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INTELLIGENT AND CONVENTIONAL METHODS OF M-PP FOLLOWING TECHNIQUES WITH PV: A REVIEW

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***Abstract* – At present, the coal shortage is a big concern in India. But if sustainable energy like solar, wind, and geothermal is used to produce electricity which fulfils the demand on a large scale. Solar energy is generated using photovoltaic cells, but its efficiency is about 20-25%. The Maximum-Power Position (M-PP) following methods are used to increase the maximum power extraction from PV array. In this paper, an artificial intelligence-based fuzzy logic M-PP following method is designed for PV using MATLAB/Simulink. The conditions taken are standard to the present average temperature i.e., 35^o C in India and insolation is 1000W/m^2. The second condition to examine is varying the insolation with average temperature. To analyze the results of proposed method, it compared by two conventional M-PP following methods.**

***Keywords*–Maximum Power Position, P&O, INC, PV, Fuzzy logic**

I. INTRODUCTION

Owing to the quick depletion of fossil resources including significant climate change, there has been a considerable focus on sustainable energy like sun rays, windmills, thermal, and biofuels which help to achieve effective, contamination-free generation of power. From many sustainable sources, the energy produced by using PV has proven to be capable of providing favorable energy [1] because there is no charge to use sun rays, so there is broad scope for energy reliability with easy execution, such as on houses roof, also very less maintenance custom duties since deployment. Furthermore, by incorporating appropriate electronic equipment, solar energy framework has additional benefit to work in grids linked as well as in isolation fashion [2].

Furthermore, its main disadvantages include less power conversion rate, also the installation is costly [3]. As a result, obtaining the most generated power using sun rays as an inlet of the solar array becomes critical [4]. However, solar modules have really significant non-linear working features such as high fluctuating degrees as well as irradiance, resulting in unsatisfactory framework performance.

Moreover, in specified solar irradiance as well as atmosphere degree conditions, the solar framework feature waveform reveals an optimal working position called the maximum-power position (M-PP). However, because of climate as well as atmospheric conditions such as solar irradiance, atmosphere degrees increase or decrease, it resulting in partial shadowing, then amount of production of energy using solar varies, also it starts working on a sub-optimum value. So, it can say that the optimum M-PP levels change with time. As a result, solar framework must create a controller in order to follow M-PP at a specific operational factor.

Several M-PP following methods has been developed by researchers in recent times, including open-circuit voltage [5], perturb & observe (PO) [6], incremental-conductance (IN-Cond) [7], also introduced as well as implemented artificial intelligence methods such as neural-network [8], fuzzy-based controller[9], and many others. But, because of non-linear working features, M-PP following remains difficult to work in order to develop an appropriate way for it in a variety of real atmospheric altering scenarios.

A Fuzzy-based M-PP following method with Mamdani inference system (M-I-S) is suggested in this paper. Suggested method outperforms the existing traditional M-PP following method in terms of monitoring capability as well as work regardless of environmental variables. In addition to the suggested M-PP, two more well-known M-PP followings, namely PO, IN-Cond were modelled using Matlab/Simulink software.

II. SOLAR MODEL

Modelling of the PV array's smallest part which is called a PV cell andis made up of p-layer and n-layer semiconductors on which sun rays fall and DC ampere is produced. Fig. 1. shows the electrical connection which consists of ampere input, diode, in-line and shunt resistor, the ampere input produced amperes when sun rays fall on it. The resistor is used to show the losses in potential in the path to the connection from externals, also ampere leaks go through the parallel resistor [10].

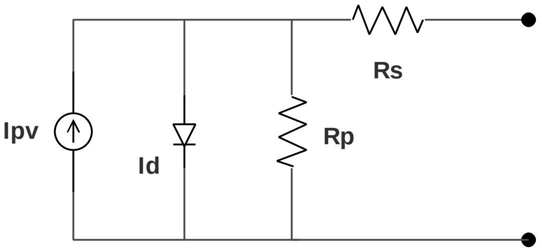


Fig. 1. Electrical connections pf PV cell

The equations used to model in which the relation between yield ampere to yield potential are shown [11,12].

$$I = I_{ph} - I_o \left[\exp\left(\frac{q}{KTA}(v + IR_s) - 1\right) - \frac{(v+IR_s)}{R_{sh}}\right] \quad (1)$$

Whereas Iph is ampere produced by sun rays (ampere is uniformly dependent on the falling sunrays);
I and v denoted yield value of ampere and potential of solar panel respectively;
q represents charge of electron (1.60218 e -19 C);
K is for Boltzmann constant (1.38065 e-23 J/K);
A is the constant ideal value of diode;
Rs, Rsh are resistors connected in-line, parallel in circuit; T denotes degrees in the PV cell (in Kelvin).

