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# Grid connected solar PV system with MPPT control using Advanced Controlling Techniques

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***Abstract—*** *As the use of energy is increasing, the requirements for the quality of the supplied electrical energy are more tighten. Energy is the most basic and essential of all resources. As conventional sources of energy are rapidly depleting and the cost of energy is rising, photovoltaic energy becomes a promising alternative source. Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it exhibits a great many merit such as cleanness, little maintenance and no noise. The output power of PV arrays is always changing with weather conditions, i.e., solar irradiation and atmospheric temperature. Therefore, a Maximum Power Point Tracking (MPPT) control to extract maximum power from the PV arrays at real time becomes indispensable in PV generation system. In recent years, a large number of techniques have been proposed for tracking the maximum power point (MPP). MPPT is used in photovoltaic (PV) systems to maximize the photovoltaic array output power, irrespective of the temperature and radiation conditions and of the load electrical characteristics the PV array output power is used to directly control the dc/dc converter, thus reducing the complexity of the system. The resulting system has high-efficiency. So here we going to study of different MPPT techniques then compare them and choose one of them for different application according to their efficiency.*

***Keywords—*** *pv cell; grid integration; MPPT; P&O; Integrated cunductio; fuzzy; neural network controller*

## I. INTRODUCTION

It's certainly clear that fossil fuels are mangling the climate and that the status quo is unsustainable. There is now a broad scientific consensus that the world needs to reduce greenhouse gas emissions more than 25 percent by 2020 and more than 80 percent by 2050. The idea of harnessing the sun's power has been around for ages. The basic process is simple. Solar collectors concentrate the sunlight that falls on them and convert it to energy. Solar power is a feasible way to supplement power in cities. In rural areas where the cost of running power lines increases.

One of the major concerns in the power sector is the day-to-day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and has drastically affected the environment depleting the biosphere and cumulatively adding to global warming.

## II. PV CELL EQUIVELENT CIRCUIT

The maximum operating point of solar photovoltaic (PV) panels changes with environmental conditions. The maximum power point (MPP) of a PV system depends on cell temperature and solar irradiation, so it is necessary to continually track the MPP of the solar array. Many methods have been proposed to locate and track the maximum power point (MPP) of PV cells. The difficulties that face these methods are the rapid changes in solar radiation and the variety in cell temperature which affects the MPP setting. [1]



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External sensors are used in many approaches to measure solar irradiation and ambient temperature to estimate the MPP as a function of data measured. A solar cell basically is a p-n semiconductor junction. When exposed to light, a dc current is generated which varies linearly with the solar irradiance. Figure (1) shows the equivalent circuit of the PV cell [2].

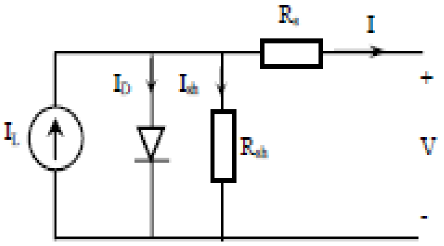


*Figure 1. Equivalent circuit of PV cell*

$$I = I_L - I_D\left(e^{q(V+IR_s)/KT} - 1\right) - \frac{V+IR_S}{R_{sh}} \qquad \text{------eq}^n(1)$$

Where,

I cell current (A)
$I_L$ light generated current (A)
$I_D$ diode saturated current (A)
q Charge of the electron
K Boltzmann constant (J/K)
$R_t$ cell temperature (T)
$R_s$ cell series resistance (ohm)
$R_{sh}$ cell shunt resistance (ohm)
V cell output voltage (V)

*Table 1. PV Module Parameters*

| **Electrical Parameters** | **Value** |
|---|---|
| Maximum Power (Pmax) | 250 W |
| Voltage at Pmax (Vmp) | 30.2V |
| Current at Pmax (Imp) | 8.3A |
| Open Circuit Voltage (Voc) | 37.3V |
| Short Circuit Current (Isc) | 8.71A |
| Number of Series Cells (Ns) | 60 |

