive–negative (P–N) junction diode where the electrons flow from the N layer to the P layer of the PV cell via an external connection circuit and rejoin the holes. Since this book deals with the utilization of the PV cells and arrays rather than their structural properties, the internal structures and physical properties of the PV solar cells will not be given here. However, the equivalent circuit and mathematical modeling of the PV cells and arrays are discussed and given in MATLAB and Simulink environments for the system simulation. A detailed modeling of the PV cells including the effects of the weather conditions is given next. A solar cell converts solar energy to electric output power only if there is a load-connected across the P–N layers. Without any load or any connection between P–N layers via an outside path, the electrons cannot flow and therefore no photocurrent is generate. If the solar irradiation level and temperature change, the MPP values will also change, resulting in new base values for the per-unit system. In order to simulate a PV solar cell array, an equivalent circuit model is needed. Different circuit models of PV cells have been studied over the years A review of PV cell models used in steady-state and transient analysis is given in . In this reference, the authors reviewed seven different static PV cell models based on the equivalent circuit and current equation given in Figure 1 and 2 respectively:

$$I_C = I_{ph} - I_0\left[\exp\left(\frac{e}{kT_C}(V_C + R_S I_C)\right) - 1\right] - \frac{V_C + R_S I_C}{R_{SH}}$$

where IC is the cell output current (A); Iph the photocurrent, function of irradiation level and junction temperature (A); I0 the reverse saturation current of the diode D (A); VC the cell output voltage (V); RS the series resistance of the cell (W)

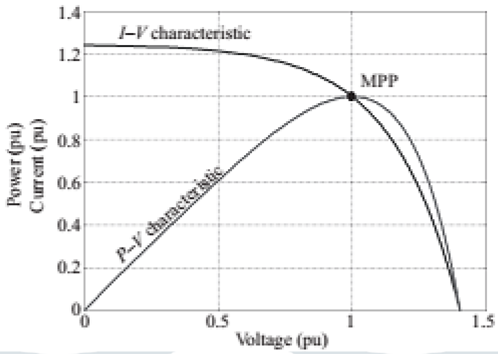


Figure 1.Typical I–V and P–V characteristics of a PV cell

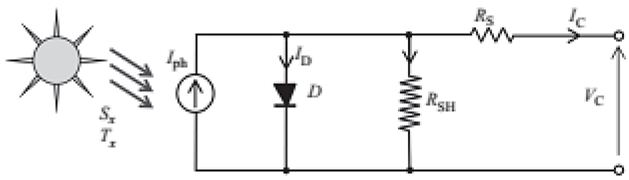


Figure 2. Generalized static equivalent circuit of a PV cellif the corresponding bit is 1

III. PROPOSED METHODOLOGY

3.1 Mppt Model

The circuit diagram of the energy conversion system is shown in Fig.4. The system consists of photovoltaic panel, a DC-DC boost converter, a fuzzy-based MPP tracker and a resistive load. The PV array consists of 50 series PV cells. The I-V characteristic of array depends on the temperature and solar insolation level. The photovoltaic array operation depends on the load characteristics at which it is connected to. So when connected to load directly, the output of the PV array rarely works at MPP. However, to adapt the load and extract maximum power from a PV module, a DC-DC boost converter is used by adjusting its duty cycle under control of selected controller (in our case fuzzy and P&O algorithms) based MPPT controller such that the maximum solar panel output power is extracted under all operating conditions

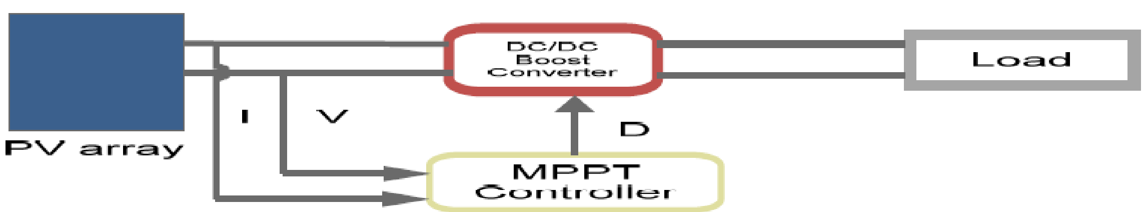


Figure.3. MPPT system

3.2 DC-DC converter

A boost converter is a step-up DC-DC power converter. Fig.5 shows the boost converter circuit using MOSFET switch. The converter operation can be divided into two modes. Mode 1 begins when the transistor is switched ON, the current in the boost inductor increases linearly, and the diode is OFF state, mode 2 begins when the transistor is switched OFF, the energy stored in the inductor is released through the diode to the load. The power flow is controlled by varying the on/off time of the MOSFET. The relationship between input and output voltages is given by equation

$$\frac{V_o}{V_i} = \frac{1}{(1-D)}$$

Where Vi is the PV output voltage, Vo voltage of boost converter, D is duty cycle, that can be expressed by equation (4

