Genetic Algorithm Enhanced Fuzzy Logic Based Controller of MPPT of PV Cells under Partially Shaded Condition

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Abstract- **In this paper evaluated a Fuzzy based Inference System for better tracking of power point under partially shadowed conditions. The Fuzzy System's knowledge base is constructed with the information extracted by using GA functions for maximum power point tracking. The total insolation over the PV panels at any given instant is given as input to the fuzzy system. The system using its membership functions and a rule base calculates the value of reference current to be given to DC-DC converter. A Madani Fuzzy solver is used in the proposed approach and a Centroid function is used for defuzzification.**

Key words-**Photovoltaic Cells, PV-IV Curves, Modeling, Simulation,Matlab/Simulink**

I. Introduction

The ever-increasing demand for low-cost energy and growing concern about environmental issues has generated enormous interest in the utilization of non conventional energy sources such as the solar energy. The freely and abundantly available solar energy can be easily converted into electrical energy using photovoltaic (PV) cells. A PV source has the advantage of low maintenance cost, absence of moving/rotating parts, and pollution-free energy conversion process. However, PV systems suffer from a major drawback which is the nonlinearity between the output voltage and current particularly under partially shaded conditions.

During partially shaded conditions, the system P–V characteristic curve has multiple peaks. Therefore, a conventional maximum power point (MPP) tracker (MPPT) such as Hill Climbing, Incremental Conductance, and Ripple Correlation could miss the global maximum point. In general, a PV source is operated in conjunction with a DC–DC power converter, whose duty cycle is modulated in order to track the instantaneous MPP of the PV source. Several tracking schemes have been proposed. Among the popular tracking schemes are the perturb and observe (P&O) or hill climbing, incremental conductance, short circuit current, open-circuit voltage, and ripple correlation approach.

An MPPT scheme for a PV system under partial shadowing conditions is proposed based on this observation. In a simulation of a partially shaded PV system rejects the observation in an MPPT based on conventional P&O and a partial shadowing identifier has been proposed. Also, it is observed that the global maximum point of a PV system under non uniform conditions is always located to the left of maximum power at normal weather conditions. Therefore, a trajectory line of the PV system under different isolation levels is stored in a data-based memory to identify the partially shaded conditions.

II. Review of the Two-Diode Model

In this model, an extra diode is attached in parallel to the circuit of single-diode model. This diode is included to provide a more accurate I-V characteristic curve that considers for the difference in the flow of circuit at low current values due to charge combination in the semiconductor's depletion. The mathematical form of the model is shown in Figure-1. The terminal current I of the cell can be divided into four components, as shown in Equation. (1): the photo generated current (IPH), the current through the shunt resistance (IP), the diffusion-diode current (ID1), and the recombination-diode current (ID2).

$I_L = -I_{ph} + I_{D1} + I_{D2} + I_{sh}$ - (1)

Where, I_{ph} is the cell-generated photocurrent,

$I_{D1} = I_{SD1}[\exp (q (V_L - I_L Rs)/n_1 K_t)] - 1$-- (2)

$I_{D2} = I_{SD2}$ [exp_ $(q (V_L - I_L Rs)/n_2 k_T)] - 1$-(-3) and

$I_{sh} = V_L - I_L Rs/R_{sh}$ --- (4)

$$(V) = I_{PH} - I_P - I_{D1} - I_{D2} = I_{PH} - V + I\,R_{S/RP} - I_{01}\left[\exp^{V+I R_S/n_1 V_t} - 1\right]$$
$$- I_{02}\left[\exp^{V+I R_S/n_1 V_t} - 1\right] \quad \text{-------} \quad (5)$$

The seven unknown parameters in the model are: the photo generated current I_{PH}; the series resistance R_S; the shunt (or parallel) resistance R_P; the reverse saturation current I_{01} and the ideality factor n_1 of the diffusion diode; and the reverse saturation current I_{02} and the ideality factor n_2 of the recombination diode. n_1 is assumed to be equal to one by many authors, in accordance with the diffusion theory of p-n junctions [9], whereas n_2 is sometimes set equal to two, in accordance with the theory of recombination via traps.

