Design of a solar MPP tracker with improved fuzzy logic

Durbanjali Das, Saptadip Saha, Priyanath Das

Abstract*: *This article introduces a fresh control technique for monitoring the maximum power point of the standalone photovoltaic system at variable solar cell temperature and insolation. Here, the method uses a fuzzy logic controller which is used to track maximum radiation of solar at all time and both the azimuth and elevation angles of sun. A sampling process is used to measure the PV array power and voltage that decides an optimal increment of sample which is required to get the optimal operating voltage that permits maximum power tracking. This method provides high accuracy and reliable result around the optimum point. This proposed fuzzy logic based MPP tracker has shown a better performance compare to existing methods with a power conversion efficiency of ~95.7%. Different steps of designed controller and the set of fuzzy logic has been shown along with its simulation.

Index Terms*: *Solar photovoltaic, fuzzy, Mamdani, member function, MPPT.

I. INTRODUCTION

Energy shortage problem is more and more aggravating with the development of industries. To overcome this problem renewable energy sources are used as an electrical power technological option for generating clean green energy. Among them, the year-round photovoltaic (PV) scheme has brought excellent attention as it guarantees that it is one of the most permanent sources of renewable energy. Solar cell has an optimum point corresponding to maximum point. The output power of the PV array varies according to the azimuth and elevation angle of sun. To obtain the maximum power from PV array, a maximum power point controller is required in PV power system. Till date, to implement MPPT a various approach has been reported technologically. One of the easiest techniques of P & O is to calculate dp / dv in order to determine the maximum energy point (MPP).

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Although easy to implement, it can't monitor the MPP with the fast change in irradiance and instead of tracking it directly around the MPP fluctuates [1]. The IC method monitors the MPP with the rapid change of irradiance but it is increasing the complexity of calculation of dp/dv algorithm [2].

The technique of constant voltage, which utilizes 76% of V_{oc} as the MPP voltage, and the technique of I_{sc} is easy, but they do not correctly monitor MPP. Recently fuzzy logic based MPPT has been proposed for grid connected PV system which can track MPP with the rapid change of irradiance.This study reveals that the fuzzy control algorithm is able to improve the performance of tracking compared to conventional methods. A fuzzy logic controller is suggested in this paper to track the maximum solar power with a three-phase grid networked system boost converter. The inherent advantage of auto tracking maximum power point with the rapid change of irradiance has been utilized in the mooted scheme. This scheme only needs fuzzy control rules to track the maximum power point.

II. PROPOSED PV SYSTEM MODELLING

The block diagram of proposed scheme is shown in fig.1. This system is made up of a PV panel, a converter boost, and the Fuzzy Logic Controller (FLC). The solar radiation is converted into electric power by the PV array. This fed to boost up converter, which boost the electric power and transfer the PV power to the utility grid. The FLC has been used to peak power point of PV modules because of its robust nature, simple to design and also not requires knowing of exact model. Typical FLC-based MPPT controller involves three fundamental parts, i.e. module of fuzzification, inference engine and module of defuzzification. [3] (Fig. 1).

A. Fuzzification module

The fuzzification allows the transition from real data to fuzzy data. It is possible to measure the real voltage (V) and present (I) of the PV generator continually and to calculate the energy (P= V I). The control is determined on the grounds of the fulfillment of two requirements pertaining to the suggested controller's two input factors, namely error E (representing the slope of the trait P-I) and shift of this error (CE), at instant sampling k [4]. The followings are expressed in variable E and CE,

