

Maximum Power Point Tracking Using a Fuzzy Logic Control Scheme

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Abstract

The maximum power point tracking (MPPT) of a photovoltaic system under varying temperature and insolation conditions is the subject of this paper's intelligent control proposal. A DC-DC converter device is used in this method and is controlled by a fuzzy logic controller. This controller's simulation is presented alongside the various design stages. This simulation's results are compared to those of the perturbation and observation controller. They show that the fuzzy logic controller exhibits a much better behaviour.

Keywords: MPPT - fuzzy logic - photovoltaic system - DC-DC converter

INTRODUCTION

Due to energy crisis and environmental issues such as pollution and global warming effect, photovoltaic (PV) systems are becoming a very attractive solution. Unfortunately the actual energy conversion efficiency of PV module is rather low. So to overcome this problem and to get the maximum possible efficiency, the design of all the elements of the PV system has to be optimised.

To build this proficiency, MPPT regulators are utilized. In PV systems, such controllers are becoming increasingly important. Since the 1970s, a significant

number of MPPT control schemes have been developed, ranging from basic methods like voltage and current feedback-based MPPT to more advanced power feedback-based MPPT like the perturbation and observation (P&O) or incremental conductance techniques [1-3].

MPPT, or intelligent-based control schemes, have recently been made available. In this paper, an intelligent control technique using fuzzy logic control is associated to an MPPT controller in order to improve energy conversion efficiency.

DESIGN OF SOLAR PV ARRAY

Tekkali, K Kotturu, Andhra Pradesh Tekkali, K Kotturu, Andhra Pradesh, the output power of PV array is given as

$$P = IV = n_p I_{ph} V \left[\left(\frac{q}{KTA} * \frac{V}{n_s} \right) - 1 \right]$$

Where I is the PV array output current, V is the PV array output voltage, n_s is the number of module in series, n_p is the number of module in parallel, A is the p-n

junction ideality factor it ranges between (1-5), T is the cell temperature (K), K is the Boltzmann constant. Here the PV array is design for 40KW. According to the design considerations one PV module

consists of 36 cells in series. Each cell has open circuit voltage of 0.54V and short circuit current of 1A. Thus one module has open circuit voltage of 19V (18-21V) and short circuit current of 1A. For 40KW PV array we require 474V maximum voltage and maximum current of 84.39A corresponding to peak power of 40KW, to achieve this voltage (474/19) and current (84.39/1) 24 solar modules are connected in series and 84 are connected in parallel respectively[5].

PRINCIPLE OF MAXIMUM POWER POINT TRACKING CONTROL

The photovoltaic module operation depends strongly on the load characteristics, (Fig. 1) to which it is

connected [4, 5]. Indeed, for a load, with an internal resistance R_i , the optimal adaptation occurs only at one particular operating point, called Maximum Power Point (MPP) and noted in our case P_{max} .

Thus, when a direct connection is carried out between the source and the load, (Fig. 2), the output of the PV array is seldom maximum and the operating point is not optimal.

Between the source and the load, a MPPT controller equipped with a DC-DC converter must be added in order to resolve this issue. (Fig. 2)[3].

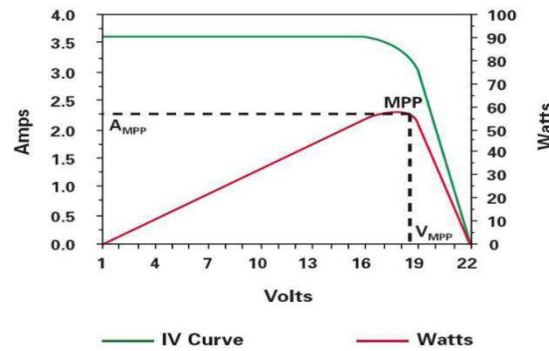


Fig. 1: I-V and P-V characteristics of PV module.