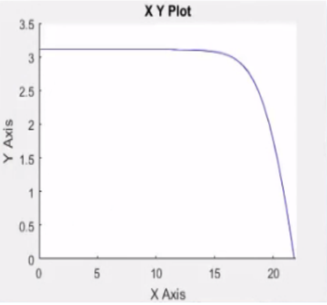


*Figure 2. IV graph*

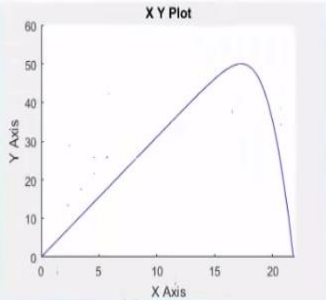


*Figure 3. PV graph*



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## III. GRID INTEGRATION

Electricity generation using renewable energy resources is often taking place in small scale due to disperse nature of the resources. Good example is solar photovoltaic electric generation system. The size of these generators typically varies from a few hundred of kilowatt to several megawatts; these small scale electricity generators are generally connected to the grid at primary or secondary distribution level and are consider distributed generation (DG) or distributed resources [3].
The unit formed by the energy transport line and all the connection transformers between the various voltage levels, will be indicated by network (Fig. 4). It is modelled by a Thevenin equivalent circuit composed by a sinusoidal voltage source in series with an impedance (Z = R + jX ). It includes all the impedances which are indicated above and the output inverter filter L. This circuit is fed by the inverter output voltage [4]. Converters interfacing PV module with the grid involves two major tasks. One is to ensure that the PV module is operated at the maximum power point. The other is to inject a sinusoidal Current to the grid. These tasks are further reviewed in this paper. Simulating results are obtained for the normal regime.
Grid integration phenomenon is more complex with compare to the standalone system. So we compare both of the result of the grid connection and the standalone systems then we find some solution regarding to this.

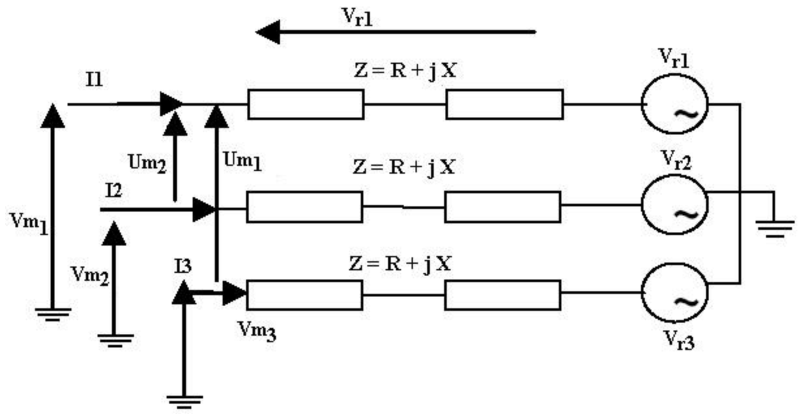


***Figure 4. Thevenin equivalent circuit of the utility grid***

## IV. MPPT

The maximum power point of any PV varies with the variation of the atmospheric conditions (solar irradiance and temperature). This means that there is always one optimum terminal voltage for the PV array to operate at with each condition to obtain the maximum power out of it i.e. increase the array's efficiency.
There is a need to implement an MPPT algorithm to track changes and extract the maximum power from the PV solar panel, because the power generated by the panel is significantly affected by variations in irradiation, temperature and panel voltage, revealing a non-linear characteristic.

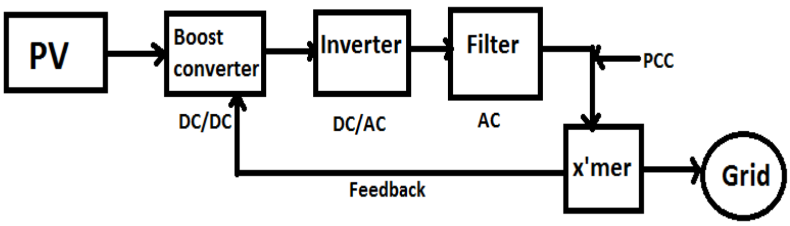


***Figure 5. Grid connected solar PV***

There is a need to implement an MPPT algorithm to track changes and extract the maximum power from the PV solar panel, because the power generated by the panel is significantly affected by variations in irradiation, temperature and panel voltage, revealing a non-linear characteristic. An MPPT system can be defined as an electronic device that operates the PV panel in such way that it delivers all the power it can produce.



