A Review of Different M-PP Following Techniques in Integration with DC-DC Converter

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Abstract - A fuzzy-based technique is described for the maximum power position (M-PP) following for a system with the variable insolation. The considered system consists of a solar array with a boost converter. The proposed approach was analyzed with the perturb and observe (PO) technique and incremental conductance (IN-Cond), which is extensively used from all traditional techniques for M-PP following. All strategies were modelled and analyzed in MATLAB/Simulink. The results gone show that the fuzzy method provides a good, also greater dependable technique.

Keyword- M-PP, Convertor, Controller

1. INTRODUCTION

Sustainable resources are crucial to producing power. Examples of sustainable sources are airflow, sun rays, tidal energy, etc. are used to produce energy that fulfils our everyday power requirements. PV power generating is more and more popular as a sustainable resource as it has numerous benefits like no price required for material, no pollution, need less upkeeps, also no sound pollution in comparison to others.

The behavior of the PV array is not linear and also varies according to insolation and temperature. In curves, a point indicates where potential, also ampere is at a maximum which is called maximum-power position (M-PP), at this point array gives maximum watts i.e., efficiency at its peak. The methods used to follow the peak watt of an array and produce maximum efficiency of the overall framework are known as M-PP following [1]. Adjusting the M-PP following of the array is important for the framework. Various methods were designed to adjust M-PP, all the methods differ in design, price, output, working difficulties, etc. [2].
The most famous and easy working technique of the M-PP following is Perturb and Observe (PO). A fuzzy-based method is presented here which gives better results compared to the PO and IN-Cond methods. Simulation and results of all methods are presented.

2. PV MODEL

Modelling of the PV array's smallest part which is called a PV cell and is 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 [3].

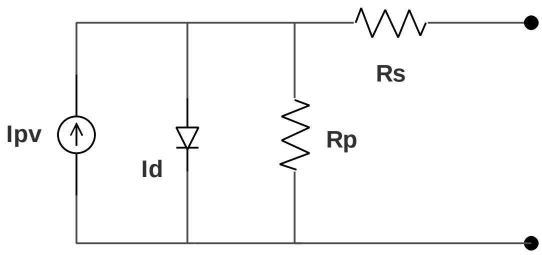


Figure 1: Electrical connections pf PV cell

The equations used to model in which the relation between yield ampere to yield potential are shown [4,5].

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

Whereas I_{ph} 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.
R_s, R_{sh} are resistors connected in-line, parallel in circuit; T denotes degrees in the PV cell (in Kelvin).

The yield ampere of PV i.e., I_{ph} is changed according to solar isolation and degrees of the cell, as shown below,

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

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

3. MODEL OF 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 [6]. 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.

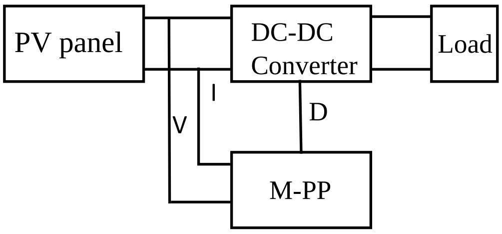


Figure 2: M-PP following framework [6]

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-PP following controller [7]. The converter used in this analysis is a DC-DC boost converter.

3.1 Converter

Figure 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 [8].

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

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

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

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

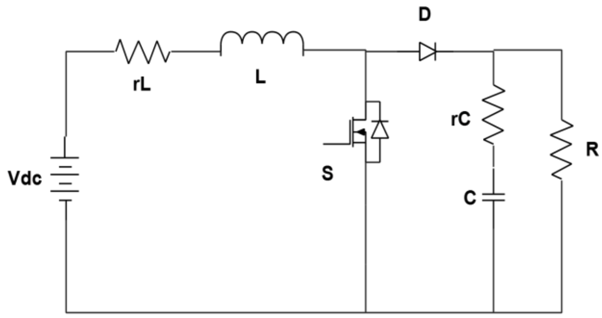


Figure 3: Electrical setup of the DC-DC converter

4. M-PP FOLLOWING METHODS

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.

4.1 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 [9,10].

As PO is the easiest and very used algorithm, there are some demerits also [11]

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 flowchart is presented in Figure 4

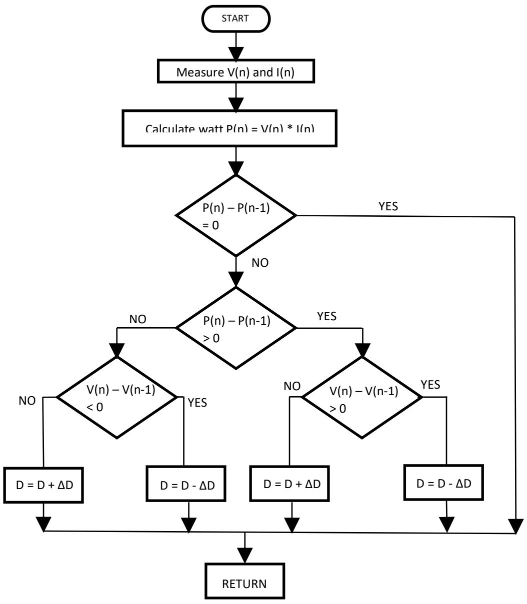


Figure 4: Flow-chart of PO

4.2 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 [12,13]. 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.