Theyield ampere of PV i.e., Iph is changed according to solar isolation and degrees of the cell, as shown below,

$$I = \left(I_{sc} + K1\,(T - T_{ref})\right) \quad (2)$$

Whereas Isc represents short-circuit ampere at standard values of insolation and degrees;
K1 is ampere in short-circuit condition of PV cell;
Tref is known as the reference value of degrees in cell (25°C);
λ denotes sun insolation value (in kW/m^2).

III. MODELOF M-PP FOLLOWING

The overall framework which is used to examine M-PP following methods is presented in Fig. 2. The framework has a PV array, a DC-DC converter, M-PP following controller, a resistor as a burden [13].

The panel of PV used to have 10 module strings and 4 parallel strings. The curves of the PV panel are changed according to the sun-ray intensity and degrees. The operation of a PV array is varied according to the burden type.

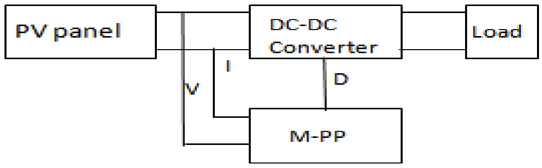


Fig. 2. M-PP following framework [6]

When the burden is attached to PV in a straight line, then it does not perform at M-PP. So, to get maximum watts from an array and adjust according to the burden, a converter is used which helps in adjusting the on-off cycle with the help of the M-PPfollowing controller [14]. The converter used in this analysis is a DC-DC boost converter.

A. Converter

Fig. 3. present a DC-DC boost converter that increases the input potential. The mode of working is two. Mode 1 starts MOSFET is in ON position, the amperes through L rises uniformly and D is in OFF condition, mode 2 have MOSFET in OFF state, L work as a source for D and burden. Duty cycle of MOSFET can control the watts produced. Equation (3) presents relation in source and yield potential [15].

$$\frac{V_o}{V_i} = \frac{1}{1-D} \quad (3)$$

Whereas V_i represents array yield; Vo is potential of converter; D is on/off cycle and its equation is

$$D = \frac{T_{on}}{T} \quad (4)$$

Whereas T_{on} time at this MOSFET is in ON condition; T represents total time.

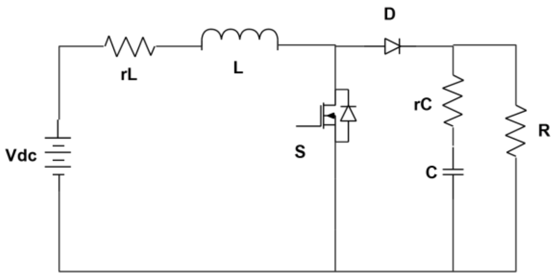


Fig. 3. Electrical setup of the DC-DC converter

IV. METHODS OF M-PP FOLLOWING

It is an immediate treatment that helps to find an optimum position where the highest value of watts can be taken from the solar panel on any value of irradiance.3 different methods for M-PP following will be modelled and simulated.

A. Perturb and Observe (PO or P&O)

The concept at which PO works is to perturb means rise or fall in ON/OFF cycle of the DC-DC converter is done, then observe the changing value of yield watts. For example, at an instant the watt (P(n)) and potential (V(n)), are more than the former watt (P(n-1)) and (V(n-1)), so the path of perturbing is followed else get inverted [16,17].

As PO is the easiest and very used algorithm, there are some demerits also [18].

1. The speed of PO steps is very low then not every time it can work on an optimum value of M-PP, hence maximum watts may not be taken from solar panels.
2. The yield of the solar framework has oscillations, so some filters are required which remove harmonics produced.

The PO method's working is presented in Fig. 4.