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*a) Why MPPT is important?*

The system is always working at the peak power point regardless of changes in load and weather conditions. In the source side a boost converter is connected to a solar panel in order to enhance the output voltage. By changing the duty cycle of the boost converter appropriately the source impedance is matched with that of the load impedance.

The MPPT system is basically an electronic device inserted between the PV array and the load.

## V. METHODS FOR MPPT

When using P&O method, the PV array current (or voltage) is perturbed by a small Increment ($\Delta I$ or $\Delta V$) and the resulting change in power ($\Delta P$) is measured. If P is positive, the next perturbation is also in this direction (with same algebraic sign). If $\Delta P$ is negative, the system's operating point has moved away from the MPP, thus the sign of the perturbation will be changed in order to step back, towards the MPP. Despite of its advantages, this method has certain limitations: **-** It becomes difficult for the MPPT algorithm to find the location of the MPP at low solar irradiances because the MPP curve flattens out. **-** The P&O algorithm doesn't locate the MPP, but oscillates around it, changing the sign of the perturbation after each measurement. Finally, it is known that most of the P&O implementations can have random behaviour under rapidly changing solar irradiance [5].

And some of the advanced controlling techniques based on artificial intelligence known as fuzzy logic controller and neural network controller.

### *A. Perturb and Observe (P&O) Method*

The P & O algorithm, as shown below in figure, operates by increasing or decreasing the array terminal voltage, or current, at regular intervals and then comparing the PV output power with that of the previous sample point. If the PV array operating voltage changes and power increases (dP/dV PV > 0), the control system adjusts the PV array operating point in that direction; otherwise the operating point is moved in the opposite direction. At each perturbation point, the algorithm continues to operate in the same manner. The main advantage of this approach is the simplicity of the technique. Furthermore, previous knowledge of the PV panel characteristics is not required. In its simplest form, this method generally exhibits good performance provided the solar irradiation does not vary too quickly. At steady state, the operating point oscillates around the MPP voltage and usually fluctuates lightly. For this reason, the perturbation frequency should be low enough so that the system can reach steady state before the next perturbation [6].

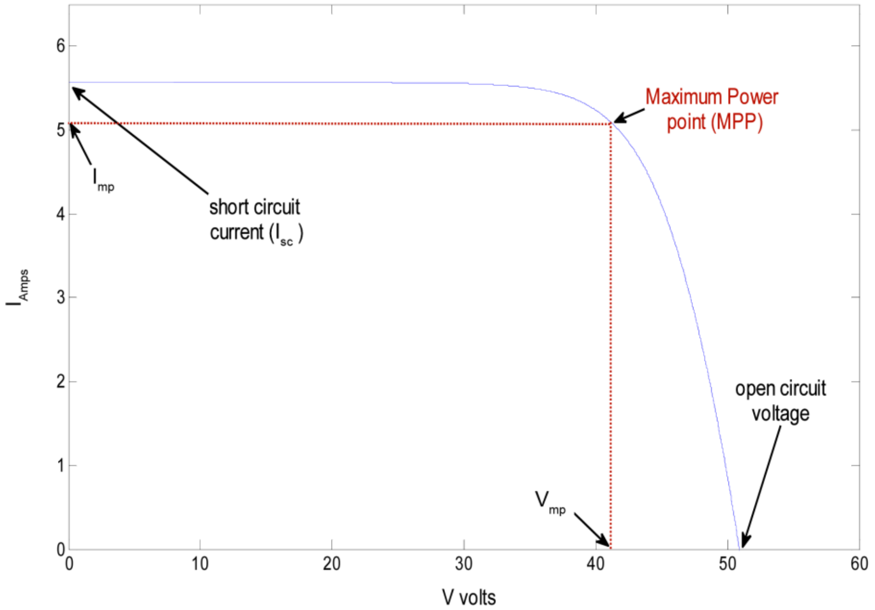


***Figure 6. I-V characteristics of a typical PV panel with MPPT control.***

The P & O algorithm [5] [6], as shown below in (**Figure 2**), operates by increasing or decreasing the array terminal voltage, or current, at regular intervals and then comparing the PV output power with that of the previous sample point. If the PV array operating voltage changes and power increases (dP/dV PV > 0).