$$D = \frac{T_{on}}{T}$$

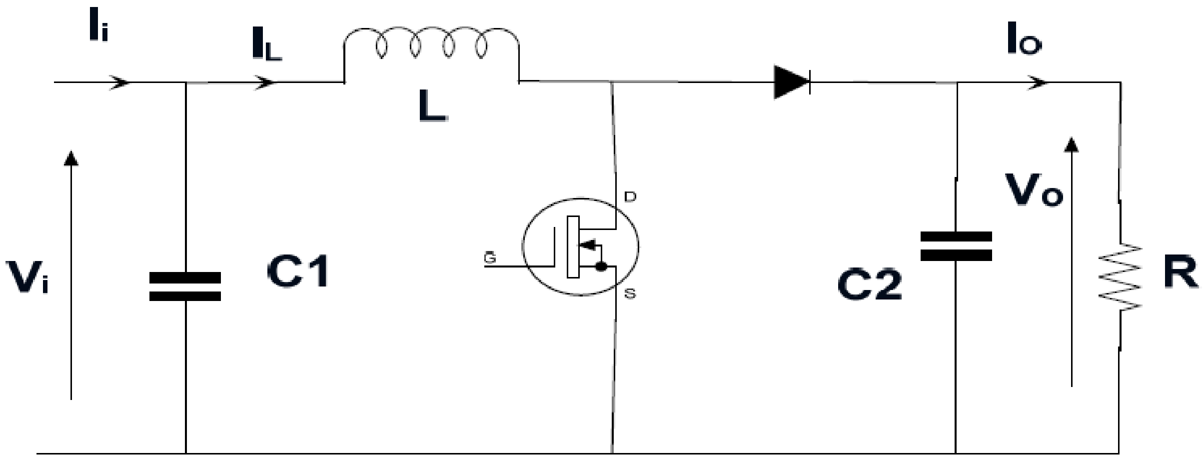


Figure 4. Boost converter Circuit diagram

3.3 MPPT controller

MPPT is essentially a real time process to search for the operating point which gives the maximum available power that can be extracted from the PV array at any insolation level. Two MPPT techniques will be presented and simulated. 4.1 perturb & observe The principle of P&O is to perturbation by acting decrease or increase on the PWM duty cycle of boost converter and then observing the direction of change of PV output power, If at any instant j the output PV power P (j) & voltage V (j) is greater than the previous computed power P (j−1) & V (j-1), then the direction of perturbation is maintained otherwise it is reversed [10, 11]. The flow chart of algorithm has 4 cases as shown in Fig.6 and can be detailed as following

- When ΔP <0 & V(j)>V(j-1), this yields to D (j+1) = D (j) - ΔD
- When ΔP <0 & V(j)<V(j-1), this yields to D (j+1) = D (j) + ΔD
- When ΔP >0 & V(j)<V(j-1), this yields to D (j+1) = D (j) - ΔD
- When ΔP >0 & V(j)<V(j-1), this yields to D (j+1) = D (j) + ΔD

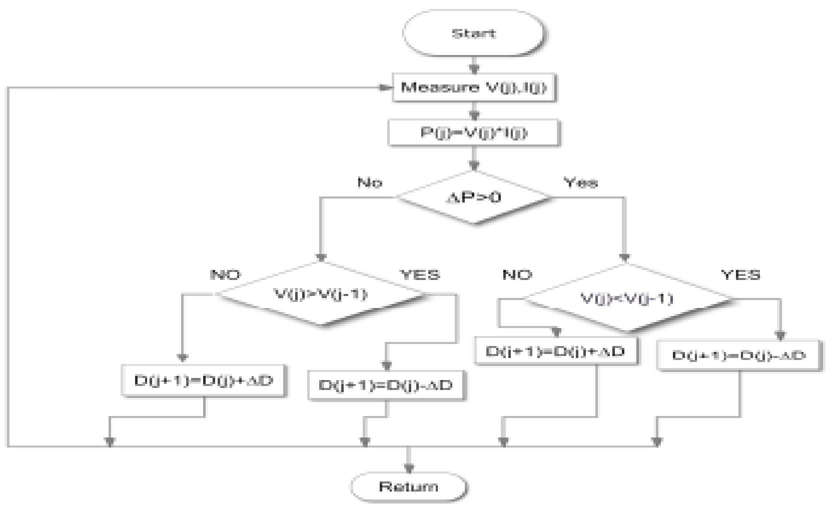


Figure 5.P&O flowchart

3.4 MPPT with FLC

Where ΔD is chosen value by trial and error in simulation. A simulation of the P&O algorithm has been implemented by using MATLAB; Figure .6 shows the simulation results for different values of ΔD. Despite the P&O algorithm is easy to implement it has mainly the following drawbacks: • Cannot always operate at the maximum power point due to the slow trial and error process, and thus the maximum available solar energy from the PV arrays cannot be extracted all the time.. • the PV system always operates in an oscillating mode which leads to the need of complicated input and output filters to absorb the harmonics generated. Fuzzy logic controller design In the MPPT configuration, Fuzzy Logic Controller (FLC) is used to determine the duty cycle of the buck converter. In general, the input on the FLC is error value and changes in error. The main parts of the FLC include: fuzzification, system inference, rule base and defuzzification. The block diagram of the FLC is shown in Fig. 9.

