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Numerical Simulation of Fuzzy Logic Based Maximum Power Point Tracking System for Solar Photovoltaic System

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Abstract: The output power of a photovoltaic (PV) module relies upon the solar irradiance and the operating atmospheric temperature; hence, it is important to execute maximum power point tracking regulators (MPPT) to acquire the maximum power for the PV system.The customary conventional technique for MPPT regulators is the perturb and observe (P&O) based calculation. The perturb and observe and incremental conductance method suffers from serious drawbacks of oscillatory response and early convergence on first peak of PV and IV characteristics where ever the case of multiple peak is present. India is working hard to use renewable energy to generate 175 GW (GW) by 2022, with solar energy predominant, with a target of 100GW, followed by wind power. India has 450,000 KW of hydropower, has an installed wind power capacity of 230,000 KW, but has almost no great level for renewable power. Solar energy represents a large proportion of the government's expansion strategy. Photovoltaic energy must be converted from DC to AC to supply the grid or AC load. When using an IGBT inverter, the applied DC voltage on the DC link is converted to a single-phase AC voltage.. In this research, a diode based circuit model of solar photovoltaic system has been developed under MATLAB. . The simulation work is exhibited on matlab exhibited the prevalence of the fuzzy regulator regarding settling time, power loses and stable output at the maximum power point. The given research utilizes the application of fuzzy logic based maximum power point method for detection and operation of PV module system at maximum power point.

***Keywords**: Fuzzy rationale regulator; maximum power point tracking (MPPT); dc-dc converter; photovoltaic system, Fuzzy Inference System.*

I. INTRODUCTION

Photovoltaic energy conversion in solar cells has two basic advances. Initial one is the assimilation of light which creates an electron-hole pair. The electron and hole are isolated by the structure of the gadget. The electrons go to the negative terminal and the holes go to the positive terminal[11]. The electric potential is produced dependent on the partition of the holes and the electrons.Solar photovoltaic systems are arranged either in series connected arrangement or the parallel arrangement and its goal is correspondingly to set the ideal terminal voltage and current. On account of arrangement string setup, a higher voltage level can be accomplished however the current evaluations are restricted by the individual rating of photovoltaic cell.[12]

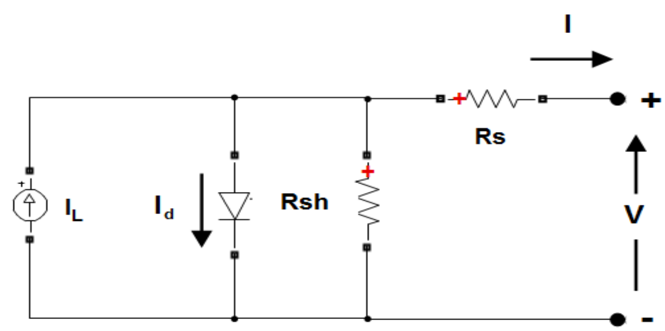

Fig. 1.1: Diode Modelling of Solar Cell

Figure 1.1indicates about the diode modelling of solar cell. The diode model of solar cell is used to ascertain the I-V and P-V attributes of solar cell. The administering conditions for the diode model is given by keeping in consideration of the impact of Rs and Rp, the mathematical condition is examined as follows:

$$I = I_{sc} - I_{01}\left[e^{q\left(\frac{V+I.R_S}{kT}\right)} - 1\right] - I_{02}\left[e^{q\left(\frac{V+I.R_S}{kT}\right)} - 1\right] - \left(\frac{V+IR_S}{R_p}\right) \quad (1.1)$$

$$I = I_{sc} - I_0\left[e^{q\left(\frac{V+I.R_s}{nkT}\right)} - 1\right] - \left(\frac{V+IR_s}{R_p}\right) \qquad (1.2)$$

Where: n is known as the "ideality factor" and by and large the estimation of ideality factor relies upon the manufacturing technology involved insolar cell. [12]

II. MAXIMUM POWER POINT TRACKING

Maximum power point system is most essential component of charge controller which is essential to operate the photovoltaic system under maximum operational efficiency by load matching and maximum power transfer from source to load..Thus according to the distinction in the solar radiation condition and load condition, the MPPT control following the perfect working voltage is required.Figure 2.2 discuss the I- V and P-V characteristics of photovoltaic module..[14]