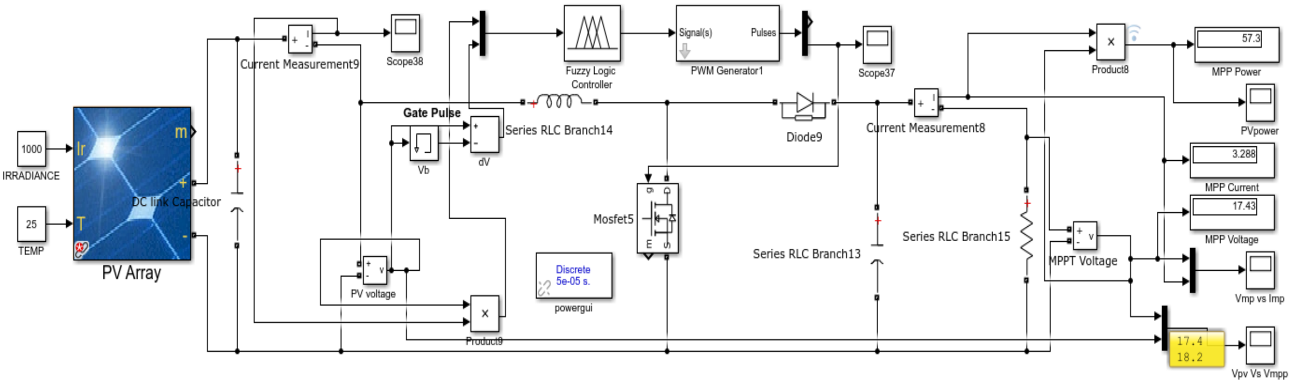

Fig. 1. Simulink Model of the MPPT model with fuzzy logic controller

$$E(K) = \frac{P(k)-P(k-1)}{I(k)-I(k-1)}$$
$$CE(k) = E(k) - E(k-1)$$

Where P(k) and I(k) are the PV generator's power and current, respectively. Input E(k) therefore shows whether the working point at instant k is located on the left or right of the MPP's P-I function, while input CE(k) represents the dispersion direction of this stage. The duty ratio change of the DC-DC converter is used as the suggested output of the controller. The control is therefore performed by altering this duty ratio according to the slope E(k) to return the operating point to the ideal level where the slope is zero. As shown in Fig. 4, The input variables of the fuzzy controller (P, dV) are acquired from the actual signals (e, ce) by multiplying the corresponding rises in scale (S_E, S_{CE}) and then converting to semantic factors such as VH (Very high), H (elevated), M (medium), L (low), VL (very small) using the basic fuzzy subset. Fig.6 demonstrates the affiliation grades for input and output factors of five fundamental fuzzy subsets.

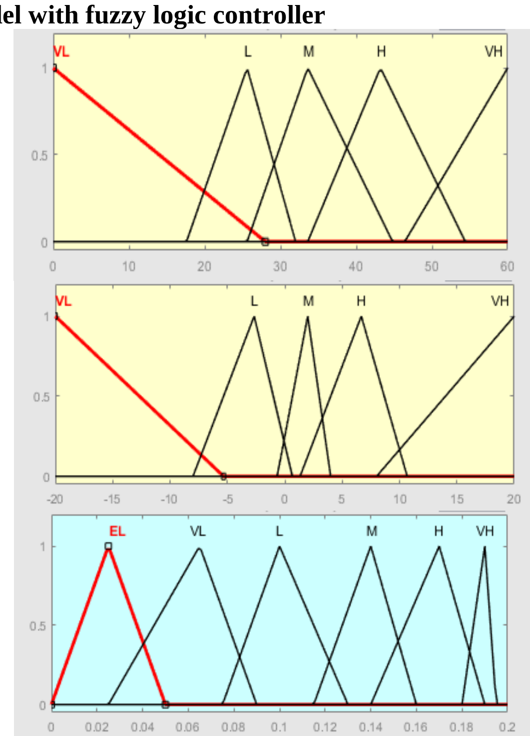

Fig. 2. Membership functions for: (a) P, (b) dV, and (c) D.

B. Interference engine

Inference Engine determines fuzzy output by applying rules to the fuzzy input that generated from fuzzification process [5-6]. Therefore, in order to acquire the respective linguistic value (which is essential to determine fired or active laws), the crisp input value must be flushed after the rules can be assessed and the degree to which each portion of the precedent has been satisfied for each rule. [7]. The rule table of fuzzy controller has shown in table, where all the enter s of the matrix are fuzzy sets of P, dV and change of duty ratio D of the controller.