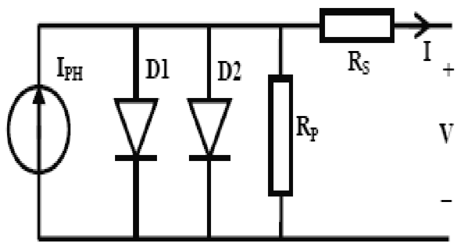

Fig-1: Lumped-circuit, two-diode model of a PV cell.

The thermal voltage $V_T = k_B T/qe$, where T is the p-n junction temperature (considered to be a known or controlled quantity), k_B is Boltzmann's constant, and qe is the elementary charge .The parameters in the two-diode model depend on the irradiance and cell temperature [10]. With reference to Figure-1, the current–voltage relation of a two diode model for a silicon solar cell may be expressed as, In the above equations, R_s and R_{sh} are the series and shunt resistances respectively, I_{SD1} and I_{SD2} are the diffuse and saturation currents respectively, n_1 and n_2 are the diffusion and recombination diode ideality factors, k is Boltzmann's constant, q is the electronic charge and T is the temperature in Kelvin [12]. From the above equations, it is seen that the solar cell parameter extraction problem reduces to the determination of the seven parameters (R_s, R_{sh}, I_{ph}, I_{SD1}, I_{SD2}, n_1 and n_2) from the I–V characteristics.

III. Proposed Fuzzy Based System

A fuzzy based system is designed in the proposed work for tracking the maximum power point under non uniform shading and partial shadowed conditions. To achieve this objective Simulink and fuzzy logic toll boxes available in the Matlab environment are put to good use. To simulate the effect of partial shadow and nonuniform insolation 6 PV modules are considered.

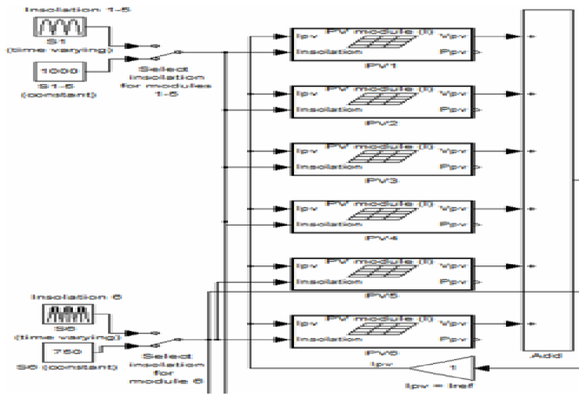

Fig-2: Fuzzy base system

From the above figure it can be observed that modules 1-5 are subjected to one amount of insolation and module 6 is subjected to a different level of isolation as may be required to emulate different environmental condition. As can be observed the model can also be subjected to randomly varying insolation as a time varying signal. The random variation can be subjected to a single module or all the six modules. These types of arrangement help us to simulate rapidly varying insolation conditions to study the effectiveness of the proposed setup in tracking the maximum power points under such conditions.

IV. Fuzzy MPPT Simulation Diagram

In this paper the efficacy of the proposed system is compared with the performance of a standard MPPT controller designed on the basis of P&O method. The job of controllers both fuzzy and P&O is to supply the necessary reference current value so that the system shall be operated at its maximum power point in spite of the changes in the insolation values. The idea is to supply the optimum value of reference current so that the PV panels operate at their maximum efficiency. A fuzzy logic controller with rule viewer is used in the proposed system.

The fuzzy controller tracks the operating reference current value compared to the standard P & O method enabling better stability of the system. This feature enables the proposed system to track maximum power points under partially shading and rapidly varying insolation conditions. To validate the above we have used PV array comprising of 6 PV cells connected in series. For validation 4 panels are considered to have uniform insolation and remaining 2 panels having different insolation.

The PV characteristics clearly exhibit the occurrence of multiple peaks for partial shadow conditions. A GA function is used to extract maximum power points for different temperature and irradiance values. This data is used to create the knowledge base for the proposed fuzzy controller. The fuzzy controller feeds on the insolation as input and gives the reference current value for operating the DC to DC converter.