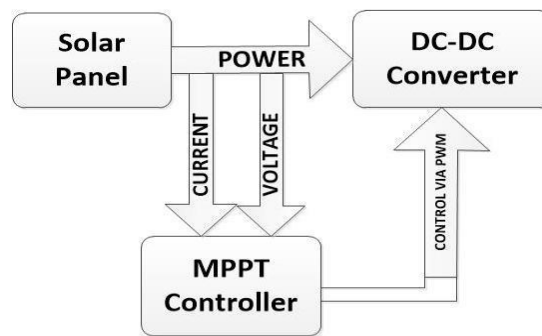


Fig. 2: Block diagram of MPPT technique used in PV system.

Many MPTT control techniques have been conceived for this purpose these last decades [1,2]. They can be classified as:

- Voltage feedback based methods which compare the PV operating

voltage with a reference voltage in order to generate the PWM control signal of the DC-DC converter [8].

- Current feedback based methods which use the PV module short circuit current as a feedback in order to estimate the

optimal current corresponding to the maximum power.

- Power based methods which are based on iterative algorithms to track continuously the MPP through the current and voltage measurement of the PV array. In this category, one of the most successful and used method is perturbation and observation (P&O), which is presented in the next section.

P&O METHOD

The simplest approach is perturb and observe (P&O). Because we only use one sensor, the voltage sensor, to measure the voltage of the PV array, this is less expensive to implement and simpler to do so. This algorithm has a very low time complexity, but when it gets very close to the MPP, it doesn't stop there and keeps perturbing in both directions. When this occurs, the algorithm is very close to the MPP. We can either use a wait function, which increases the algorithm's time complexity, or set an appropriate error limit. However, the method calculates the incorrect MPP because it disregards the rapid change in irradiation level, which causes MPPT changes, and treats it as a change in MPP caused by perturbation[3].

The principle of this controller is to provoke perturbation by acting (decrease or increase) on the PWM duty cycle and observing the effect on the output PV power. If the instant power $P(k)$ is greater than the previous computed power $P(k-1)$, then the direction of perturbation is maintained otherwise it is reversed. Referring to figure 1 this can be detailed as follows:

When $dP/dV > 0$, the voltage is increased, this is done through $D(K) = D(K-1) + C$, (C is incremental step)

When $dP/dV < 0$, the voltage is decreased, this is done through $D(K) = D(K-1) - C$, the parameter D indicates the duty cycle of this chopper, which is the closing time of the switch over one period.

FUZZY LOGIC MPPT CONTROLLER

Recently, in PV systems, fuzzy logic controllers have been used to track the MPP [12-14]. They are advantageous because they do not require knowledge of the precise model, making them robust and relatively straightforward to design. On the other hand, the designer must be completely conversant with how the PV system works.

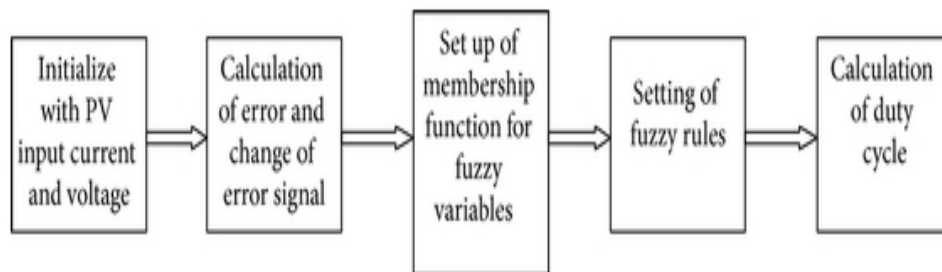


Fig. 3: General diagram of a fuzzy controller.

The proposed FL MPPT Controller, shown in Fig.3, has two inputs and one output. The error E and change in error CE at sampled times k are the two FLC input variables that are defined as:

$$E(K) = \frac{P_{ph}(k) - P_{ph}(k-1)}{V_{ph}(k) - V_{ph}(K-1)} \quad (1)$$

$$CE(K) = E(K) - E(K-1) \quad (2)$$

Where $P_{ph}(K)$ is the instant power of the photovoltaic generator.