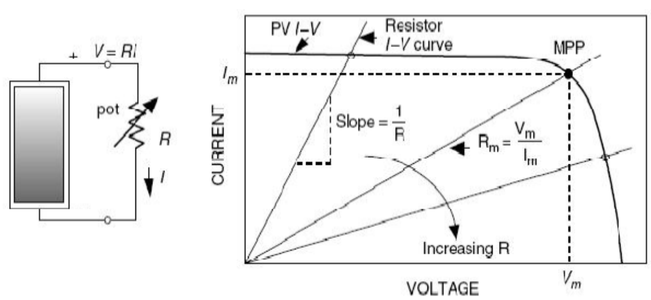

Fig 2.1 PV Model with Resistive Load

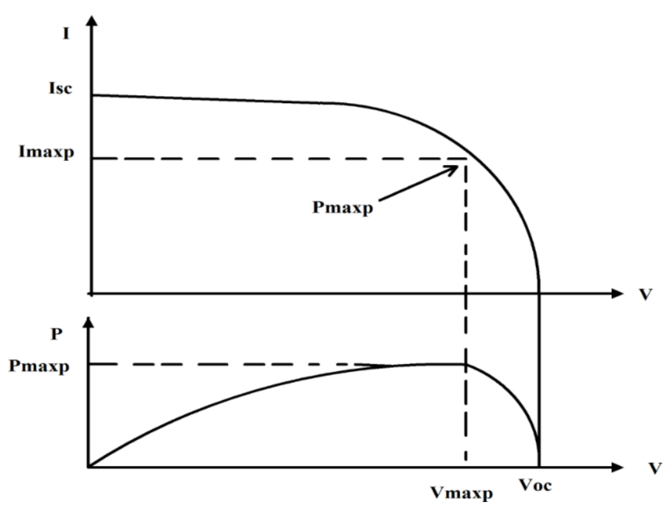

Figure 2.2. Characteristics of a PV Module

Figure 2.2 denotes the variation in P-V and O-V characteristics of the photovoltaic module with respect to irradiation and temperature. It is evident that there is rapid decrease in short circuit current due to change in irradiation and there is rapid change in voltage due to change in temperature, the change of irradiation and change of temperaturecannot be avoided and it is related to dynamic behavior of characteristics of solar photovoltaic system.The point related to maximum power in the characteristic curve is known as maximum power point it is denoted as maximum power point (MPP).[10]

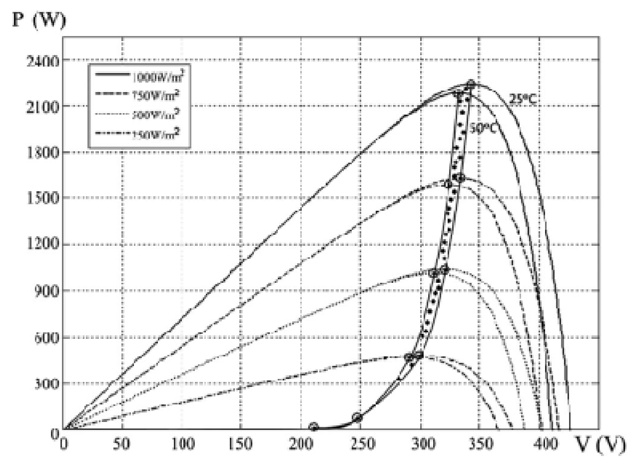

Figure 2.3. Effect of Irradiation and Temperature on Characteristics of a PV Module

V_m and I_m are voltage and current associated with this maximum power point is known as the important value of concern at the MPP. The situation related to dynamicbehavior of solar photovoltaic system relates to the complexity to find the optimum operating point of the photovoltaic system.[08]

