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Evaluation of Optimum MPPT Controllers for PV Cells using Matlab Simulink Platform

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Abstract: Nowadays, the Photovoltaic cell is one of the most essential parts in the electrical field to convert photo light to voltage and current, at the desired output voltage and frequency by using various control techniques The Solar panel can produce maximum power at a particular operating point called Maximum Power Point (MPP).To produce maximum power and to get maximum efficiency, the entire photovoltaic panel must operate at this particular point. Maximum power point of PV panel keeps on changing with changing environmental conditions such as solar irradiance and cell temperature. Thus to extract maximum available power from a PV module, MPPT algorithms are implemented. The output power of a photovoltaic (PV) module depends on the solar irradiance and the operating temperature; therefore, it is necessary to implement MPPT controllers to obtain the maximum power of a PV system regardless of variations in climatic conditions. This project reviews the most used MPPT algorithms, which are Perturb and observe (P&O), Incremental conductance method (ICM), and Fuzzy logic control (FLC).
Keywords: Perturb and observe, PV, MPPT, Fuzzy, Power

I. INTRODUCTION

Renewable energy also called non-conventional type of energy sources are the sources which are continuously replenished by natural processes. Solar energy, bio-energy (bio-fuels grown sustainably), wind energy and hydropower etc., are some of the examples of renewable energy sources .

Photovoltaic (PV) offers an environmentally friendly source of electricity since it is clean, pollution-free, and inexhaustible.

However, the output from a PV solar cell alone is not good enough to input into an electricity bank or the main grid because its output is not constant in terms of voltage.

This raises a need to design a controller which can calculate and extract the maximum power point (MPP) at any instant from the solar cells. Maximum Power Point Tracking, frequently referred to as MPPT is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of at that time.

II. SOLAR ENERGY

Solar energy is a non-conventional type of energy. Solar energy has been harnessed by humans since ancient times using a variety of technologies. Solar powered electrical generation relies on photovoltaic system and heat engines. To harvest the solar energy, the most common way is to use photo voltaic panels which will receive photon energy from sun and convert to electrical energy. Solar technologies are broadly classified as either passive solar or active solar depending on the way they detain, convert and distribute solar energy.

Active solar techniques include the use of PV panels and solar thermal collectors to strap up the energy. Passive solar techniques include orienting a building to the sun, selecting materials with favourable thermal mass or light dispersing properties and design spaces that naturally circulate air. Solar energy has a vast area of application such as electricity generation for distribution, heating water, lighting building, crop drying etc.

The comparison between different photovoltaic cells can be done on the basis of their performance and characteristic curve. The parameters are always given in datasheet. The datasheet make available the notable parameter regarding the characteristics and performance of PV cells with respect to standard test condition. Standard test conditions are as follows:

Temperature (Tn) = 250C

Irradiance (Gn) = 400 W/m2.

III. PROBLEM STATEMENT

Photovoltaic (PV) systems have become an important source of power for a wide range of applications. Unfortunately, PV generation systems have two major problems: the conversion efficiency of electric power generation is very low (9-17%), especially under low irradiation conditions, and the amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, the solar cell V-I characteristic is nonlinear and varies with irradiation and temperature.

IV. PROJECT OBJECTIVES

The primary objective of this project is to design an MPPT controller for photovoltaic systems.
In addition, this project has various objectives, which comprise of:
1) To design the optimum controller by simulation for the maximum power point tracking.
2) To analyze simulation results of the maximum power point tracking.

V. MAXIMUM POWER POINT TRACKING

Maximum power point plays an important role in photovoltaic system because they maximize the power output from a PV system for a given set of conditions, and therefore maximize the array efficiency. The different methods
used to track the maximum power point are:
(i) Perturb and Observe method
(ii) Incremental Conductance method
(iii) Parasitic Capacitance method
(iv) Constant Voltage method
(v) Intelligent Control methods (Fuzzy Logic, Artificial Neural Network and Genetic Algorithms etc).

A. Perturb and Observe Algorithm:

The Perturb and Observe (P&O) algorithm is an extensively habituated system of Maximum Power Point Tracking(MPPT) used to control the power affair of a photovoltaic(PV) system. It's a simple and robust algorithm that's generally used in small-scale PV systems. The P&O algorithm works by continually conforming the operating voltage of the PV array and measuring the corresponding power affair. The algorithm starts by setting the voltage to an original value and also perturbing the voltage slightly in one direction. However, the algorithm continues to undo MPPT the voltage in that direction, If the power affair increases. However, if the power affair diminishes, the algorithm changes direction and starts perturbing the voltage in the contrary direction. This process continues until the maximum power point is reached.

