A Comprehensive Analysis on Solar PV Maximum Power Point Tracking Techniques

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Abstract- In this paper, electrical power is generated from solar energy using Solar PV cell. The system is designed with 1- KW PV module and connected with DC/DC converters with DC load.There are two main drawbacks with PV plants, the high cost of PV cells and their conversion efficiency. In the I-V characteristics of PV module which is non-linear but has a unique maximum power point. To increase or to maximize the output power of photo-voltaic system Maximum power point tracking (MPPT) techniques are used. These techniques give maximum output power, irrespective of the irradiation condition, temperature and load electrical characteristics. For the purpose of tracking the maximum power the MPPT techniques use some electronic converters. This paper presents comparative analysis of two well-known maximum power point tracking algorithms- perturb-and- observe (*P&O*), and Fuzzy Logic Control Technique (*FLC*) are utilized with DC-DC Buck-Boost converters to observe various output response like power and voltage and comparisons between the controlling techniques using FLC and P&O for Solar PV system which provides a convenient choice of right technique for DC micro grid system and find out the efficiency of the converter.

Keywords—*Solar PV Cell, MPPT, Perturb and Observe, Fuzzy Logic Controller, Buck-Boost converter.*

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I. INTRODUCTION

With the increasing penetration of DG and availability of solar irradiation the demand of green energy can be supplied using solar PV system. But due to intermittent nature of solar source the output of PV module needs to be making over using the different converters. This calls for the controlling part of the converter for suitability of the PV system. Photovoltaic (PV) is used to absorb solar energy from solar irradiations and convert it into electrical energy. That energy is transmitted through converters to increase or decrease the amplitude of voltage [1].

The problem associated with solar irradiations is that it is variable by nature, so the generated power is also variable and need to be stable for utility. This energy is further stored in storage devices such as batteries. [1]-[2]

The solar system is that it depends upon weather conditions and irradiations, which are intermittent in nature. Impedance matching of load is required for tracking maximum power from solar module and it depends on Voltage and Current parameters. For this DC/DC converters are used that needed to be controlled as per required conditions. For getting maximum power from solar modules, it is to be tracked by taking in consideration of minimum losses as well. For every different converter a different tracking method is feasible Parameters considered for control are PV side controlled voltage and current and towards load side impedance. For each parameter above some method is to be prepared for controlling converters to increase system efficiency.[4]

II. MODELLING OF PV BASED SOLAR SYSTEMS

Photovoltaic (PV) energy is clean, inexhaustible and free to harvest. Regardless of intermittency of sunlight solar energy is widely used to generate direct current (DC) from sun intensity. The flow occurs when the photo conductive cell is connected to the external load. PV array has nonlinear characteristics so it is necessary to model it for the design and simulation of MPPT for PV application. [3]

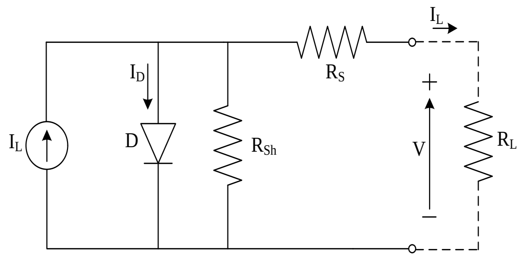

Fig. 1. Correspondent circuit of PV (solar cell)

The solar cell is represented by the electrical model is shown in Fig. 1. Its I -V characteristic is expressed by the following equation (1).[3]

$$I = I_L - I_0(e^{\frac{q(V-IR_S)}{AKT}} - 1) - \frac{V-IR_S}{R_{SH}} \quad (1)$$

A. *DC-DC Converters*

DC-DC converters are used in solar PV system to regulate the output voltage by changing the duty ratio (D) to

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maintain the operating point of the solar PV array. There are three DC-DC Converte

1. *Buck DC-DC converter*
2. Boost DC-DC Conveter
3. *Buck-Boost DC-DC converter*

In this paper, Buck *–Boost DC-DC converter is consider only.*

Buck-Boost DC-DC converter

The Buck-Boost converter is also referred to as circuit combination of a Buck and Boost converter. Buck Boost

converter offers higher output current characteristics because of the inductor on the yield stage. [4]