Table 1. Specification of ICA 100PV Module

Parameter	Symbol	Value
Maximum Power	P_{max}	100W
Voltage at max power	V_{mp}	17.5V
Current at max power	I_{mp}	5.69A
Open circuit voltage	V_{oc}	22.4V
Short circuit current	I_{sc}	6.03A
No. of series cell	N_s	36
No. of parallel cell	N_p	1

$$I(V) = \frac{I_x}{1-e^{\left(\frac{-1}{b}\right)}}\left[1 - e^{\left(\frac{V}{bV_x}-\frac{1}{b}\right)}\right] \qquad (2.1)$$

$$V_X = S\frac{E_i}{E_{iN}}TC_V(T-T_N) + sV_{max} - s(V_{max} - V_{min})e^{\left(\frac{E_i}{E_{iN}}\ln\left(\frac{V_{max}-V_{OC}}{V_{max}-V_{min}}\right)\right)} \quad (2.2)$$

$$I_X = P\frac{E_i}{E_{iN}}[I_{SC} + TC_i(T-T_N)] \quad (2.3)$$

An interconnected dc-dc converter having PV cluster as source and an induction motor connected as the end as load is demonstrated in Figure 2.4.

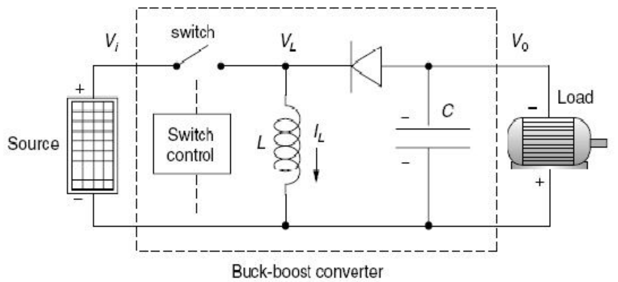

Fig 2.4 Buck- Boost converter used as a maximum Power Tracker

Since the yield voltage is higher than the info voltage, it is known as a lift converter. It is actualized by utilizing a diode and a MOSFET. In the lift converter the normal yield current is less than the normal inductor current. what's more, an a lot higher rms current would course through the channel capacitor because of this reason an enormous estimation of the inductor and channel capacitor is required than those of buck converter. [16]

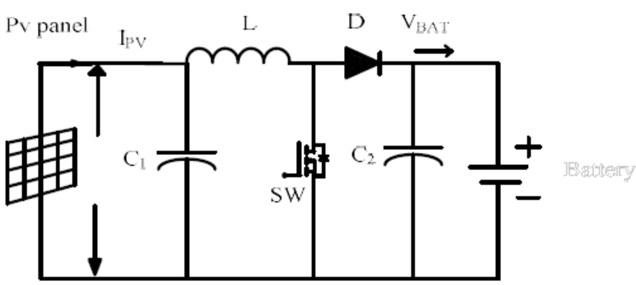

Fig. 2.5 Boost dc-dc Converter topology used as photovoltaic power interface

Here is a series connection between the output of the DC-DC converter and the photovoltaic panel to obtain high efficiency. Each panel is connected in series to a DC-DC converter. Switch The frequency of the converter (F_{sw}) is 50 kHz, and the output current ripple (Δi_l) and voltage ripple (Δv) they are considered 10% and 5% respectively.When the semiconductor is directing, the diode is in open circuit (Ton). Utilizing Equation (2,5), the value of the inductor is generated and calculated as discussed in following Equation. [15]

$$V_L = \frac{L\Delta L_L}{\Delta t} \quad (2.4)$$

Assuming V_d,$R_{Ly}V_{DS}$ are very small values;

$$\Delta I_l(+) = \frac{(V_s - V_o)}{L}T_{on} \quad (2.5)$$

$$\Delta I_L(-) = \frac{V_o}{L}T_{off} \quad (2.6)$$

In this research work, a charge controller with a boost configuration and a duty cycle controlled by a soft-computing-based controller is based on an improved fuzzy logic. The fuzzy controller is programmed to be able to operate in variable radiation Underilluminance and complex operating conditions, effectively and use the IV characteristics of the photovoltaic system to track the maximum power point. Stability has been simulated. The charge controller is connected to the output of the PV module, and the output of the charge controller is connected to the battery in storage applications and to the inverter in high-power applications. Therefore, according to aspects of this research, a high-efficiency power converter equipped with a soft computing-based MPPT controller system is used to improve the operating efficiency of the solar photovoltaic system. Through the implementation of an efficient charge controller based on the intelligent MPPT control system, the operating efficiency of the solar photovoltaic system is improved.