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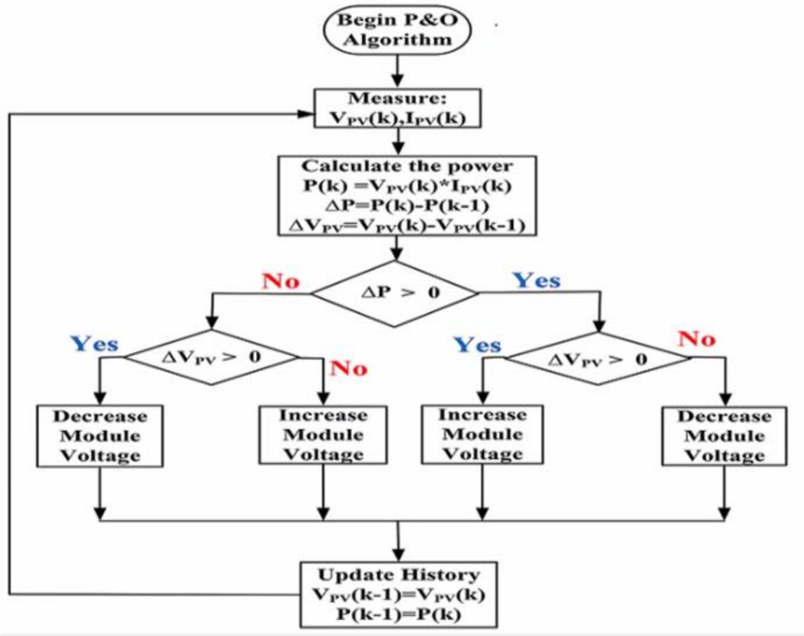


***Figure 7. Flowchart of the P & O method***

### *B. Incremental Conduction method*

The incremental conductance (IC) algorithm which is shown in figure, seeks to overcome the limitations of the perturbation and observation algorithm by using the incremental conductance of the photovoltaic. This algorithm works by searching for the voltage operating point at which the conductance is equal to the incremental conductance. At this point, the system stops perturbing the operating point. The advantage of this algorithm is that it has the ability to ascertain the relative “distance” to the maximum power point (MPP), therefore it can determine when the MPP has been reached [7]. Also, it is capable of tracking the MPP more precisely in highly variable weather conditions, and exhibits less oscillatory behaviour around the MPP compared to the P & O method, even when the P & O method is optimized. Nevertheless, the IC algorithm has the disadvantage that instability can result due to the use of a derivative operation in the algorithm. Also under low levels of insolation, the differentiation process difficult and prone to measurement noise; and results can be unsatisfactory.

The controller senses the grid voltage and grid current and gives the corresponding grid active and reactive power. And also the power controller sense the inverter output voltage and current and give the corresponding active, reactive power. After that through PI controller we get the direct axis reference current ($I_{dref}$) which is the one input of another Controller which is current controller. Here we also sense the load voltage and load current and determine the RMS value of the load. By using PI controller we can get quadrature axis reference current which is another input of current controller.

The flowchart of the incremental conduction method is shown below. Therefore it can determine when the MPP has been reached. Also, it is capable of tracking the MPP more precisely in highly variable weather conditions, and exhibits less oscillatory behaviour around the MPP compared to the P & O method, even when the P & O method is optimized.



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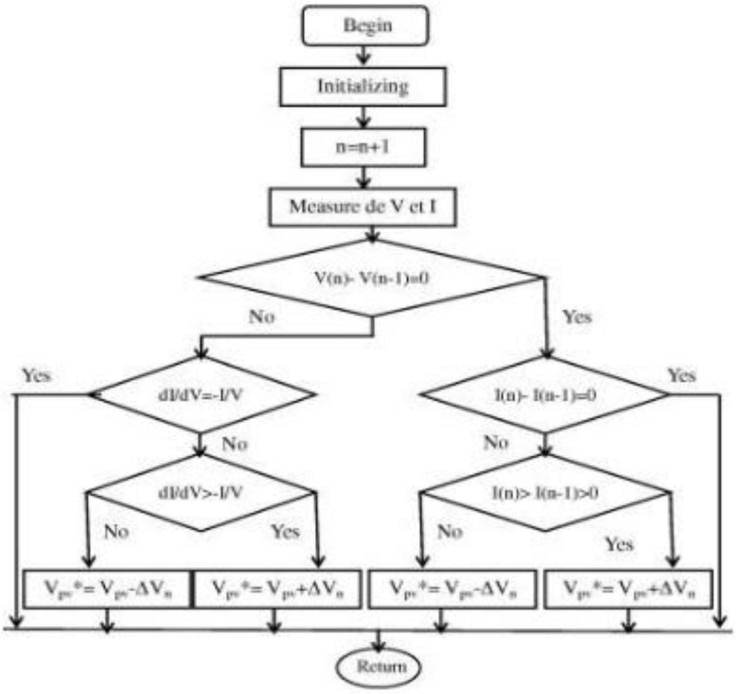