The balance equations for the switch conduction mode-

$$V_{L1}=V_d \quad (2)$$
$$V_{L2}=-V_1-V_2 \quad (3)$$
$$I_{C1}=I_2 \quad (4)$$
$$\mathbf{I_{C2}=I_2-V_2/R} \quad (5)$$

On the 2nd operating mode when the switch is open (OFF). Then

$$V_{L1}=V_d-V_1 \quad (6)$$
$$V_{L2}=-V_2 \quad (7)$$
$$I_{C1}=I_1 \quad (8)$$

$$V_o/V_{in}=D/1-D \quad (9)$$
$$I_{in}/I_o=D/1-D \quad (10)$$

III **Flow Chart and Algorithms of Maximum Power Point Tracking (MPPT)**

The most generally used techniques for maximum power point tracking are considered here.

- Perturb & Observe Method
- Fuzzy Logic Controller

The flow charts for the techniques perturb and observe method are discussed in sections

Perturb and Observe Method for MPPT

This method is the most common. In this method very less number of sensors are utilized [5] and [6]. The operating voltage is sampled and the algorithm changes the operating voltage in the required direction and samples$dPdV$. If $dPdV$ is positive, then the algorithm increases the voltage value towards the MPP until $dPdV$is negative. This iteration is continued until the algorithm finally reaches the MPP. This algorithm is not suitable when the variation in the solar irradiation is high. The voltage never actually reaches an exact value but perturbs around the maximum power point (MPP). Fig. 2. shows the flow diagram of perturb & observe algorithm for photovoltaic system.

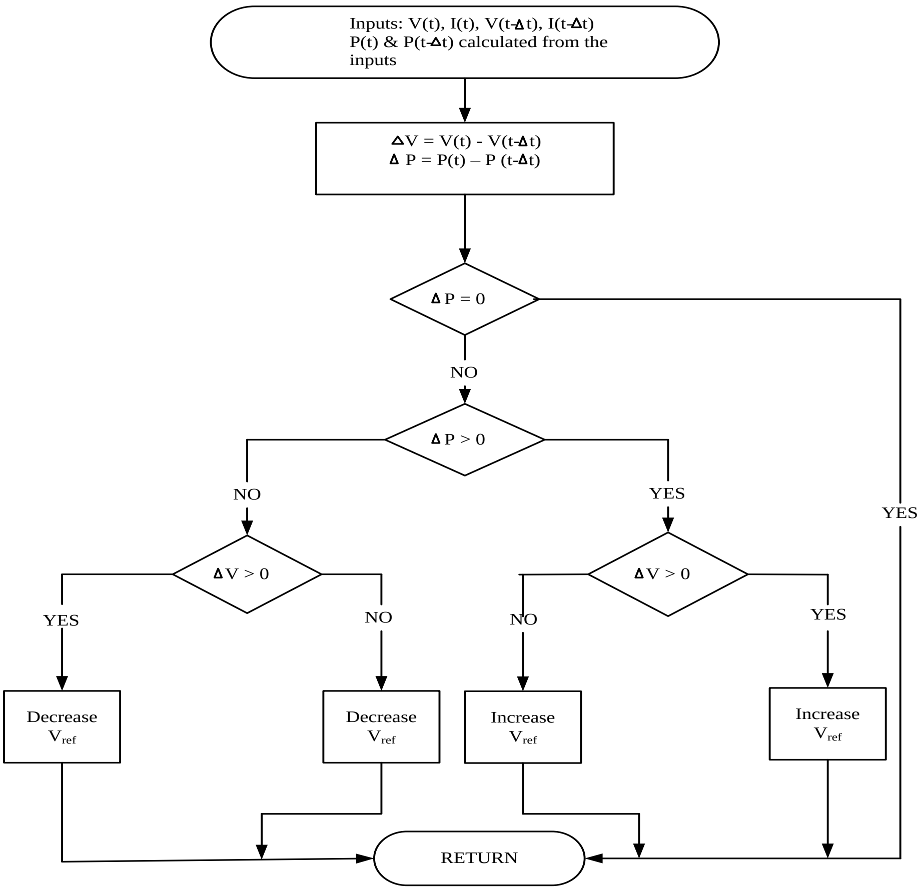

Fig. 2 Flowchart of the P&O algorithm

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Fuzzy Logic Controller for MPPT