III. PROPOSED METHODOLOGY

There are many ways to track the maximum power point. Perturbation and Observation algorithm(P&O) is a basic computational technique for calculation of MPPT. The implementation of this algorithm is easy and less complex, so it is easy to apply. The output of this process algorithm is not very precise in case of rapidly changing climating conditions and multiple peak in characteristics of power vs voltage. However, this technology ensures that rapid modification of radiation levels (which can cause changes in MPPT) are not taken into account, and it is expressed as changes in MPP due to interference and incorrect MPP calculations. To avoid this difficulty, we can use the incremental conduction method.In the incremental conductance method, two current sensors and two voltage sensors are used to sense the output current and voltage of the PV array.

$$\left(\frac{dP}{dV}\right) MPP = \frac{d(VI)}{dV} \quad (3.1)$$

$$0 = I + \frac{VdI}{dV} MPP \qquad (3.2)$$

$$\frac{dI}{dVMPP} = -\frac{I}{V} \qquad (3.3)$$

Now, it is evident that the system can identify current and voltage at the maximum power point by calculating conductance with respect to power variation of the system. But the uncertainty caused by the change in irradiance was eliminated. Fuzzy Logic has been utilized for tracking the Maximum Power Point (MPP) of PV module since it has the upsides of being accurate, aggressive in tracking power point, moderately easy to plan and doesn't require the information on PV precise model. Fuzzy rationale control by and large comprises of three fundamental components: fuzzification module, fuzzy induction system, and defuzzification module. [14]The fuzzy logic system with improved rule base and membership function parameters can perform power tracking immediately, avoiding the problems of early convergence and stable response of power point tracking under given temperature and irradiation conditions. The purpose is to take care of the optimal duty cycle of the proposed system under given irradiance and temperature conditions. Figure 4.4 shows the curve of tracking power versus simulation time. It can be seen from the figure that the application of this method improves the tracking power and stability of the system.

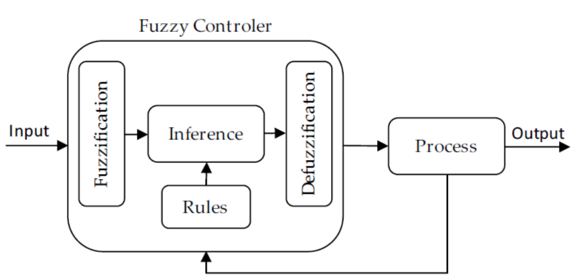

Fig-3.1- Building Blocks of Fuzzy Based System

During fuzzification, numerical information factors are changed over into semantic variable dependent on a weight and value. For MPPT, the genuine voltage and current of PV module estimated consistently is determined for obtaining the power as P=V_{xI}:[14]

$$E(k) \frac{P(k)-P(k-1)}{V(k)-V(k-1)} \quad (3.4)$$

$$CE(k) = E(k) - E(k-1) \quad (3.5)$$

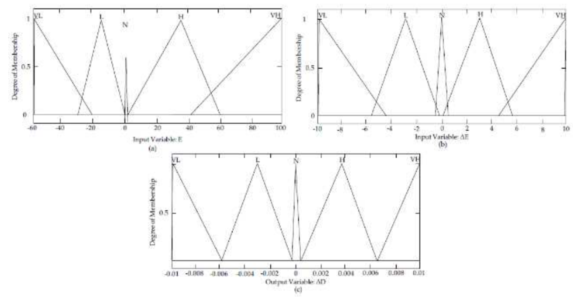

Fig-3.2- Membership Function for Designing Fuzzy Inference System

Fuzzy control is a strategy that permits the development of nonlinear regulators from heuristic data that originates from the information on a specialist. The fuzzification plot is answerable for preparing the information and arrangement of rules to permit a sequential portrayal of the factors to be controlled and is in view of the information on the procedure. . [15]Membership function is decided to interrelate the input to output with a trapezoidal or centroid approach. This membership functions assign fuzzy rules and assign values as per the input parameters and scenario.Table2 shows the 25 fuzzy standards applied in the regulator. The lines and sections speak to the two information sources E and ΔE. The output ΔD is a variable related at the crossing point of a line with a maximum power point.

