Maximum Power Point Tracking of Solar Photovoltaic System Using Fuzzy Logic Controller

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Abstract- Solar photovoltaic (PV) utilization is a significant renewable energy source. The energy converted directly from sunlight through PV system is not steady due to different solar intensity. This paper proposes a method of Maximum Power Point Tracking (MPPT) of a PV System through Incremental Conductance method using Soft Computing technique i.e. with the help of Fuzzy Logic Controller (FLC). FLC basedMPPT is capable in tracking the maximum power from PV panel. Here, the incremental conductance technique with Fuzzy Logic controller with its various membership function (MF) is applied to optimize the MPPT. The simulation result of the proposed method establishes the maximum powerwhich is tracked from PV panel. It also increases the output voltage with the help of boost converter.

Keywords- Boost Converter;Fuzzy Logic Controller, Incremental Conductance, Photovoltaic system.

I. INTRODUCTION

In modern world the renewable energy resources is going to be the utmost used energy resources because of the boost and soaring cost of fossil fuels. Amongst, solar energy is one of the most mandatory green energy resources due to its environmental sustainability and inexhaustibility. Since the I-V characteristic of PV cells varies non linearly with the irradiation and temperature, it is very much essential to operate the PV system to a specific point to extract its maximum energy. This is known as MPPT method. So far as various methods are studied previously for tracking the MPPT from a PV system, including Incremental conductance[1], perturb and observe(P&O), fractional open circuit voltage, line approximation, ripple correction control and FLC approaches. Incremental conductance method is enormously used due to its higher steady state accuracy and environmental adaptability.

In this paper, incremental conductance method is applied to track the maximum power of a PV system with the help of FLC approach [2]. FLC based MPPT technique has advantages due its parameter can be determined without precise and complicated mathematical model and it is also capable of operating under highly non-linear system. By applying the boost converter the output voltage increases and it can be used as per our future requirements.it also provides superior tracking performance with less distortion.This paper presents the application of FLC to the MPPT control to enhance the performance of the incremental conductance algorithm. The simulation study in this paper is carried out in MATLAB/Simulink environment.

II. CONFIGURATION OF THE SYSTEM

The whole system with its components is shown in figure 1 having PV panel though which the voltage and current is measured and given to MPPT block to generate pulse, by Pulse Width Modulation (PWM) generator for working of DC-DC converter having load.

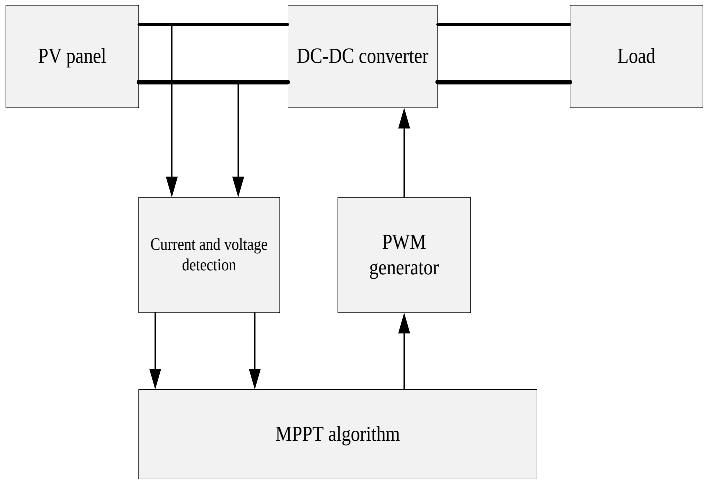

Fig.1: Configuration of whole system

III. PHOTOVOLTAIC SYSTEM

Solar cell converts sunlight directly to dc power also generates electricity from the sun. PV panel works under the phenomenon of photoelectric effect [3]. When solar cells are exposed to sunlight, it converts solar energy into electrical energy.The photovoltaic cell is a five parameter model using a current source I_L(light generated current), diode, series resistance $R_S$and shunt resistance $R_{Sh}$to represent the irradiance and temperature dependent I-V characteristics of the modules which is shown in figure 2 and figure 3 respectively.