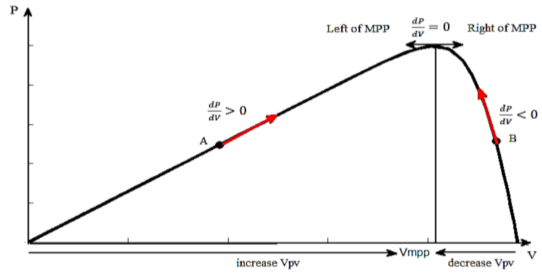


Fig. 4. Working Concept of PO

B. Incremental Conductance (IN-Cond or INC)

This method is easy and simple, also better than PO to follow M-PP more precisely during changing insolation factors. The concept used in IN-Cond is comparing the impedance of solar panels and the overall impedance of DC-DC regulators on the panel side. When method reached M-PP, it ends the perturbing for working position [19,20]. If not equal to M-PP, then perturbation continuously measure working point using relation in dI/dV and -I/V, if dI/dV is negative means measured point is right side to M-PP and if it is positive means value lies on left of M-PP presented in Fig. 5. But this method has some demerits like slow in responding, high fluctuations occur during insolation change and also complex.

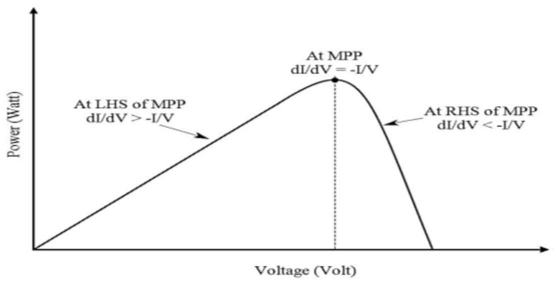


Fig. 5. IN-Cond concept of working

C. Fuzzy-based method

This method is also known by many-rules built solution or many-variable consideration. It becomes famous in previous periods. The controller based on the fuzzy method can work by in accurate in-let values, because it does not want proper measured value, also it grips for non-linear conditions [21]. The controller is presented in Fig. 6., where 2 in-lets with one yield value. The in-lets parameters are error (E) and change in error (CE), the equations shown below [22].

$$E(k) = \frac{P_{PV}(k) - P_{PV}(k-1)}{V_{PV}(k) - V_{PV}(k-1)} \quad \text{(v)}$$

$$CE(k) = E(k) - E(k-1) \quad \text{(vi)}$$

Where P_{PV}, V_{PV} denotes watt, potential respectively at point k. E(k) is value of difference of yield at burden to the optimum M-PP value in the curve and if equal to M-PP then zero value. Change in error (CE(k)) denotes E(k) value slope in the curve. The controller has 3 steps in design which are as follows:

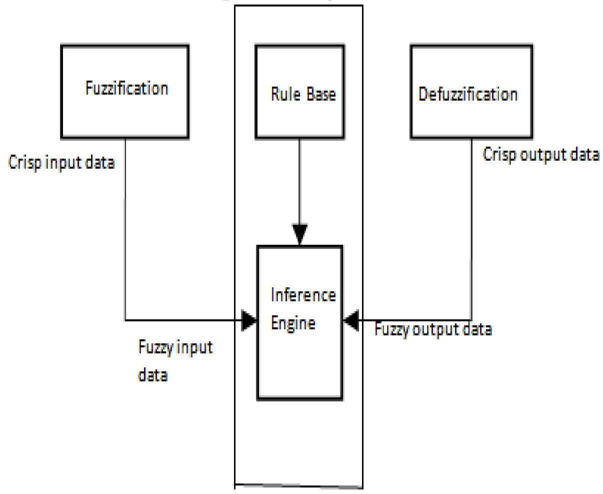
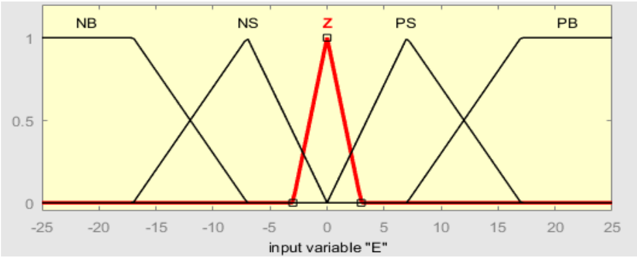