The Madani fuzzy solver is used for Fuzzification, triangular membership functions are used for creating the knowledge base and a centroid function is used for defuzzification. The fuzzy controller tracks the operating reference current value compared to the standard P&O method enabling better stability of the system. This feature enables the proposed system to track maximum power points under partially shading and rapidly varying insolation conditions.

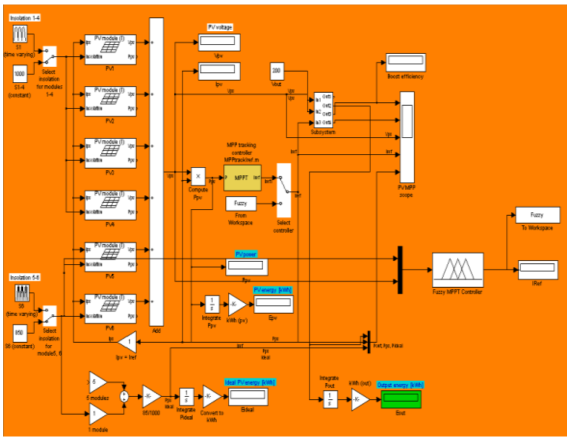

Fig-3: Fuzzy MPPT Simulink Diagram

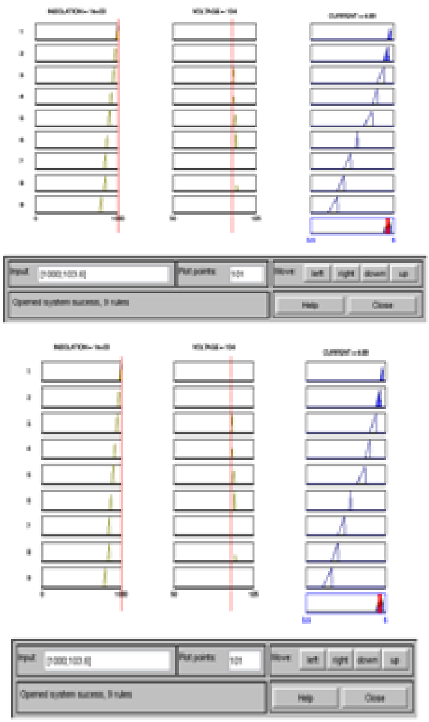

Fig-4: Rule base view diagrams

V. Simulation Results of MPPT under partial shadow conditions at different Isolation

The following shows the results of maximum power point tracking under the fuzzy approach .The system is tested for different grouping of insolation values like 4 modules are subjected to an irradiance of 1000 W/m^2 and the remaining 2 modules subjected to 900W/m.$^{2.}$ Two panels which are subjected to variable insolation are tested for different insolation values like 850 W/m^2. The results clearly point to the fact the reference value of the current being DC To AC converter varies as the insolation varies and the system is able to operate at its maximum power point.

It can be deduced that the fuzzy controller is faster than the P&O controller in the transition state and presents also a much smoother signal with less fluctuations in steady state. The controllers by fuzzy logic can provide an order more effective than the traditional controllers for the nonlinear systems, because there is more flexibility. A fast and steady fuzzy logic MPPT controller was obtained. It makes it possible indeed to find the point of maximum power in a shorter time runs compared to the well known P&O controller