Fuzzy logic controller has been introduced in the tracking of the MPP in PV system [3]. It has the advantage to be robust and relatively simple to design as they do not require the knowledge of the exact model. The proposed system in this thesis consist of two input variables: error (E) and change of error (CE), and one out variable, duty ratio or duty cycle (D).

Membership function values are assigned to the linguistic variables, using five fuzzy subsets: NB (negative big), NS (negative small), ZE (zero), PS (positive small) and PB (positive big), the partition of fuzzy subsets and the shape up to appropriate system. The value of input error (E) and charge of error (CE) are normalized by an input scaling factor. In this system the input scaling factor has been designed such that input values are between -1 and 1. Normally the triangular shape of the membership function of this arrangement presumes that for any particular input there is only one dominant fuzzy subset [6], [7]. The input variable error (E) and change of error (CE) for the fuzzy logic controller can be calculated as follows, from these linguistic rules, the FLC proposes a variation of the reference voltage $\Delta V_{pv,ref}$ according to Equations (11 – 12).

$$E(K)=\frac{\Delta I}{\Delta V}+\frac{I}{V}=\frac{\Delta P}{\Delta V}=\frac{\Delta P}{\Delta I} \quad (11)$$

$$CE(K)=E(K)–E(K-1) \quad (12)$$

Where I is the output current from PV panel, I = I (k)-I(k-1), V is output voltage from PV panel, V = V(k)-V(k-1). Table 1.1 shows the rule table for fuzzy logic controller.

TABLE 1.1- RULE BASE FOR FLC

	CE				
E	NB	NS	ZE	PS	PB
NB	ZE	ZE	NB	NB	NB
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS
PS	PS	PS	PS	PS	ZE
PB	PB	PB	PB	PB	ZE

In this paper, Show comprehensive analysis between P&O MPPT and FLC MPPT techniques for PV Cell.

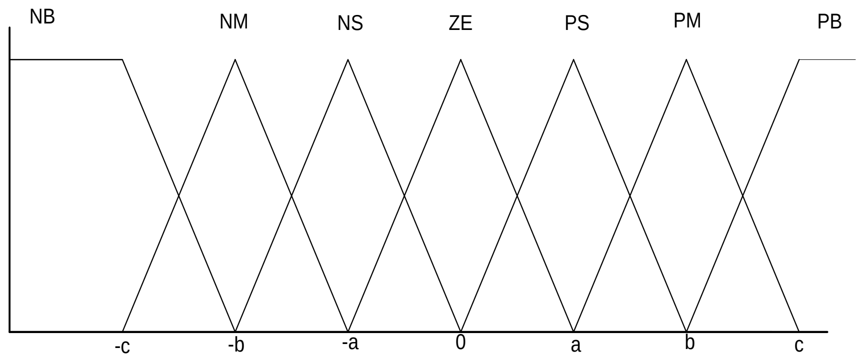

Fig. 3. Fuzzy Membership Function (mf)

IV. RESULTS AND DISCUSSIONS

The test system undergone is taken as 1000W solar power and the converter topologies namely Buck-Boost dc-dc Converter are utilized for the study. The hourly based irradiation and temperature variable condition is taken in consideration and for the sake of representation only irradiance and temperature changes are taken for three different climatic conditions. Fuzzy based rule is developed. Different MPPT techniques are compared with and without control scheme. For the simplicity the R load (consider to be DC load) is taken.Fig.10. shows the MATLAB/Simulink model for P&O, MPPT and FLC MPPT with DC-DC Converters