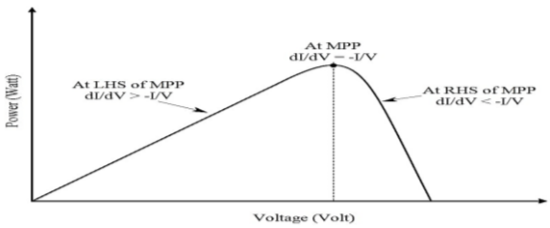


Figure 5: IN-Cond concept of working

4.3 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 inaccurate in-let values, because it does not want proper measured also it grips for non-linear conditions [14].

The controller is presented in Figure 6 which has different layers of the fuzzy method. The in-lets parameters are error (E) and change in error (CE), the equations shown below [15].

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

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

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:

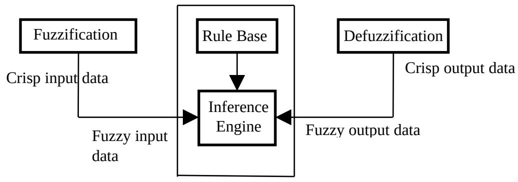
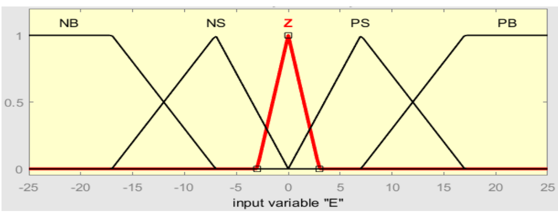


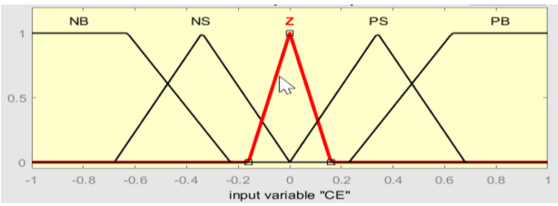
Figure 6: Fuzzy-based controller

4.3.1 Fuzzification

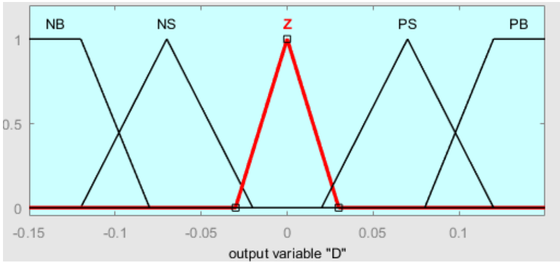
In this step, the in-let parameter E and CE values changed to linguistic sets for fuzzy using membership rules [16]. The parameters are five in number, like ZE, PB, PS, NB, NS as shown in Fig 7. All have particular range according to which they active.
PB – positive big
PS – positive small
ZE – zero
NS – negative small
NB – negative big
In figure 7 (a), (b) have different ranges [-25. 25], [-1,1] respectively. The trapezoidal and triangular functions are used.



(a)



(b)



(c)

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

Figure 7 (c) presents the output duty cycle (D) with a range of [-0.15, 0.15] and has trapezoidal and triangular functions.

4.3.2 Rules and Inference Engine

The rules defined in fuzzy is a group of if-then commands which have knowledge related to parameter control [17]. These rules are arranged by professional experience, also the procedure of controlling the framework. Total 25 rules in the fuzzy method are used presented in Table 1.
The engine used is a functioning way that sets logical results according to rules set and changes rules to linguistic yield. This work uses Mamdani's inference method.

Fuzzy rules are based on the logic of human knowledge for the input and output variables. When positive big error and zero change in error then output is negative big. When positive small error and the positive big change in error then output zero. And all 25 rules are defined in the same way.
Rules defined in the controller like,
if E = PB and CE = ZE then D = NB;
if E = PS and CE = PB then D = ZE and so on.

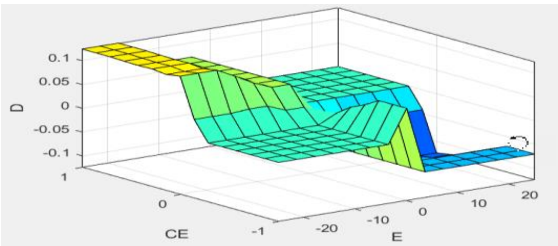


Figure 8: Surface viewer of Fuzzy-based controller

Table 1: Rules 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

4.3.3 De-fuzzification

This step uses a rule table to change fuzzy controlling action into a numeric on the yield side, it makes a union of the yields from every rule [18]. For example, E is NB; CE is ZE; resulting in D being PB. It said that the working value is more away from M-PP in right, change in slope is zero, so rise the ON/OFF cycle value.