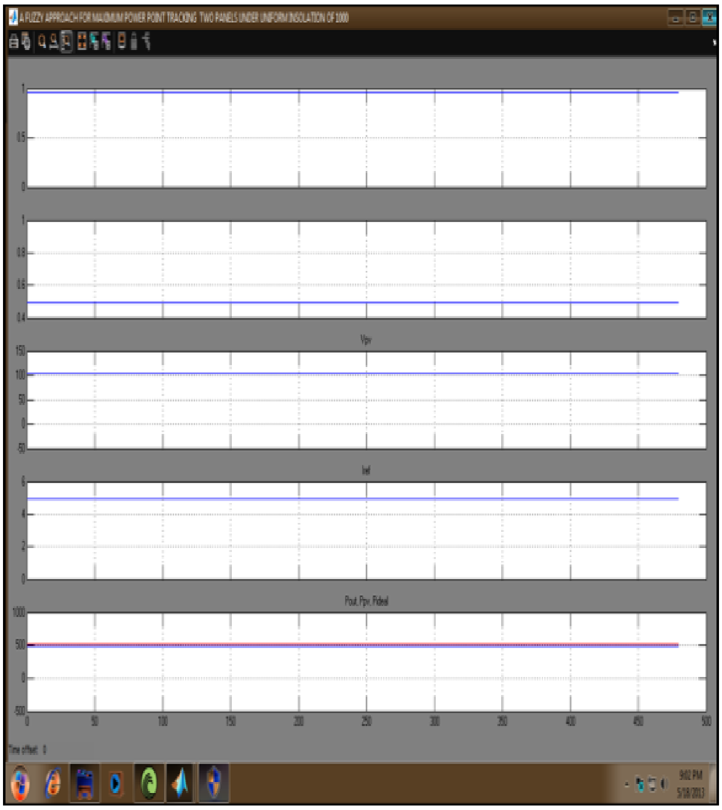

Fig-5: PV Characteristics under constant isolations (6modules 1000 W/m^2)

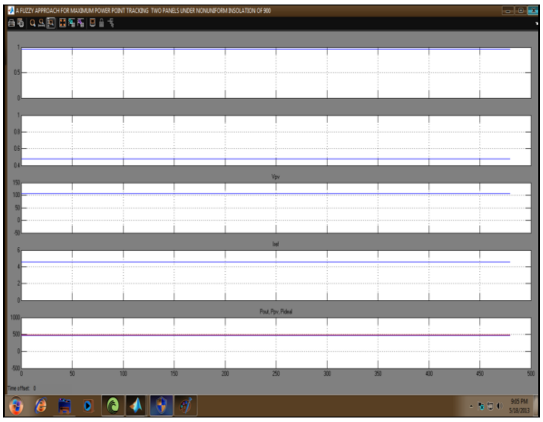

Fig-6: PV Characteristics under different isolations (4 modules 1000 W/m^2, 2 Modules 900W/m^2)

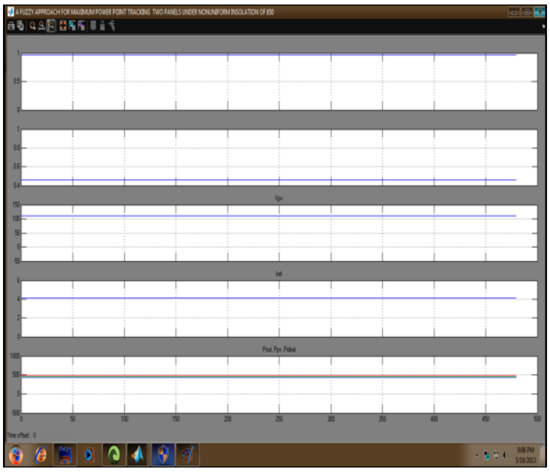

Figure-7: PV Characteristics under different isolations (4 modules 1000 W/m^2, 2 modules 850W/m^2)

VI. Conclusion

This paper explores the ambit of maximum power point tracking using fuzzy logic control .For the above proposed methods a new mathematical model was designed to represent the behavior of the P–V characteristic under partial shadow conditions. Matlab/Simulink simulations representing partially shaded conditions of PV system was carried out to validate the proposed MPPT. The results validate the fact that the proposed MPPT is capable of reaching the global MPP under any partial shading conditions. A GA function is used to extract maximum power points for different temperature and irradiance values. This data is used to create the knowledge base for the proposed fuzzy controller Moreover; the controller exhibits a fast convergence speed, with small oscillation around the MPP during steady state conditions. This feature enables the system to track maximum power points under partially shading and rapidly varying insolation conditions.

APPENDICES

Table-1:Specifications of solarex MSX 60

Characteristics	Specification
Typical peak power (P_p)	60W
Voltage at peak power (V_{PP})	17.1V
Current at peak power (I_{PP})	3.5A
Short-circuit current (I_{sc})	3.8A
Open-circuit voltage (V_{oc})	21.1V
Temperature coefficient of open-circuit voltage	-73mV/^{0}C
Temperature coefficient of Short-circuit current	3mA/^{o}C
Approximate effect of temperature on power	-0.38W/^{0}C
Normal operating temperature of cell	49^{0}C

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