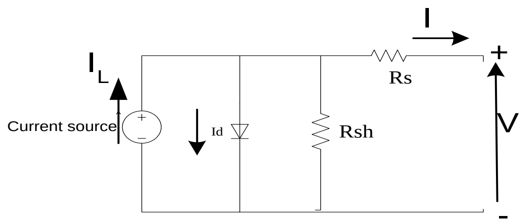

Fig.2: Circuit diagram of single cell in PV array

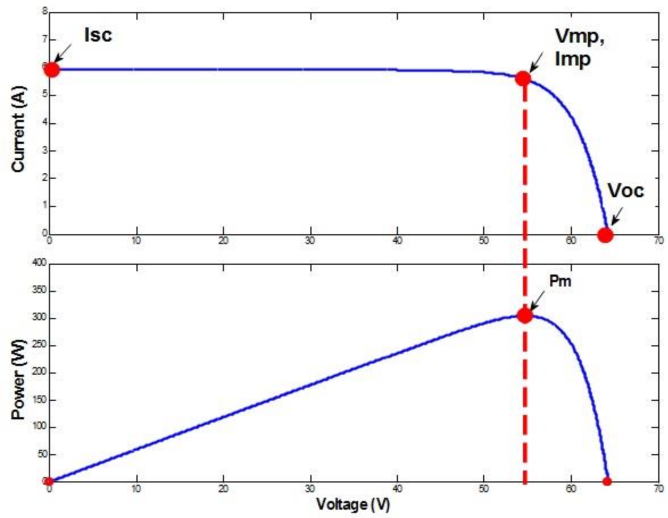

Fig.3: Graph between Current and Power with respect to Voltage

From figure 2 the diode current (I_d) and terminal voltage (V_T) will be found as:-

$$I_d = I_o[\exp(\frac{V_d}{V_T} - 1)] \quad (1)$$

$$V_T = \frac{kT}{q} * nI * N_{cell} \quad (2)$$

Where,
I_d = diode current (A)
k = Boltzmann constant = 1.3806e-23 J/K
V_d= diode voltage (V)
q = electron charge = 1.6022e-19 C
I_o = diode saturation current (A)
T = cell temperature
nI = diode ideality factor, a number close to zero
N_{cell} = number of cells connected in series in a Module.

IV. DC-DC BOOST CONVERTER

Choppers are DC-DC converters for generating variable DC voltage source from a fixed voltage source. The DC-DC converter consists of capacitor, inductor, switches and diode as shown in figure 4. All of these devices in ideal condition do not consume power. The switch is typically an IGBT transistor which is a semiconductor device. DC-DC boost converter by using the fair concept, the input-output relationship for continuous conduction mode is given by

$$\frac{V_o}{V_{in}} = \frac{1}{1-D} \quad (3)$$

Where,
D=Duty cycle
V_{in}=Input voltage
V_o=Output voltage

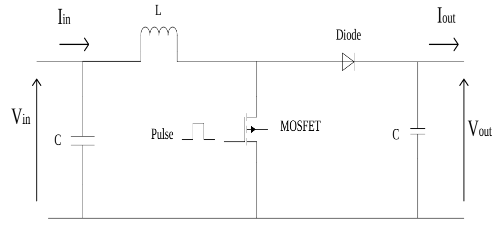

Fig.4: Circuit diagram of DC-DC Boost converter

V. MPPT TECHNIQUES

There are various methods developed and implemented by researchers for maximum power point tracking. In general, MPPT techniques are self- sufficient from prior knowledge of PV module characteristics. The MPPT algorithms that include in this kind are perturb and observe (P&O) [4], incremental conductance (IC), feedback voltage and current, fuzzy logic control and neural network methods. MPPT plays a very important role in photovoltaic (PV) power system because they maximize the power output from a PV system for a given set of conditions and therefore maximize the array efficiency. Thus, an MPPT can minimize the overall system cost. As said there are many methods available but the most widely used technique is the incremental conductance method described in the following section.

