Simulation of Fuzzy Logic Control Based MPPT Technique for Photovoltaic System

Saravana selvan.D, Mohammed feros khan.J, Umayal.V, and Indumathi.M

Abstract—Maximum power point techniques (MPPT) are employed in photovoltaic systems to make full utilization of PV array output power. The output power of PV arrays is always changing with weather conditions i.e, solar irradiation and atmospheric temperature. In this paper, a fuzzy Logic control (FLC) based MPPT technique is proposed to improve the efficiency of a standalone solar energy system. Using a fuzzy logic controller is an intelligent way of tracking the maximum power point (MPP). The performance of the proposed method has been simulated in Matlab/Simulink at different solar irradiation and temperature.

Keywords— PV Array, MPPT, 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.

The author [4-5] compares and evaluates the percentage of power extraction with MPPT and without MPPT. It clearly shows that when we use MPPT with the PV system, the power extraction efficiency is increase to 97%. Different kinds of MPPTs have been introduced and developed. Fuzzy logic is one of the suitable methods to find the maximum power point (MPP) of a solar panel which has good stability and high response rate. Nowadays, fuzzy based MPPT [6-7] research works have been published more since it has better performance, accuracy and stable. The author [8-9] proposes a fuzzy-based MPPT to enhance the efficiency and robustness of the solar photovoltaic (PV) power generation and establishes a dynamic model of grid-connected PV system by Matlab/Simulink environment. Simulation results show that the system with fuzzy-based MPPT increases the efficiency of energy production. Reference [10] a new fuzzy-based algorithm was proposed to track maximum power point of the solar panel, and it was compared with the incremental conductance and perturbation and observation methods from speed tracking point of view. The results showed that the proposed fuzzy controller tracks the MPP within 0.57 s, while it was 1.92 s and 4.36 s for both mentioned algorithms, respectively. In this paper reviews the basic characteristics of the PV cell and the simulation model of the circuit with the help of Matlab/Simulink software. In addition, a highly robust fuzzy logic based controller is designed along with the DC-DC buck boost converter in Matlab/Simulink software, to increase the efficiency of the solar PV system. The output of the fuzzy logic controller is the change in the duty cycle of the DC-DC buck boost converter.

II. Modeling of PV System

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

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the current flow, whereas the shunt resistance R_{sh} corresponds to the leakage current to the ground and it is normally ignored.

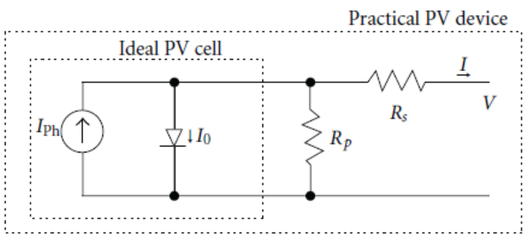

Fig.1 Equivalent circuit of PV cell

The output current is a function of solar radiation, temperature, wind speed and coefficients that are particular to the cell technology. The authors [11-12] present a detailed analysis of solar cell and its electrical equivalent model is created in Matlab /Simulink. The simulink model of the solar cell is shown in the figure 2. The net current of the PV cell is the difference between the photocurrent I_{ph} and the normal diode current I_D.

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

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

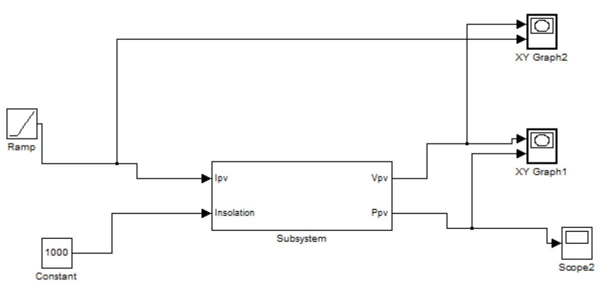

Fig. 2 Simulink Model of Solar PV Cell

PV modules have unique current v/s voltage (I-V) characteristics. From the P-V and I-V characteristics, as shown in figure 3, 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.