The principle of P&O is to create a perturbation by decreasing or increasing the duty cycle of boost converter and then observing the direction of change of PV output. If at any instant k, the output PV power P(k) & voltage V(k) arengreater than the previous computed power P(k−1) & V(k-1), then the direction of perturbation is maintained, otherwise it is reversed.

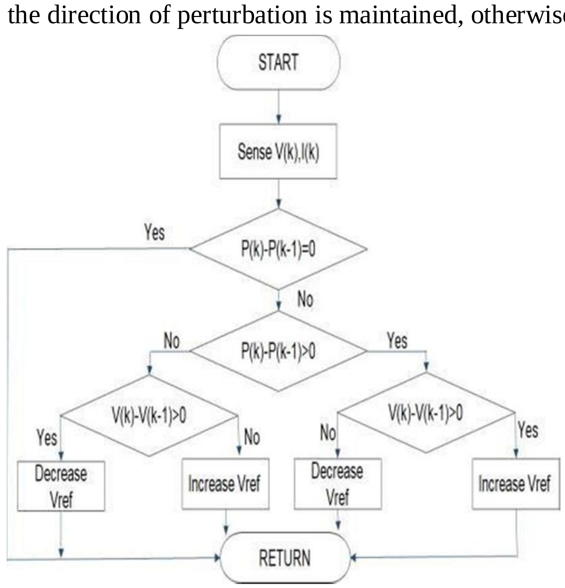

Fig.: Flowchart of P&O algorithm

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Despite the P&O algorithm is easy to implement it has mainly the following drawbacks:

- It cannot always operate at the maximum power point due to the slow trial and error process, and thus the maximum available solar energy from the PV arrays cannot be extracted all the time.
- The PV system always operates in an oscillating mode which leads to the need of complicated input and output filters to absorb the harmonics generated.