A. The incremental conductance algorithm:

Incremental conductance method is based on variation in power. Current and output voltage of PV panel is used to calculate the conductance and incremental conductance. The ratio of the derivative of power and derivative of the voltage is shown in [5, 6]

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = I\frac{dV}{dV} + V\frac{dI}{dV} = I + V\frac{dI}{dV} \quad (4)$$

The maximum power point (MPP) will be found when:

$$\frac{dP}{dV} = 0 \Rightarrow I + V\frac{dI}{dV} = 0 \Rightarrow -\frac{I}{V} = \frac{dI}{dV} \quad (5)$$

Where: I/V is instant conductance and dI/dV is the incremental conductance (instantaneous change of conductance). The comparison of these two amounts indicates which side of the MPP point currently operates the PV panel.
From the analysis of the derivatives shown in the following relationship can be determined whether the PV panel operates at the MPP or away from this point, as shown in figure 5.

$$\frac{dI}{dV} = 0 \; for V < V_{mpp} \quad (6)$$

$$\frac{dI}{dV} = 0 \; for V = V_{mpp} \quad (7)$$

$$\frac{dI}{dV} = 0 \; for V > V_{mpp} \quad (8)$$

$$\Delta I = I(k) - I(k-1) \quad (9)$$

$$\Delta V = V(k) - V(k-1) \quad (10)$$

$$\Delta P = P(k) - P(k-1) \quad (11)$$

Incremental conductance method is simple, easy to implement and has a very high efficiency tracking. In the case or ideal condition, it is able to determine whether the current operating point is MPP or not, but the measurements, the operating point could however moves around MPP. The solar industry continues to expand several solutions to simultaneously perform MPPT and control this efficient conversion of DC/DC power, especially by passing architectures more sophisticated, offering tuning per solar module.

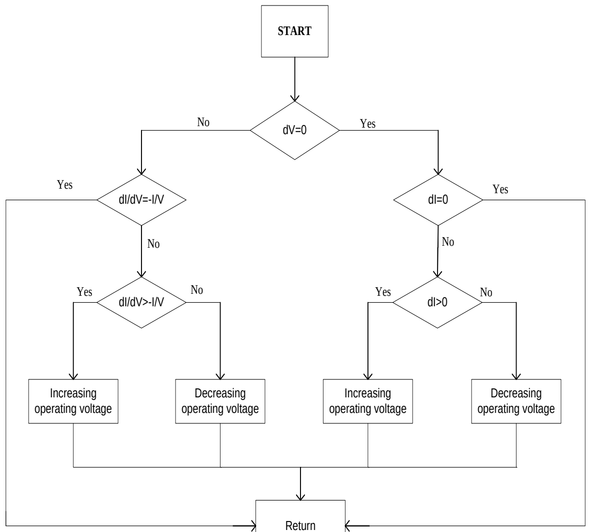

Fig.5: Flowchart of the incremental conductance algorithm

VI. SIMULINK MODEL OF INCREMENTAL CONDUCTANCE ALGORITHM AND FUZZY LOGIC

Using the following relationships (9)-(13) it is determined the variation of measured parameters of PV panel such as voltage and current. Then it is determined variation in the ratio of power derivative to voltage derivative and error variation [5-7]. With the help of above equations with fuzzy concept the Simulink model of Incremental conductance with fuzzy MPPT technique is shown in figure 6.

$$E(k) = \frac{\Delta I}{\Delta V} + \frac{I}{V} = \frac{\Delta P}{\Delta V} = \frac{\Delta P}{\Delta I} \quad (12)$$

$$dE(k) = E(\mathrm{k}) - \mathrm{E}(\mathrm{k}-1) \quad (13)$$

The model which is shown in figure 7 contains the following basic components:

1. Photovoltaic Panel
2. Signal builder block for irradiation and temperature
3. DC-DC boost converter
4. Incremental conductance MPPT algorithm and Fuzzy logic controller
5. Load connected to terminal

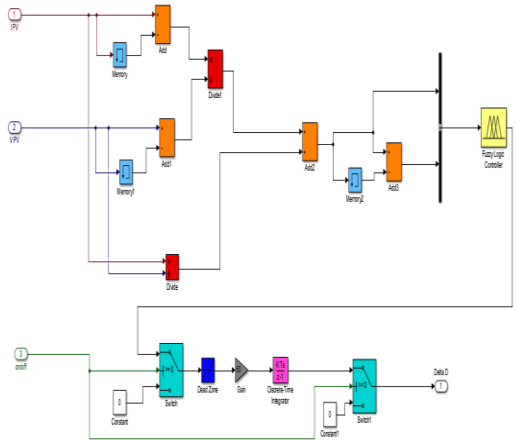

Fig.6: Simulink model of Incremental conductance algorithm with Fuzzy logic controller

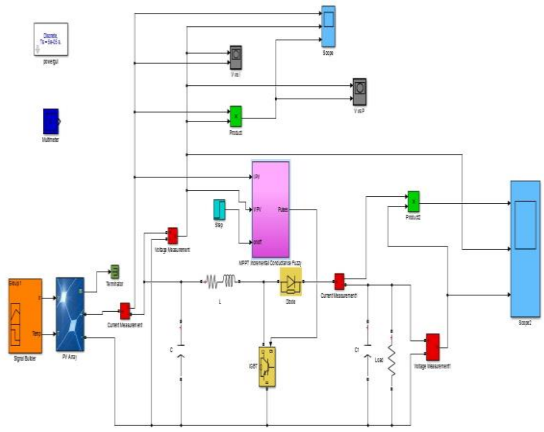

Fig.7: Simulink model of whole system

The Simulink model of Fuzzy controller on that was implemented the Incremental Conductance with its surface view and the rule base is shown in figure 8, figure 9 and figure 10 respectively.

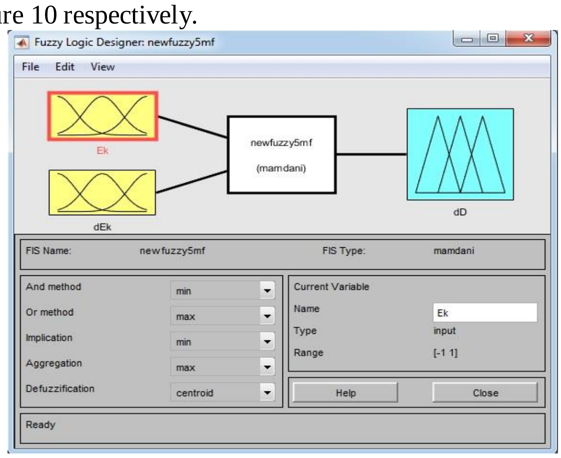

Fig.8: Simulink structure of FLC

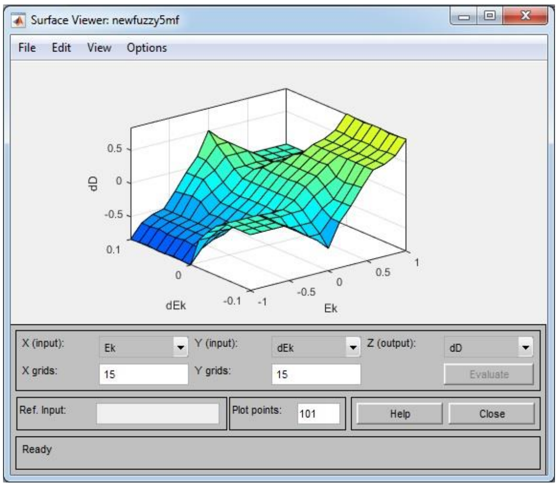

Fig.9: Surface view of fuzzy logic

dD		dE(k)				
		NB	**NS**	**ZE**	**PS**	**PB**
E(k)	**NB**	ZE	ZE	NB	NB	NB
	NS	NS	ZE	NS	NS	NS
	ZE	NS	ZE	ZE	ZE	PS
	PS	PS	PS	PS	ZE	ZE
	PB	PB	PB	PB	ZE	ZE