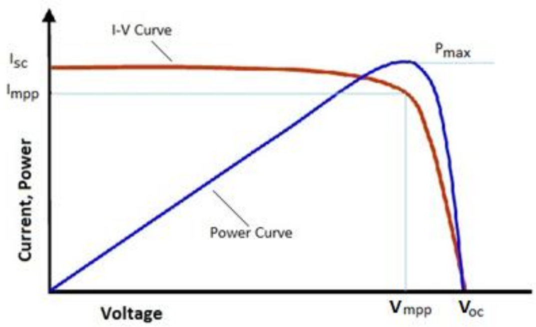

Fig.3 PV-IV curves of Solar Cell

For any PV system, the output power can be increased by tracking the MPP (Maximum Power Point) of the PV module by using a controller connected to a dc- dc converter (usually boost converter). However, the MPP changes with insolation level and temperature due to the nonlinear characteristic of PV modules. Each type of PV module has its own specific characteristic. In general, there is a single point on the V-I or V-P curve, called the Maximum Power Point (MPP), at which the entire PV system operates with maximum efficiency and produces its maximum output power. This point can be located with the help of MPPT (Maximum Power Point Trackers). PV system with MPPT controller has been shown in figure 4.

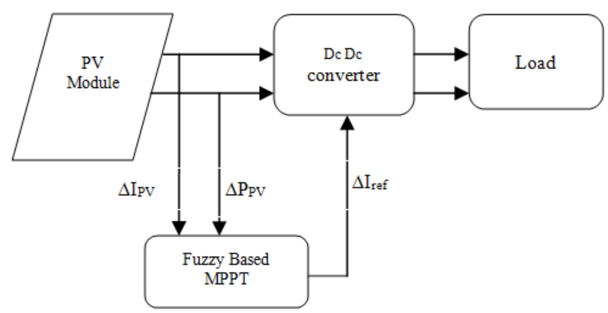

Fig .4 Block diagram

III. FUZZY LOGIC CONTROLLER

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 as shown in figure 5.

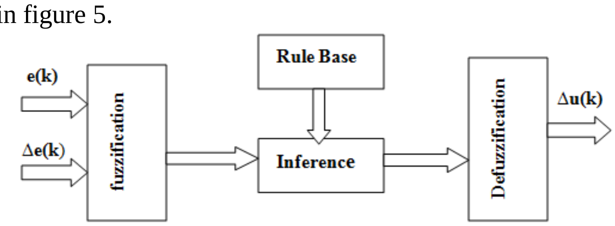

Fig. 5 Fuzzy logic block diagram

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. 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 are formed as shown in table 1.

TABLE.I
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 6, 7 & 8 respectively.