Table 2 Fuzzy Associative Matrix

E/ΔE	Very Low	Low	Neutral	High	Very High
Very Low	VH	VH	H	VL	VL
Low	H	H	H	VL	L
Neutral	H	H	N	L	L
High	H	H	L	L	VL
Very high	H	H	L	L	VL

The centre point (ΔD) is processed by,

$$\Delta D = \frac{\sum_{j-1}^{n} \mu(\Delta D_I)\Delta D_i}{\sum_{j-1}^{n} \mu(\Delta D_j)} \qquad (3.6)$$

$$D(k) = D(k-1) + S_{\Delta D}\Delta D(k) \qquad (3.7)$$

Defuzzification can be performed ordinarily by two calculations; Center of Area (COA) and the Max Rule Method (MCM).

IV. SIMULATION &RESULTS

Figure 4.1 represents the implementation of fuzzy logic based maximum power point racking system for the given scenario..The system is implemented in shading scenario for photovoltaic system in this scenario fixed temperature input with variable irradation has been provided to the system whereas radiation in increasing order has been implemented to various modules connected in series with each other.

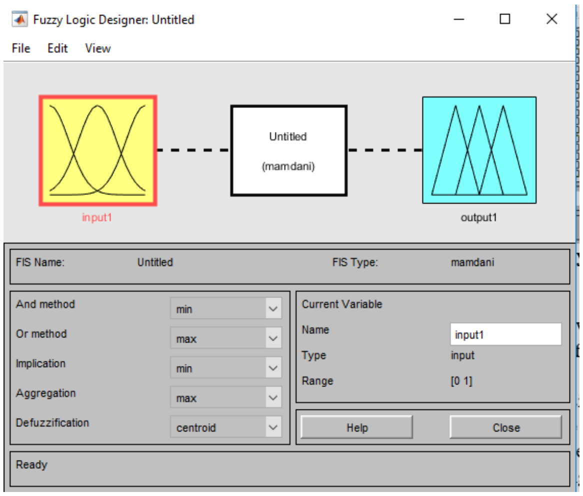

Fig.4.1 Plot of fuzzy inference system

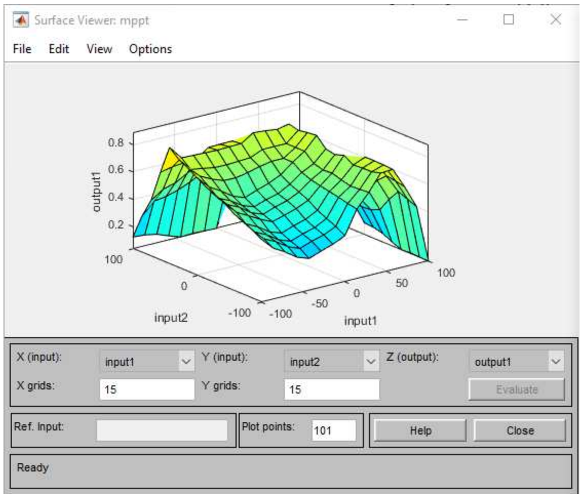

Fig.4.2 Surface Viewer of FIS

The application of fuzzy logic system is utilized here to design and effective and efficient power point tracking system for the tracking of power in variable irradiation situation. The weather irradiation data is varied in the system with the help of signal creation, whereas the power optimization and tracking algorithm is designed with the help of improved mamdani based fuzzy inference system.