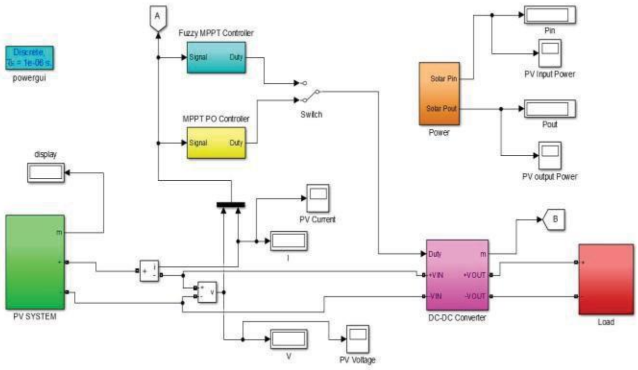

Fig.4. MATLAB Simulink block model for P&O MPPT and FLC MPPT with DC-DC Converters

The results show the comperisons of the fuzzy and P&O mppt techniqes with various converters and comparisions it.

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The output power , voltage and efficiency of the all various cnverter show in figures.

Buck-Boost Converter with FLC MPPT, P&O MPPT and Without MPPT Controller for PV system.

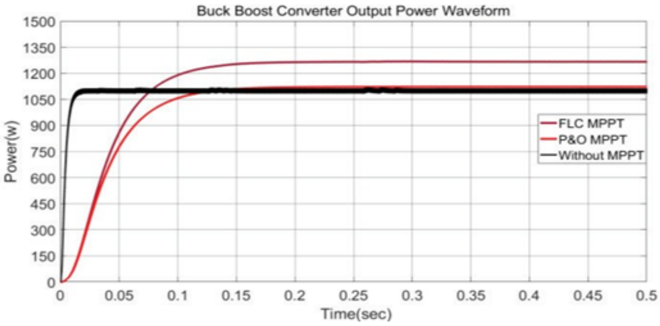

Fig.5 . Comparative Simulation result of FLC, P&O and Without MPPT output power for Buck Boost Converter at 1000w/m^2 irradiation and 35^{o}c Temperature.

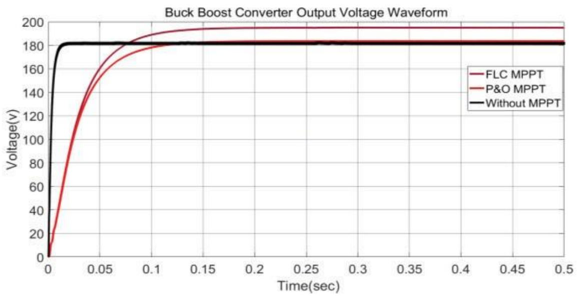

Fig. 6. Comparative Simulation result of FLC, P&O and Without MPPT output voltage for Buck Boost Converter at 1000w/m^2 irradiation and 35^{o}c Temperature.

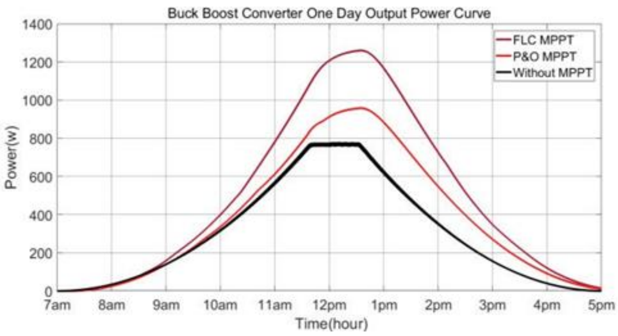

Fig.7. Comparison of P&O MPPT, FLC MPPT and without MPPT output power in Buck Boost Converter for one day energy cycle.

V. CONCLUSIONS

This paper investigates the FLC based MPPT techniques is found suitable in different operating conditions as compared to P&O MPPT technique and it is modern and fast converging method for MPPT control as compare to P&O method with DC-DC converter Buck-Boost with variable irradiation and temperature conditions. Developing fuzzy techniques give better output power and voltage as compare to P&O technique. Analyzed the all results of different operating conditions the efficiency of FLC is to be found better as compared to P&O method with Converters. The fuzzy logic based MPPT responded good power and voltage with all conditions and with buck-boost converter.

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