*Figure 8. Flowchart of the IC method*

### *C. Fuzzy logic controller*

Fuzzy logic control in MPP applications has become increasingly popular as microcontroller processing power has improved, and costs have reduced. Fuzzy logic controllers have three stages, fuzzification, rule base table lookup, and defuzzification. During fuzzification, numerical input variables are converted into linguistic variables based on a number of defined membership functions. Typically, the greater the number of membership functions used, the more accurately the controller will operate [8].

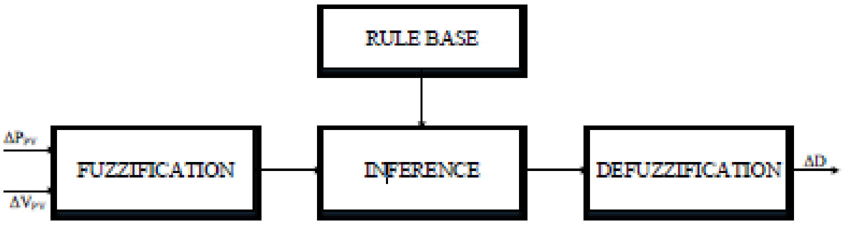


*Figure 9. Fuzzy Logic Controller*

The input to the fuzzy logic controller is an error signal, E, and the change in error; CE. The user has the flexibility of choosing how to compute E and CE. These signals are then converted to linguistic variables which define how the system is to be controlled by the user. The advantage of fuzzy logic control is that it does not need an accurate mathematical model of the system, and it is capable of handle system non-linearity. The main disadvantage of fuzzy logic control is that the effectiveness depends on user knowledge and competency in choosing the correct error computation and developing a suitable rule base table based on the chosen membership functions. Optimised variants of the fuzzy logic MPPT system have been proposed, including adaptive strategies that tune the membership functions and rule base table in real time.



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***Table 2. Fuzzy rule base inference***

| 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 |

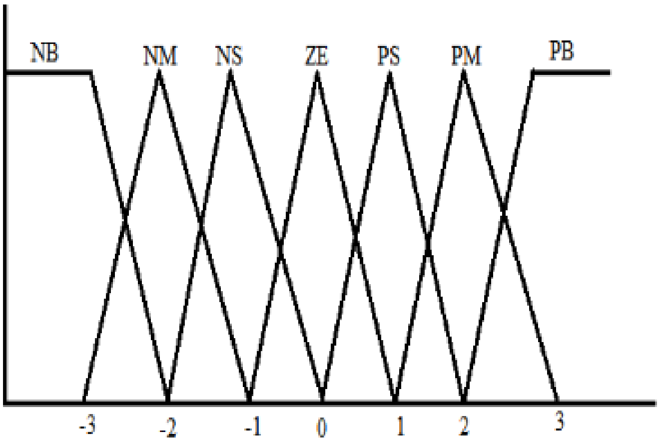


***Figure 10. Membership function***

### *D. Neural network controller*

A neural network approach is presented by T. Hiyama and L. Zhang. To guarantee accurate MPPT operation, the neural network has to be trained to operate with the PV array and adjust for time varying characteristics of the system. Once trained, the neural network does not require detail information about the PV system [9].

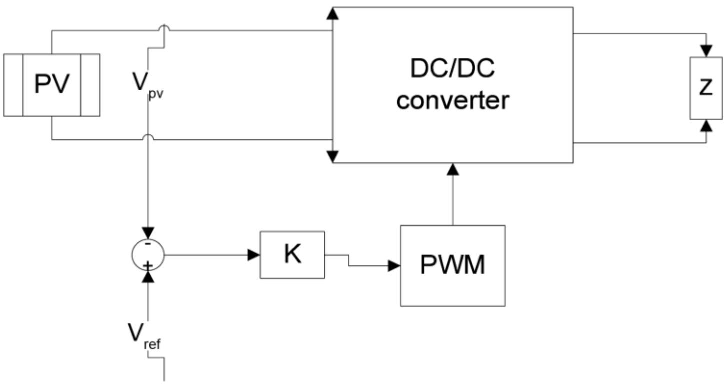


***Figure 11. Voltage-feedback with PWM modulation***

It operates like a black box model. In, the neural network has three layers: input layer, hidden layer, and output layer. The number of nodes in each layer varies and is user dependent. The PV array *Voc* and *Isc* are used as the input variables. The output is usually represented by one of several reference signals, or the duty cycle signal used to drive power converter. The hidden layers act to achieve the MPP.