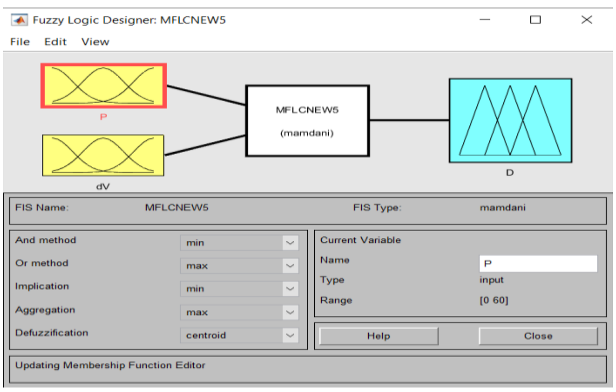

Fig. 3. Fuzzy logic designers based on Mamdani logic.

Table: Fuzzy Set

P	dV				
	VL	L	M	H	VH
VL	EL	EL	EL	EL	EL
L	VL	VL	M	M	L
M	M	H	M	H	M
H	VH	H	M	M	H
VH	VH	VH	VH	VH	VH

The 25 control fuzzy rules that shown in table can be presented in 3-dimensions (3-D) graph as shown in fig. 4. When the DC-DC boost converter reaches the PV generator's MPP, the rules are used to control that converter. The main idea of the rules, as shown in the table, is to operate MPP simply by increasing or decreasing the duty ratio depending on MPP's position. With the increasing distant of MPP from operating point, the duty ratio also increased or decreased eventually. An example of control rule demonstrates in Fig. 5 below

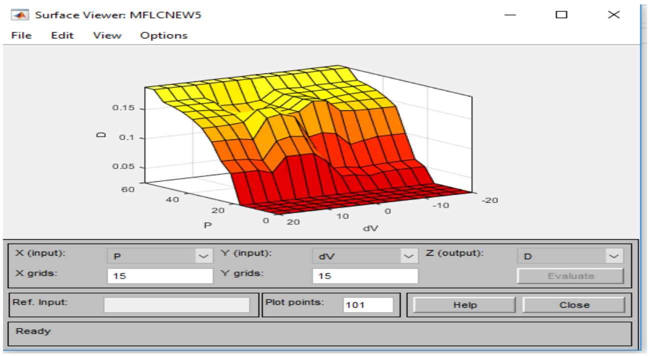

Fig. 4. Surface view for fuzzy i/ps (P,dV) vs o/p(D)

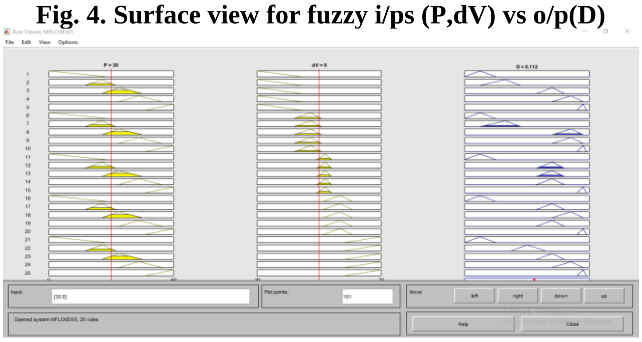

Fig. 5. Rule viewer in MATLAB windows of Fuzzy logic controller.

C. Defuzzification

The inference techniques generate resultant membership function that functions as fuzzy data. [8-9]. As the desired output is non fuzzy value thus, we need to convert the fuzzy value to non-fuzzy value with in a proper process which is called defuzzification. There are many different processes of defuzzification. Centroid method is one of them. This method calculates the center of mass of the aggregated membership function to de-fuzzify the crisp value from the fuzzy controller. This crisp value is the changing signal duty cycle that turns the IGBT on in the circuit.

D. MATLAB model

The PV was constructed and simulated in MATLAB / Simulink to evaluate the efficiency of the suggested FLC [10-11]. Using the Simscape toolbox, PV system simulation is introduced while the boost converter is applied using the Simpower toolbox. Controlled current source is used to link the booster converter to the PV system. Table lists the PV cell requirements used in this research. 72 solar cells are linked in sequence in a simulated model to make the 60 W panel. Each module is permitted to obtain distinct irradiation levels. The voltage signal is saved in a memory to subtract present and past values to enter the block of the fuzzy controller. Fuzzy block logic controller calls to the fuzzy system and transfers the inputs. This s model also passes the fuzzy engine output straight to the converter from the fuzzy system. Connected to a boost converter, a fuzzy controller controls the PV system.