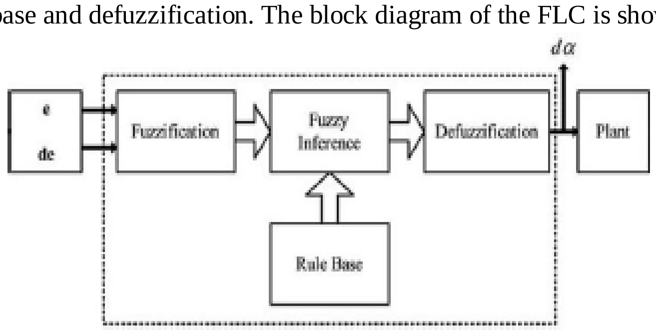


Figure 6. Block diagram of Fuzzy Logic Controller.

The value of error and changes in error used, obtained from the value of current and voltage generated by photovoltaic. The value is defined in Eq. (14) and Eq. (15)

$$e(k) = \frac{P(k)-P(k-1)}{V(k)-V(k-1)}$$

$$\Delta e(k) = e(k) - e(k-1)$$

With e(k) as the error value at the (k) sampling time, e(k-1) as the error value at the (k-1) sampling time, and $\Delta e(k)$ as the changes in error, as well as the value of power (P), and voltage (V). Fuzzy logic inference system and membership functions used in the fuzzy set in both form and number are initialized based on trial and error method Fuzzification of error values and changes in error is shown in Fig. 10 and 11, while defuzzification of the changes in duty cycle values is shown in Fig. 12. The rule base used are shown in Table 1

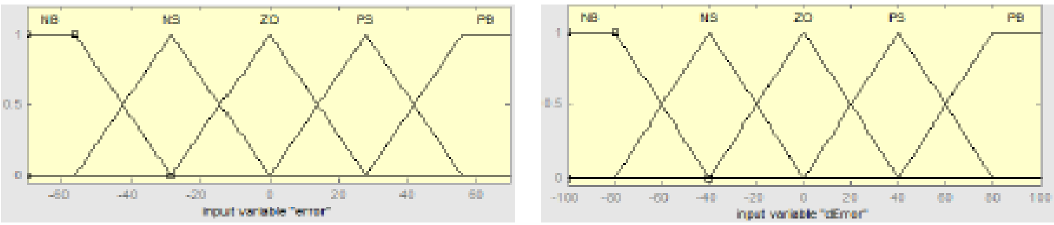
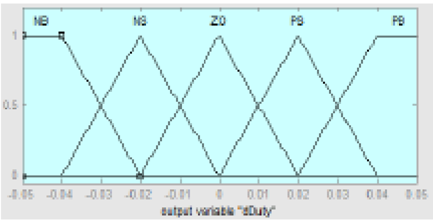


Figure 7 Membership function plots for error.and Membership function plots for changes in error



Membership function plots for changes in duty cycle.

E\dE	NB	NS	ZO	PS	PB
NB	ZO	ZO	PB	PB	PB
NS	ZO	ZO	PS	PS	PS
ZO	PS	ZO	ZO	ZO	NS
PS	NS	NS	NS	ZO	ZO
PB	NB	NB	NB	ZO	ZO

Table 1Rule base

IV. CONCLUSION

Designing of a fuzzy logic based maximum power point tracker that can act according to various situations have been presented in this paper. The simulation results of PV module depicts that the output characteristics of PV cell is nonlinear and its output power fluctuates to a large extent by solar irradiance and temperature. MPPT control techniques are implemented in order to operate the PV module at its maximum operating point at which maximum power generated can be transferred to the load connected across the output terminal of boost converter. Two MPPT techniques namely perturb and observe MPPT and fuzzy logic based MPPT have been implemented to track the MPP. The performances of these MPPT techniques were evaluated and compared. From the simulation result it can be concluded that the fuzzy logic based maximum power point tracker provides better MPP tracking and it has faster convergence speed. Although P&O algorithm is easy to implement, unlike fuzzy MPPT, they cannot cope with rapidly varying environmental condition. In Perturb and Observe algorithm, step size is fixed. When the operating point converges to MPP, system oscillates around the maximum power point due to a fixed increment or decrement in duty cycle. In contrast, FMPPT provide a stable response in tracking of MPP due to its variable step size even if there is variation in PV module characteristics. Simulation results prove superior performance of fuzzy logic based intelligent maximum power point tracking technique.

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