Fig.10: The rule base to implemented the incremental conductance algorithm

VII. RESULTS OF INCREMENTAL CONDUCTANCE WITH FUZZY LOGIC

The result of simulink model of the whole system (figure 7) having PV panel with variable irradiance and temperature , DC-DC boost converter, resistive load with incremental conductance fuzzy algorithmare given in figure 11.

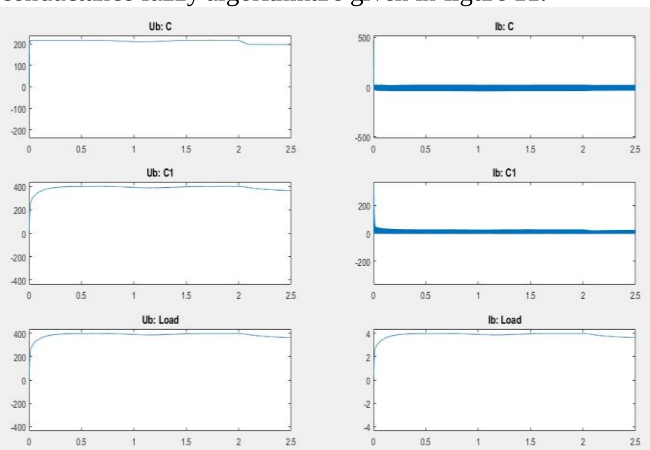

Fig.11: Voltage and current across Capacitor (C and C1) and load

Output power(P_o), input voltage(V_{in}) and output voltage (V_o) is shown in figure 12, shows how the input power, voltage and output current varies with variable irradiance and temperature given to the PV panel with the help of signal builder.

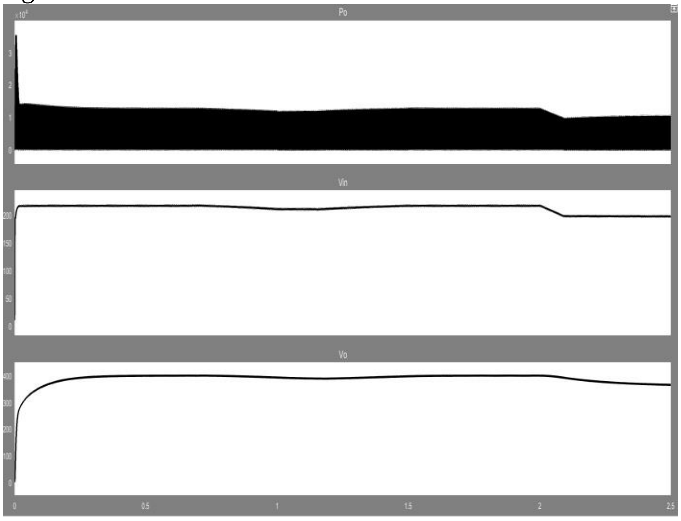

Fig.12: Output power, input voltage and output voltage.

VIII. CONCLUSIONS

This paper is successfully implemented Incremental conductance algorithm based on fuzzy logic controller.

The modeling of the PV panel with DC-DC boost converter is relazised for resistive load. The whole model is simulated for tracking MPPT which is implemented with the help of simulink model. The output voltage is boosted up with the help of DC-DC boost converter. The results reviews that the power and voltage deflects according to the variation with irradiance and temperature. From the system, the maximum voltage is achieved at 1000W/m^2 irradiance and 25 degrees celcius.

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