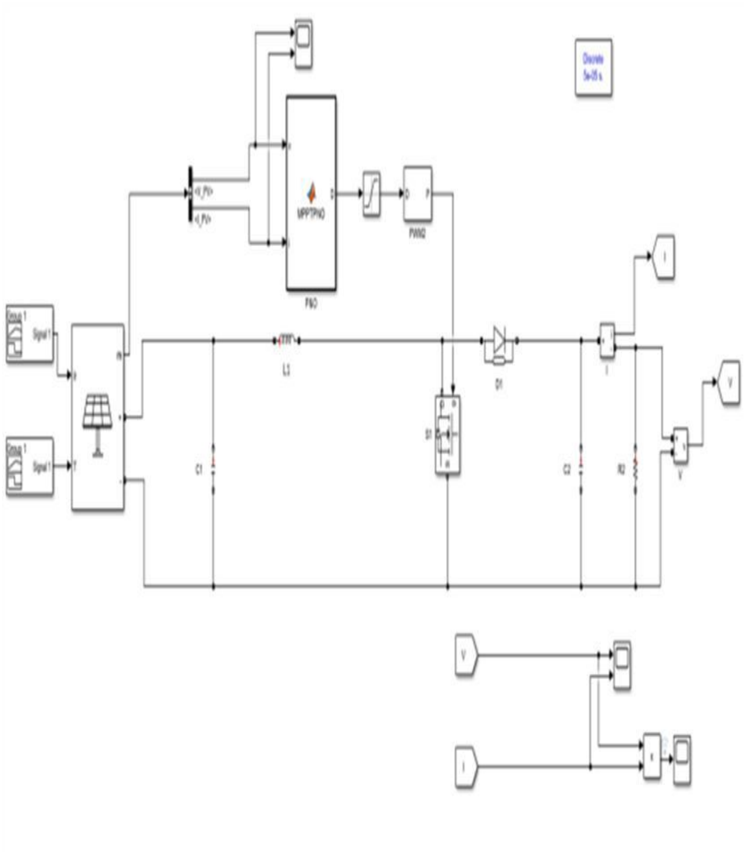


Fig.: Simulation of Perturb and Observe MPPT

VI. RESULTS

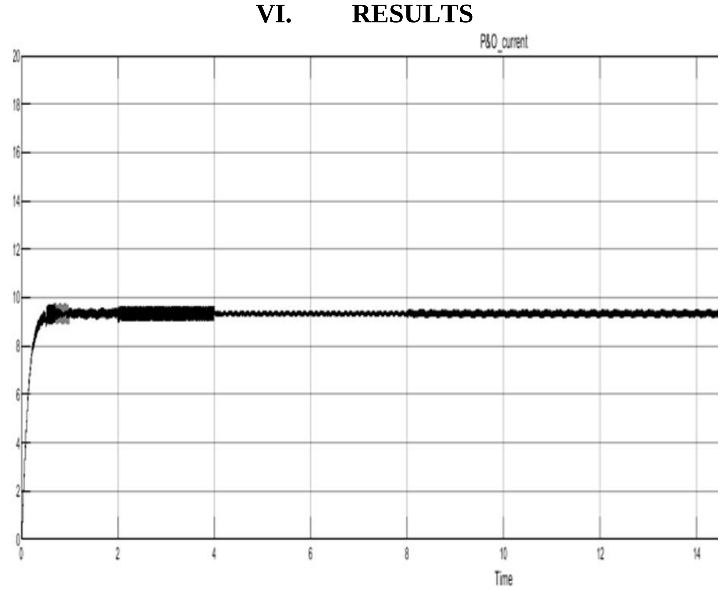


Figure: Output Current Form

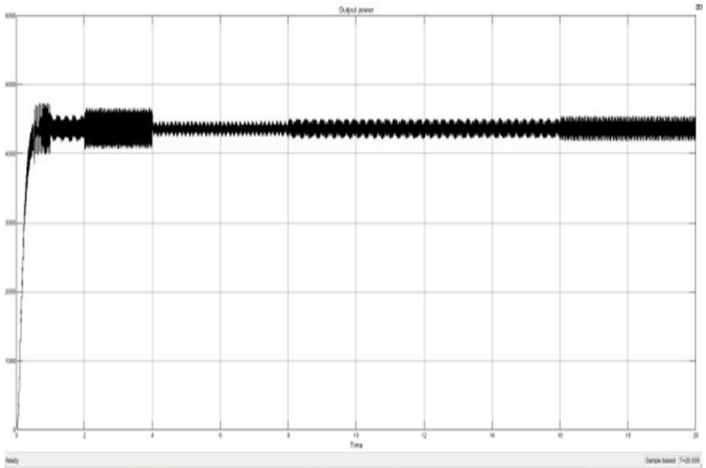


Figure: Output Voltage Form

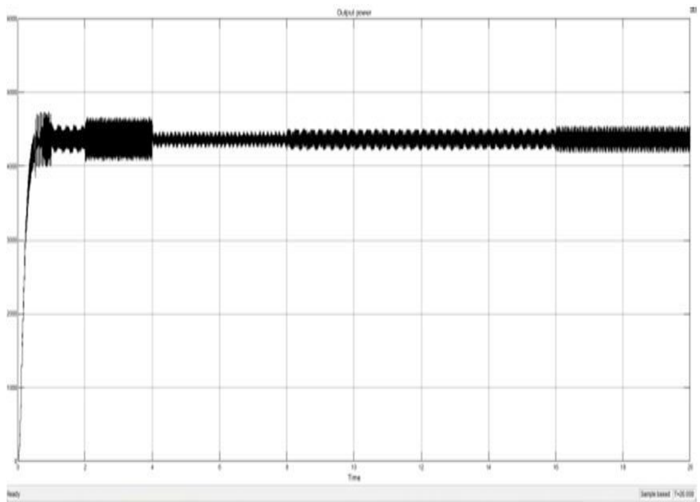


Figure: Output Power Form

B. Conventional Incremental Conductance Algorithm:

The incremental conductance algorithm detects the slope of the P–V curve, and the MPP is tracked by searching the peak of the P–V curve. This algorithm uses the instantaneous conductance I/V and the incremental conductance dI/dV for MPPT. Depending on the relationship between the two values, as expressed the location of the operating point of the PV module in the P–V curve can be determined, i.e., (1) indicates the PV module operates at the MPP, whereas (2) and (3) indicate the PV module operates at the left and right side of the MPP in the P–V curve, respectively.

di/dv = -I/V—(1) di/dv > -I/V—(2) Di/dv < -I/V (3)

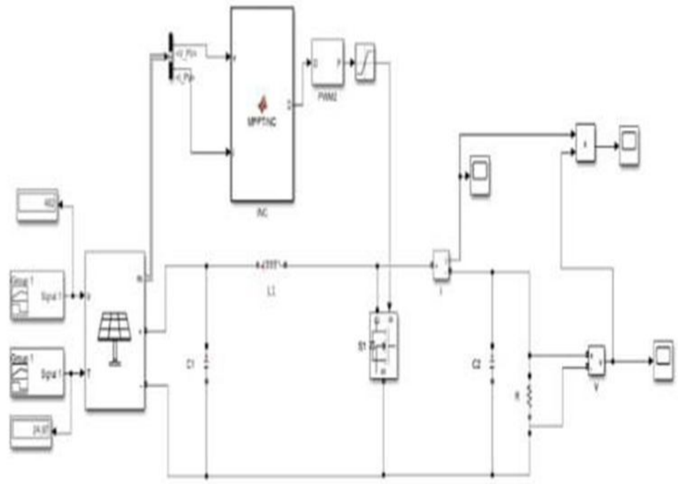
The above equations are obtained from the concept where the slope of the P–V curve at MPP is equal to zero, i.e.:

dp/dv=0—(4)

By rewriting (4), the following equation is obtained:

I+Vdi/dv=0 —(5)

In the conventional incremental conductance algorithm, (5) is used to detect the MPP, and the voltage and current of the PV module are measured by the MPPT controller. If (2) is satisfied, the duty cycle of the converter needs to be decreased, and vice versa if (3) is satisfied, whereas no change in the duty cycle if (5) is satisfied.