The specification of 60 W solar panel used in simulation is as below:

Short circuit current (I_{sc})	3.6 A
Open circuit Voltage (V_{oc})	22 V
Maximum power point voltage	18.2 V
Maximum power point current	3.3 A
Irradiance (I_{r0})	1000Watt/m^2
Series resistance (R_s)	0.30826 Ohm
Ideality factor (N)	0.601

III. RESULTS AND DISCUSSION

The proposed algorithm which is based on Mamdani logic was implemented in Simulink with a circuitry model. Two input variables: output power (P) and change in output voltage (dV) of the PV module were taken as input to the fuzzy logic controller (FLC). For both the cases 5 different levels were consider to generate the fuzzy set. These 5 levels signify the change in P and dV for different irradiance and temperature values. The corresponding output membership function (D) was generated with the combinations of membership functions of P and dV based on the rules discussed before. The output of the FLC which is a pulsative signal (D) was fed to a PWM generator to make PWM signal (Fig. 6) to control the IGBT of the converter. The switching frequency was used as 50kHz. From the panel specification it can be seen that the Vmpp and Impp of the panel is specified as 18.2 V and 3.3 A respectively and power is 60 W. The controller successfully tracked the MPP voltage which is depicted by Fig. 7. The maximum power that the controller could extract was 57.41 W at STC. Then the Vmpp and Impp was 17.43 V and 3.28 A respectively which are shown in the display unit of Fig. 1. The Vmpp vs Impp graph is shown in Fig. 9. So, the power conversion efficiency of the controller is ~95.7% which is quite impressive.

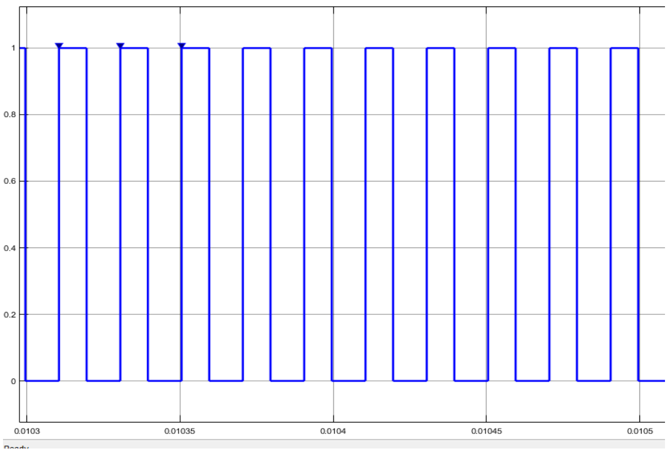

Fig. 6. PWM signal that is generated by the FL

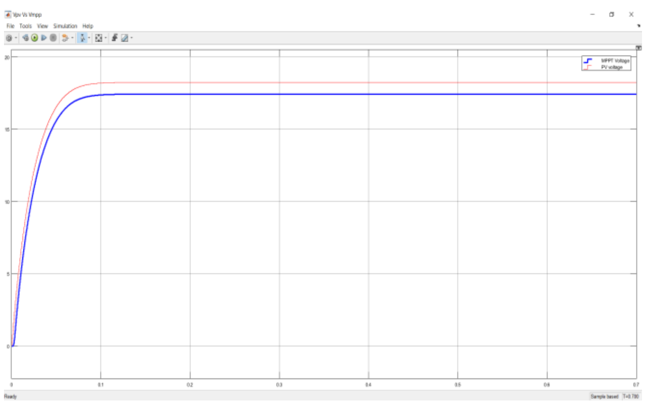

Fig. 7. Tracking of MPP voltage (Vmpp vs Vpv) by the controller.

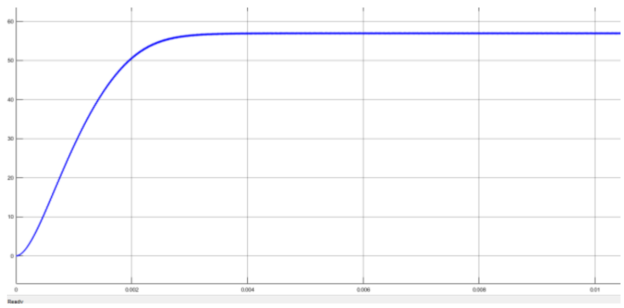

Fig. 8. Output power of the controller.