5. SIMULATION RESULTS

Modelling of both M-PP following methods has been done using MATLAB/Simulink. The results presented here are of case 1 where temperature (25^{o}C) and irradiance (1000W/m^2), are both at standard value and case 2 where irradiance changes with respect to time but the temperature is constant at the standard value of 25^{o}C.

Case 1: All the three methods of M-PP following are discussed and modelled at standards (25^{o}C and 1000W/m^2). Now, comparing these on account of the overall output watts and potentials of the system in Figure 9 and 10.
Figure 9 shows the output power by PO is less, INC curve have oscillations but fuzzy-based M-PP following method works better, fast in achieving steady-state, no oscillations.

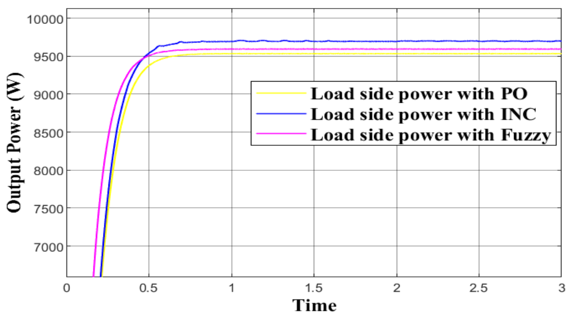


Figure 9: Comparison between output powers of 3 different M-PP methods at standard conditions

Figure 10 shows the output voltage produced by PO is less, INC curve has oscillations but the fuzzy method works better, fast in achieving steady-state, no oscillations.

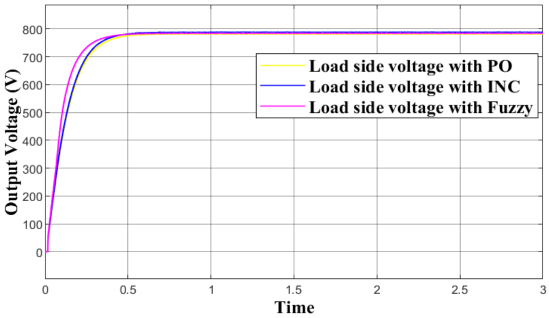


Figure 10: Comparison between output voltages of 3 different M-PP methods at standard conditions

Case 2: The results of the simulation is shown in Figure 12 and 13, in which all 3 M-PP methods are showing curves for output watts and potentials of the system when the irradiance is changing continuously, as presented in Figure 11 and the temperature remains 25ºC.

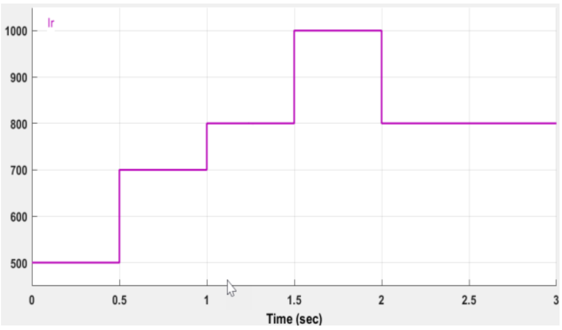


Figure 11: Change in irradiance value

Figure 11 explains the variation in irradiance that it is not constant, changes every second.
Figure 12 and 13, perfectly show that the fuzzy-based method is more optimal in extracting maximum power from the system in comparison to PO and INC methods.

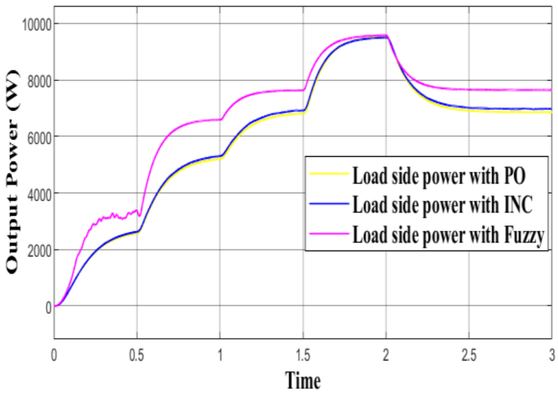


Figure 12: Comparison between output powers of 3 different M-PP methods at varying irradiance

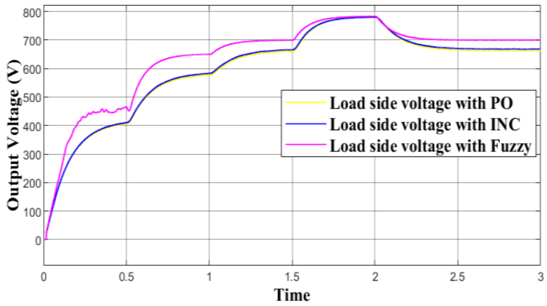


Figure 13: Comparison between output voltages of 3 different M-PP methods at varying irradiance

6. CONCLUSION

Solar array and DC-DC converter modelling is present in the paper. Also, 3 different types of M-PP following methods are presented which are compared in two different cases. All 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 preferable, related to other discussed methods.

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