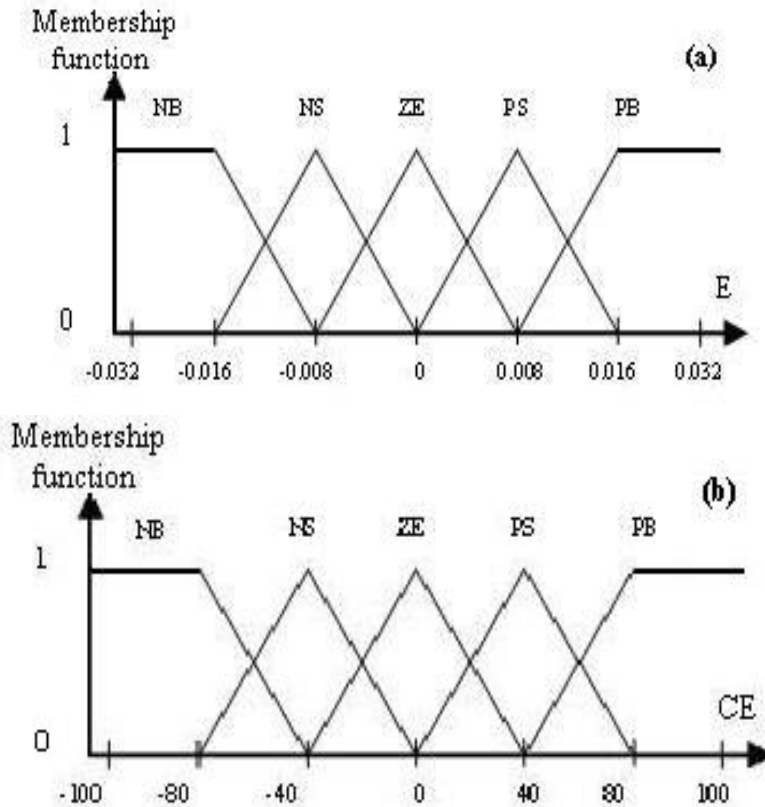
On the PV characteristic, the inputs $E(k)$ and $CE(k)$ express the moving direction of the load operation point and indicate whether it is on the left or right of the maximum power point.

Madani's method is used for the fuzzy inference (Table 1), and the defuzzification uses the center of gravity to calculate the duty cycle from this FLC's output. Table 1 depicts the control rules, with D serving as the output and E and CE serving as the inputs.

Table 1: Fuzzy rule table.

E/CE	NB	NS	ZE	PS	PB
NB	ZE	ZE	PB	PB	PB
NS	ZE	ZE	PS	PS	PS
ZE	PS	ZE	ZE	ZE	NS
PS	NS	NS	NS	ZE	ZE
PB	NB	NB	NB	ZE	ZE

The control action D for tracking the maximum power point and these two variables are shown. in fig.4 [7].



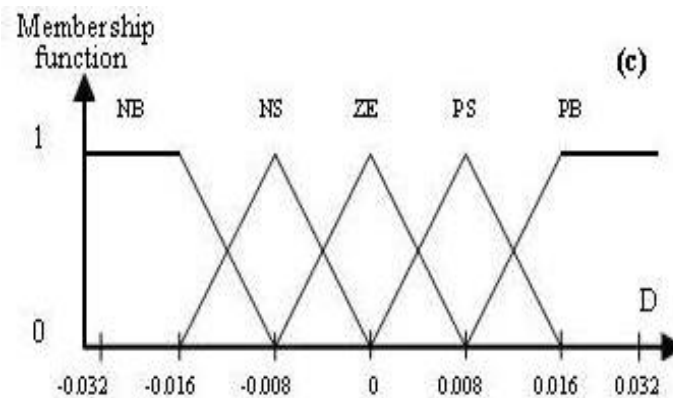


Fig. 4: Membership functions of (a) error E (b) change of error CE (c) duty ratio D .