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Fuzzy logic having the most popular technique known as mamdani method in its inference block and centre of gravity in defuzzyfication block.

## VI. SIMULATION AND RESULTS

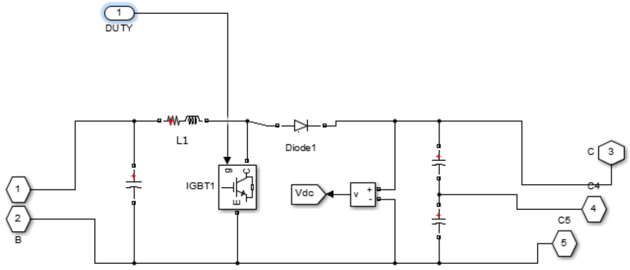


*Figure 12. Boost converter*

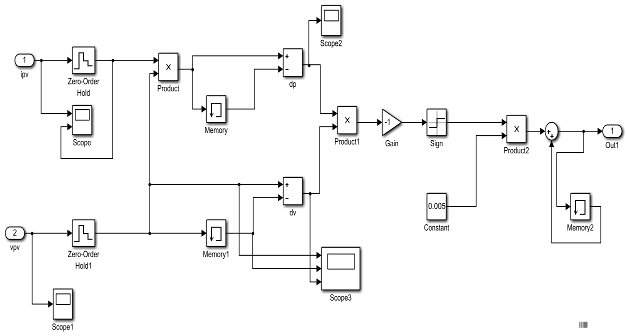


*Figure 13. P&O block*

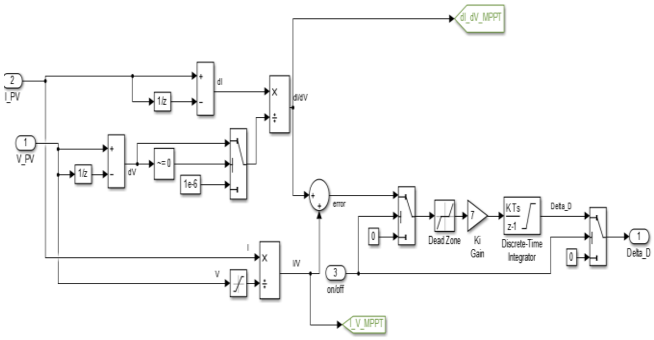


*Figure 14. IC block*



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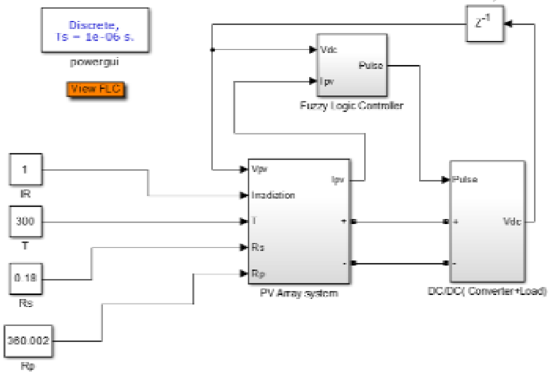