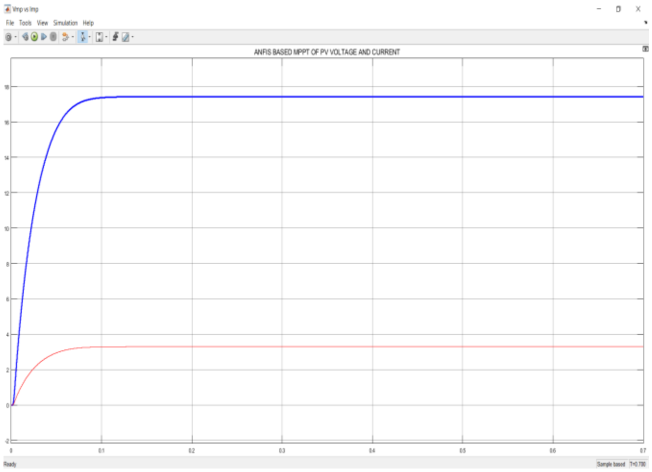

Fig. 9. Vmpp vs Impp.

IV. CONCLUSION

In this paper, MPPT controller was designed in MATLAB/Simulink using fuzzy logic controller based on Mamdani logic. A 60 W PV module was connected to the controller to extract the power at MPP. The fuzzy logic set was generated using two input signals P and dV. The output (D) of the FLC was used to generate the PWM signal which further controlled the switching of the controller. This controller is smart and quick to track the MPP very fast and accurately even there are changes in ambient parameters. The efficiency of the controller was calculated as ~95.7% which is impressive.

REFERENCES

1. Gounden NA, Peter SA, Nallandula H, Krithiga S. Fuzzy logic controller with MPPT using line-commutated inverter for three-phase grid-connected photovoltaic systems. Renewable Energy, 2009; 43:909-915.
2. Hussain KH, Muta I. Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions IEEE Proceedings on Generation, transmission and distribution 1995; 142(1): 59-64.
3. Yamakawa, Takeshi. "A fuzzy inference engine in nonlinear analog mode and its application to a fuzzy logic control." IEEE transactions on Neural Networks 4, no. 3 (1993): 496-522.
4. Piltan, Farzin, SH Tayebi Haghighi, N. Sulaiman, Iman Nazari, and Sobhan Siamak. "Artificial control of PUMA robot manipulator: A-review of fuzzy inference engine and application to classical controller." International Journal of Robotics and Automation 2, no. 5 (2011): 401-425.

5. Setnes, Magne, Robert Babuska, Uzay Kaymak, and Hans R. van Nauta Lemke. "Similarity measures in fuzzy rule base simplification." IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics) 28, no. 3 (1998): 376-386.
6. Fortemps, Philippe, and Marc Roubens. "Ranking and defuzzification methods based on area compensation." Fuzzy sets and systems 82, no. 3 (1996): 319-330.
7. Runkler, Thomas A. "Selection of appropriate defuzzification methods using application specific properties." IEEE Transactions on Fuzzy Systems 5, no. 1 (1997): 72-79.
8. Jianren, Zhang. "The simulation of the fuzzy control system based on MATLAB [J]." Automation and Instrumentation 1 (2003).
9. El-Shal, Shendy M., and Alan S. Morris. "A fuzzy rule-based algorithm to improve the performance of SPC in quality systems." In IEEE SMC'99 Conference Proceedings. 1999 IEEE International Conference on Systems, Man, and Cybernetics (Cat. No. 99CH37028), vol. 5, pp. 284-289. IEEE, 1999.
10. Algazar, Mohamed M., Hamdy Abd El-Halim, and Mohamed Ezzat El Kotb Salem. "Maximum power point tracking using fuzzy logic control." International Journal of Electrical Power & Energy Systems 39, no. 1 (2012): 21-28.
11. Algazar, Mohamed M., Hamdy Abd El-Halim, and Mohamed Ezzat El Kotb Salem. "Maximum power point tracking using fuzzy logic control." International Journal of Electrical Power & Energy Systems 39, no. 1 (2012): 21-28.

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