SIMULATION OF THE P&O AND FUZZY LOGIC MPPT CONTROLLERS AND RESULTS

The Fig.5 shows the functional diagram of the simulated photovoltaic system. The

DC-DC converter is the boost chopper of Fig. 6. The previous MPPT controllers P&O and FLC were simulated under the following tests:

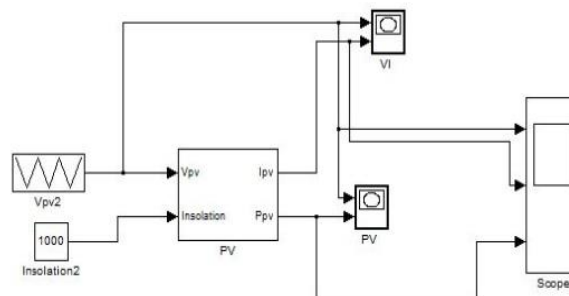


Fig. 5: MATLAB simulation of PV array.

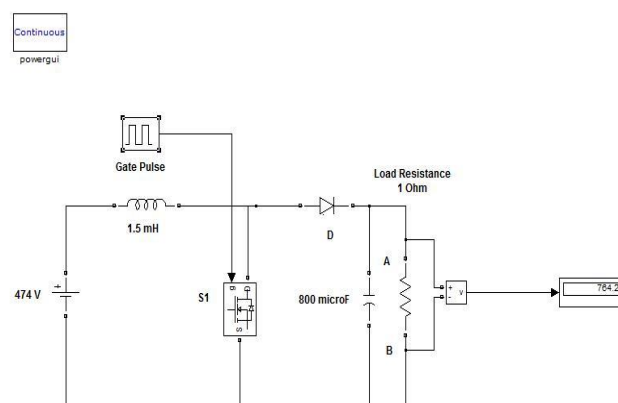


Fig. 6: MATLAB simulation of boost converter.

In fig. 7 shows the implementation of P&O method and the inputs to the MPPT is voltage, current and power which are taken PV array source of 40kw.

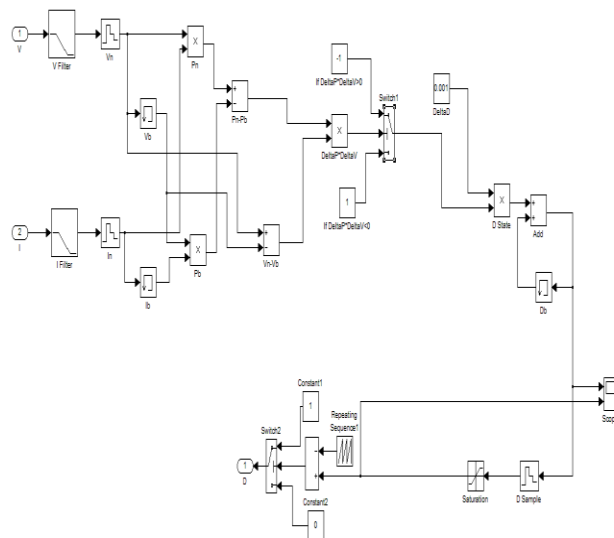


Fig. 7: MATLAB simulation of P&O Method.

In figure 8 shows the V-I characteristics of PV array and figure 9 shows the P-V characteristics of PV array is shown.

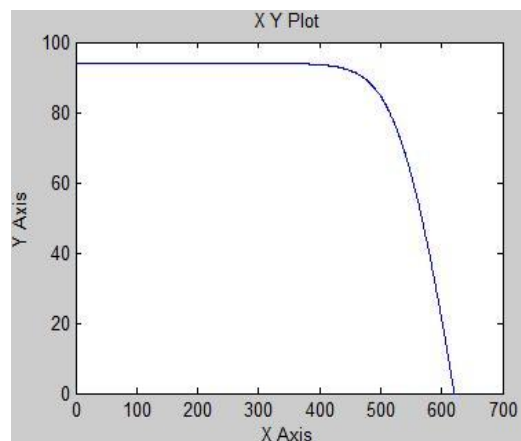


Fig. 8: V-I characteristics of PV array.