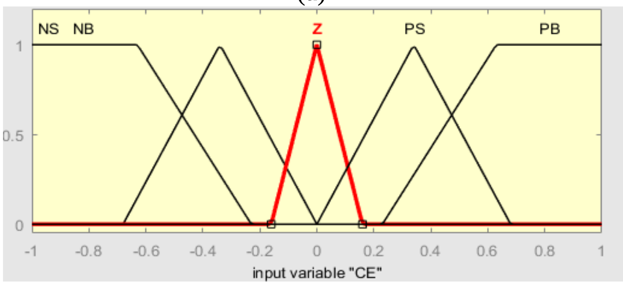
Fig. 6.Fuzzy-based controller

C.1.Fuzzification

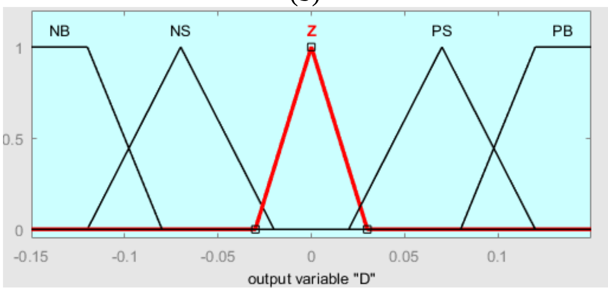
In this step, the in-let parameter E and CE values changed to linguistic sets for fuzzy using membership rules [23]. The parameters are five in number, like ZE, PB, PS, NB, NS as shown in Fig. 7.



(a)



(b)



(c)

Fig. 7.Membership functions (a) Membership function for E(k), (b) Membership function for CE(k) and (c) Membership function for D

C.2.**Rules and inference engine**

The rules define in fuzzy is a group of if-then command which have knowledge related to parameters control [24]. These rules are arranged by professional experience, also procedure of controlling the framework. Total 25 rules in fuzzy method are used presented in Table-1.

The engine used is a functioning way which set logical result according to rules set and change rules to linguistic yield. This work uses Mamdani's inference method.

C.3.**De-fuzzification**

This step uses rule table to change fuzzy controlling action into a numeric on the yield side, it makes union of the yields from every rule [25]. For example, E is NB; CE is ZE; resulting in D being PB. It said that working value is more away from M-PP in right, change in slope is zero, so rise the ON/OFF cycle value.

Table-1Rules in fuzzy method

CE E	NB	NS	ZE	PS	PB
NB	**NB**	**NS**	**ZE**	**ZE**	**ZE**
NS	**NB**	**NS**	**ZE**	**PS**	**PB**
ZE	**PB**	**PS**	**ZE**	**PS**	**PS**
PS	**PB**	**PB**	**PB**	**ZE**	**ZE**
PB	**PB**	**PB**	**PB**	**PS**	**ZE**

V. SIMULATIONRESULTS

Modelling of both M-PP following methods has been done using MATLAB/Simulink. The results presented here are of case 1 where temperature (35° C) and irradiance (1000W/m^2) are constant and case 2 where irradiance is changed but temperature is constant at present average value.

Case 1: All the three methods of M-PP following are discussed and modelled. Now, comparing these on account of the overall output watts, amperes and potentials of the system in Fig. 8, 9 and 10.

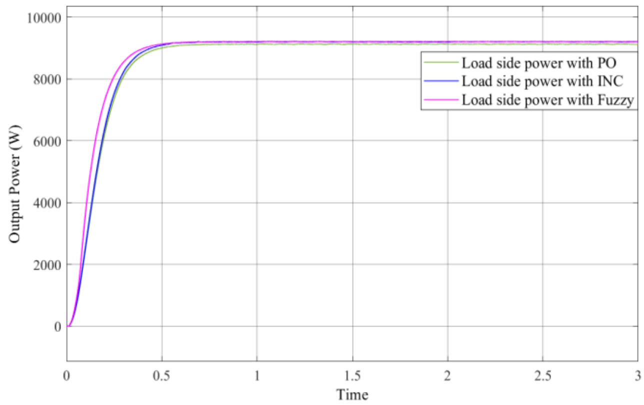


Fig. 8.Comparison betweenload-sideoutput powers of 3 different M-PP methods at standard conditions

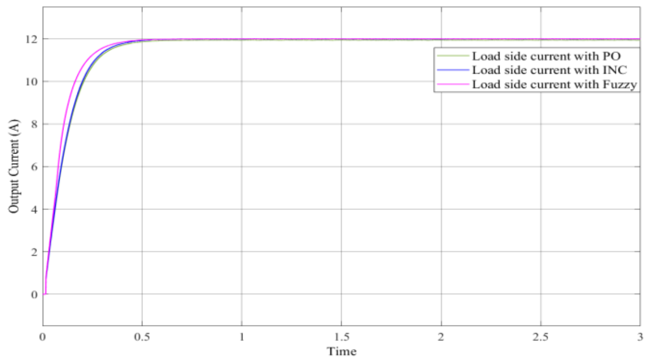


Fig. 9.Comparison between load-sideoutput amperes of 3 different M-PP methods at standard conditions