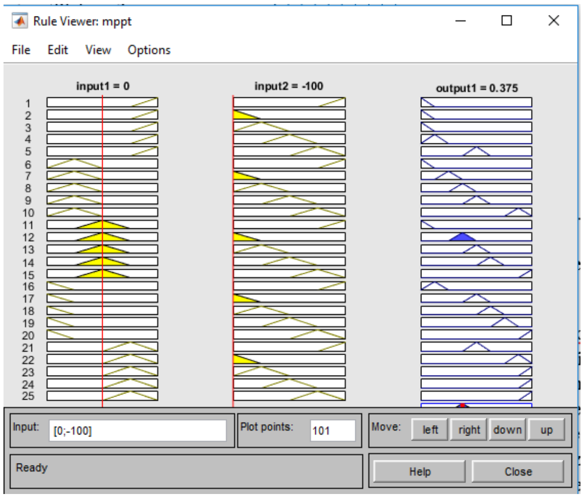

Fig.4.3 Fuzzy Rule Base

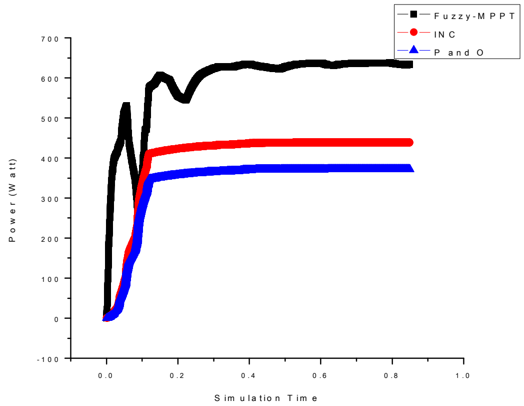

Fig.4.4Plot of tracked power

The fuzzy logic system with improved parameters of rule base and membership function enables the tracking of power instantly and it avoid the problem of early convergence and stable response of the power point tracking as per given condition of temperature and irradiance. The purpose algorithm is to look after the optimum duty cycle of the proposed system under given condition of irradiance and temperature.Figure 4.4 indicates the plot oftracked power with respect to simulation time. Figure indicates that the there is improvement in the tracked power and stability of system with application of proposed method.

Table 3: Comparative Assessment of MPPT Methods in Partial Shading Condition

Method	Maximum Power Tracked	Stabilized Output
P and O Method	355 Watt	0.18 Sec
INC Method	410 Watt	0.18 Sec
Fuzzy Logic Based MPPT (Proposed)	**610 Watt**	**0.30 Sec**

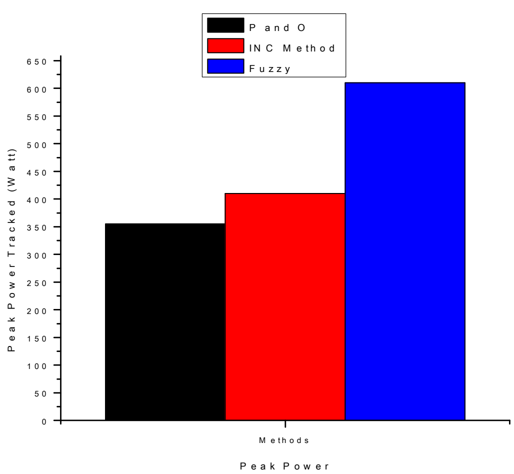

Fig.4.5 Comparative Assessment of Maximum Power Tracked by the Proposed System Under Given Condition

Duty cycle is responsible for tracking maximum power Table 3 and figure 4.5 explains the comparative assessment of peak power tracked by the proposed system as compared to the conventional system designed on the basis of perturb and observe method and incremental conductance method.

VI.CONCLUSION

In this research work a charge controller having boost configuration and duty cycle controlled by soft computing based controller which is based on improved fuzzy logic which is programmed to track maximum power point from I-V characteristics of PV system under variable irradiance and complex operating condition efficiently and with stability has been simulated. The charge controller is connected to the output of PV modules and the output of charge controller is connected to battery under storage applications and to the inverter under high power applications. Thus according to the aspects of present research it is provided with the with the enhancement of operating efficiency of solar photovoltaic system using efficient power converter equipped with soft computing based MPPT controller system. It improves the operating efficiency of solar photovoltaic system by implementation of efficient charge controller based on intelligent maximum power point tracking control system.Charge controller can be interfaced with the battery for storage applications of solar photovoltaic system and with the inverter system for high power applications..

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