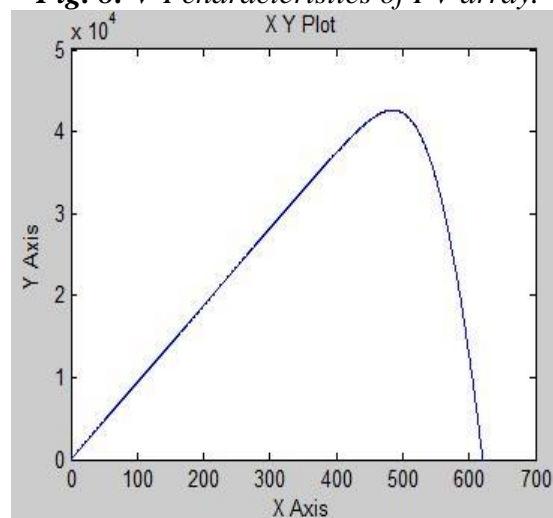


Fig. 9: Characteristics of PV array.

In fig.10 shows the pulses are generated from P&O and fuzzy algorithm according to solar radiation 1KW/m².

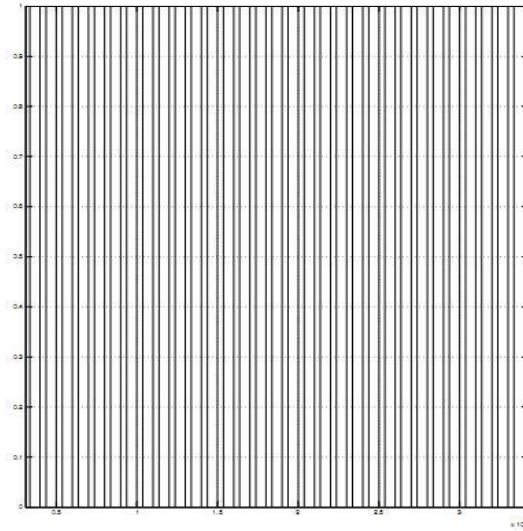


Fig. 10: Gate pulses are generated from P&O and fuzzy algorithm.

In figure.11 shows the dc link output voltage are generated from boost converter having duty cycle of 0.397 and output voltage of dc link is 780V and input of boost converter is 474V.

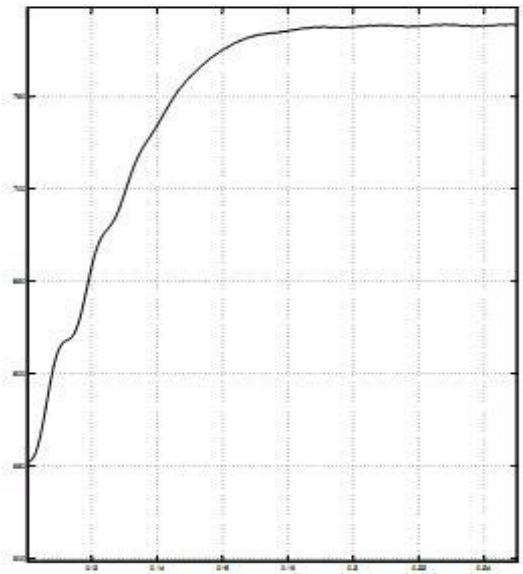


Fig. 11: DC-link output voltage of boost converter.

CONCLUSION

The objective of this project was to regulate the solar panel's voltage so that a PV generator could produce the most power possible regardless of solar insolation and temperature. Fuzzy logic controller seemed like a good idea because a lot of control schemes had already been used and had some problems. It was

necessary to find and try other ways to improve the output. Because they are more adaptable, fuzzy logic controllers for nonlinear systems can be up to an order of magnitude more effective than conventional controllers. It was possible to obtain a steady and quick fuzzy logic MPPT controller. Compared to the well-known P&O controller, it makes it

possible to find the point of maximum power in shorter runs.

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