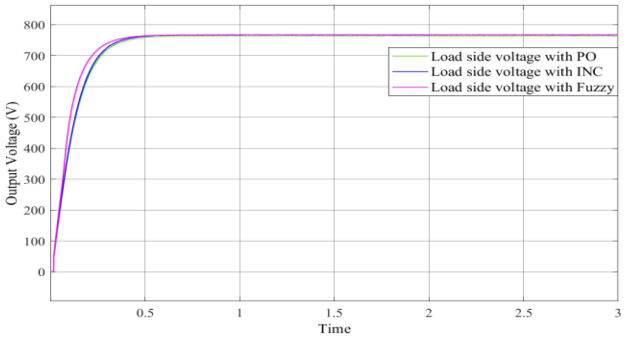


Fig. 10.Comparison between load-side output voltages of 3 different M-PP methods at standard conditions

Case 2: The results of simulation is shown in Fig. 12, 13 and 14, in which all 3 M-PP methods are showing curves for output watts, amperes and potentials of system when the irradiance is changing continuously, like presented in Fig. 11.

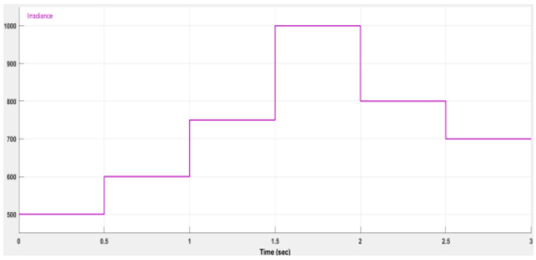


Fig. 11. Change in irradiance value

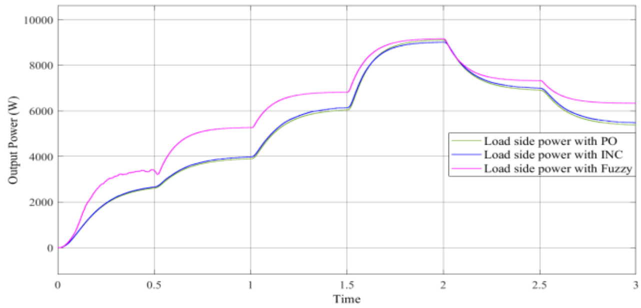


Fig. 12.Comparison between output powers of 3 different M-PP methods at varying irradiance

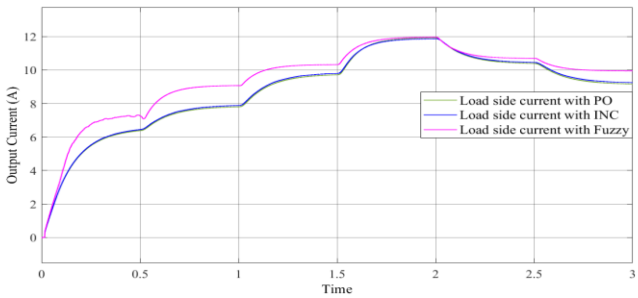


Fig. 13.Comparison between output currents of 3 different M-PP methods at varying irradiance

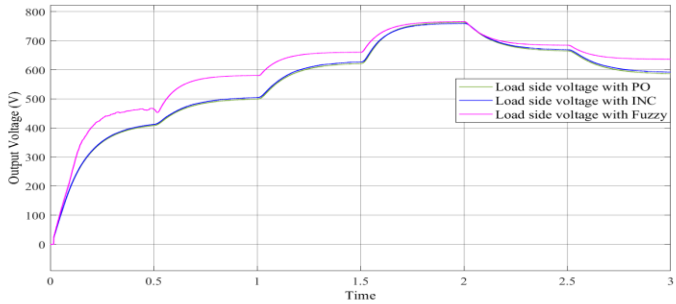


Fig. 14. Comparison between output voltages of 3 different M-PP methods at varying irradiance

VI. CONCLUSION

Solar array and DC-DC converter modelling is present in paper. Also, 3 different types of M-PP following methods are presented which compared in two different cases. All the three types of controllers were modelled in Simulink with the PV and converter. The results are shown and concluded that the fuzzy-based controller is a faster, better performer with fewer oscillations. So, the fuzzy-based method is superior to other discussed methods.

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