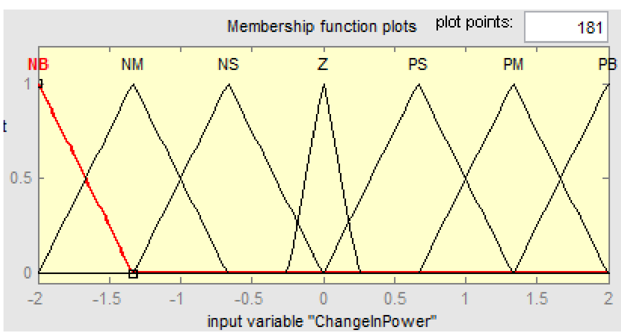

Fig. 6 Membership functions of "change in Power" input

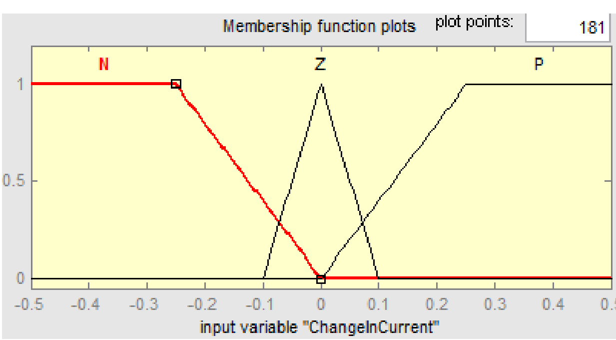

Fig. 7 Membership functions of "change in current" input

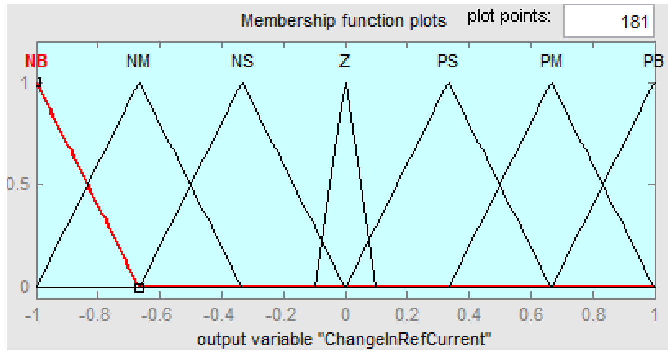

Fig. 8 Membership functions of "change in Reference current" output

IV. PROPOSED MODEL

The proposed Fuzzy Logic Control based MPPT has been modeled as shown in the figure 9. The specification of the PV module used in this simulation is tabulated in table 2.

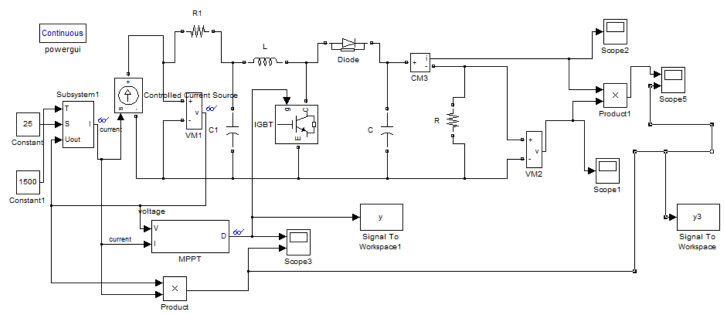

Fig.9 Proposed fuzzy logic control based MPPT

TABLE.II
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

V. SIMULATION RESULTS

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

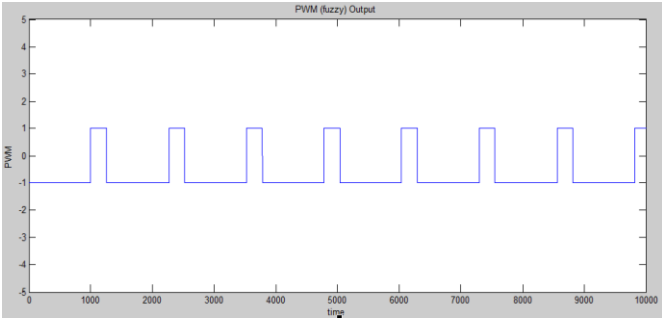

Fig. 10 Proposed fuzzy logic control PWM output

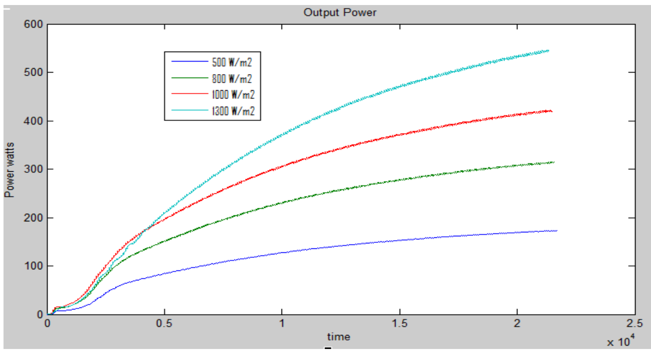

Fig.11 Output Power at different irradiations

VI. Conclusion

In this paper, a simulink model of fuzzy logic control based maximum power point tracker (MPPT) has been done. The entire PV system was simulated based on the fuzzy logic MPPT algorithm and the simulation results were verified. It is clear that the PV system becomes more efficient when a MPPT controller with fuzzy logic is included in the system. By selecting the number of membership functions, it has been proved that MPPT will follow the exact MPP point and thereby the overall efficiency of the photo voltaic system can be improved. In the future, the designed model can be implemented in hardware using PIC microcontrollers.

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