***Figure 15. Simulink of FLC with boost converter***

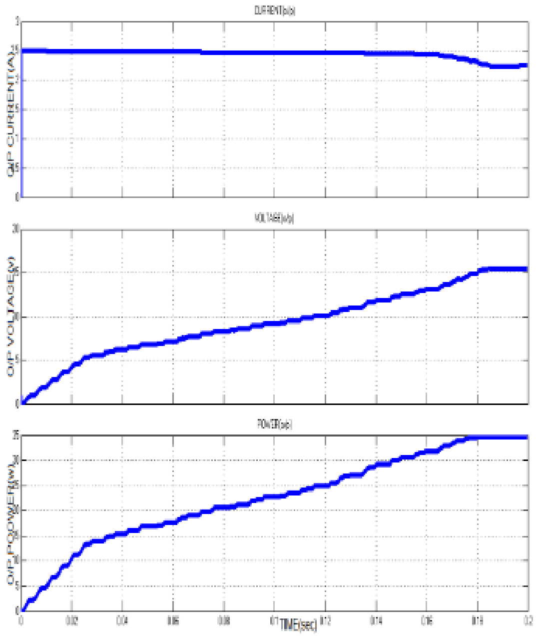


***Figure 16. Output current/voltage/power with P&O con***

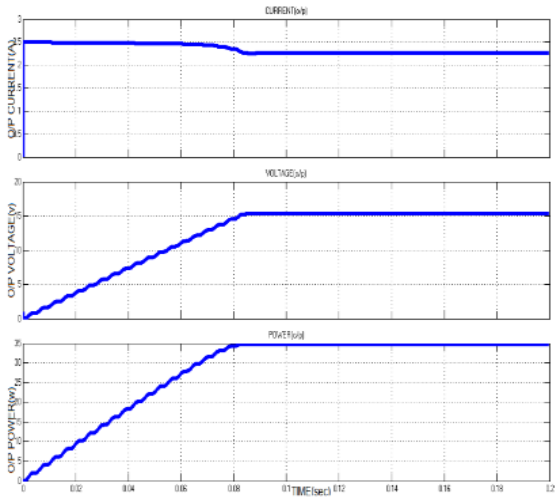


***Figure 17. Output current/voltage/power of FL controller***



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***Table 2. Comparison between P&O and FLC at 0.1 second***

| OUTPUT | P&O | FLC |
|---|---|---|
| Current | 2.476 A | 2.272 A |
| Voltage | 9.197 V | 15.34 V |
| power | 22.77 W | 24.75 W |

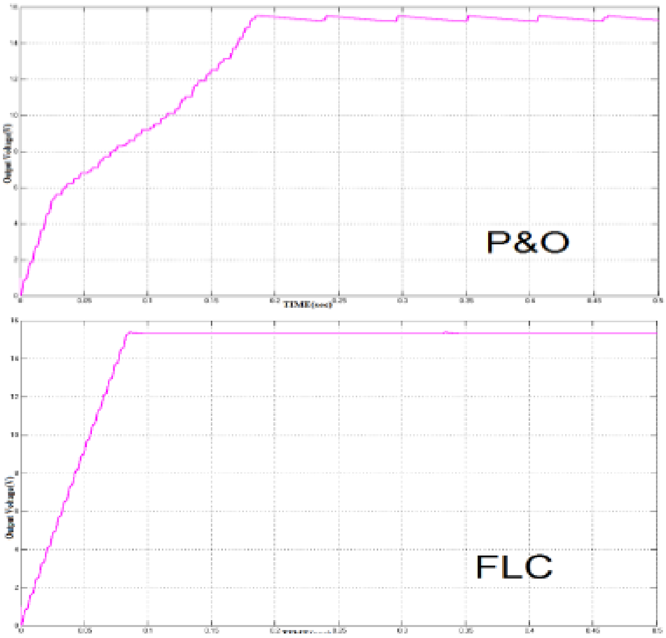


***Figure 18. Comparison of output voltage of P&O and FLC***

## VII. DISCUSSION

As we seen above results we can easily justify that the all the techniques for MPPT has owing advantages and some of disadvantages. There in two conventional techniques P&O and IC the best suitable is IC method, where as we compare this both with the fuzzy logic then the fuzzy is best suitable for that tracking.

## VIII.CONCLUSION

This paper contains the overview of the different MPPT techniques. When using solar panel in residential locations, the objective is reduced the payback time. To do so, it is minimizing the ripple around the MPP. Therefore we using different MPPT techniques in this paper and after showing all the results conclude that the advanced controlling fuzzy logic is best suitable for the necessary to constantly and quickly track the maximum power point. Furthermore, The efficiency of ANN and fuzzy control is high but high amount of computations are required. The efficiency of conventional techniques is low as compared to ANN and fuzzy. P&O contains a lot of oscillations because the voltage fluctuates around MPPT, and IC is sensitive to quick variations in the irradiance, whereas FLC and ANN gives a smooth result and have quick response.

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