Simulation Model

VII. RESULTS

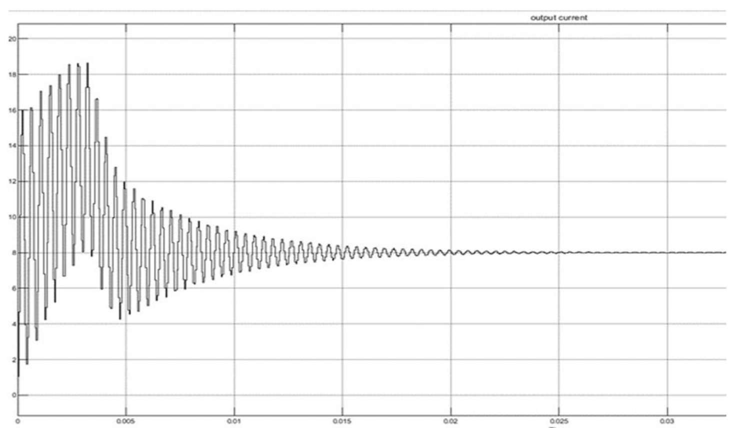


Figure: Output Current Form

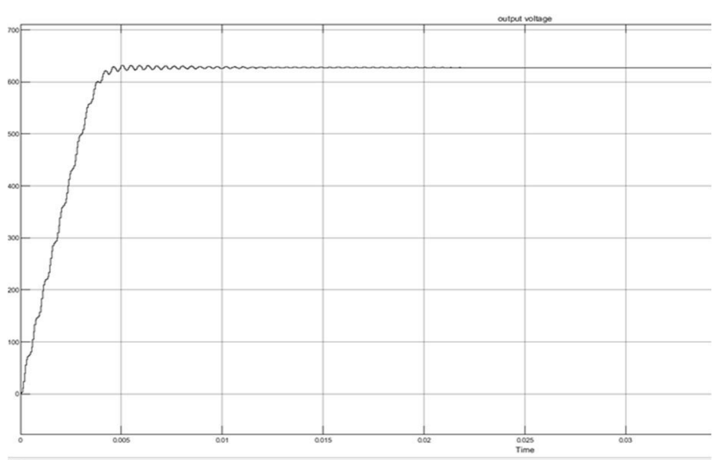


Figure: Output Voltage Form

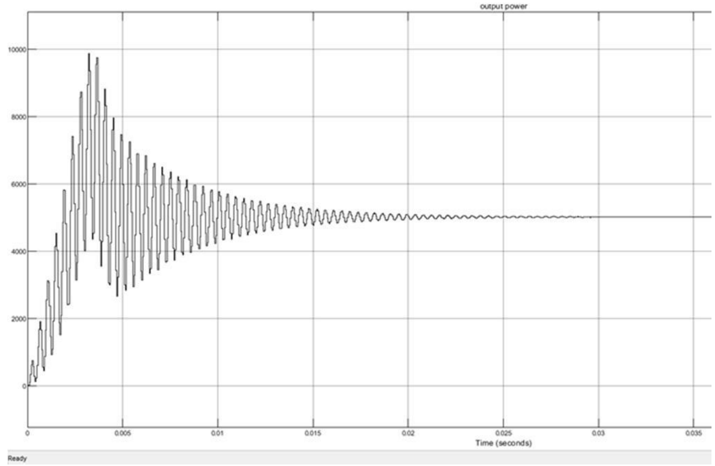


Figure: Output Power Form

C. *Fuzzy Logic Algorithm*

Fuzzy logic is one of the most powerful control methods . It is known by multi-rules-based resolution and multivariable consideration. Fuzzy MPPT is popular for over a decade. Fuzzy logic controllers have the advantages of working with imprecise inputs, no need to have accurate mathematical model, and it can handle the nonlinearity[. The flow chart of Fuzzy MPPT and Simulink model of proposed Fuzzy MPPT. It consists of two inputs and one output. The two FLC input variables are the error (E), change of error (CE) and output variable is duty cycle (D).

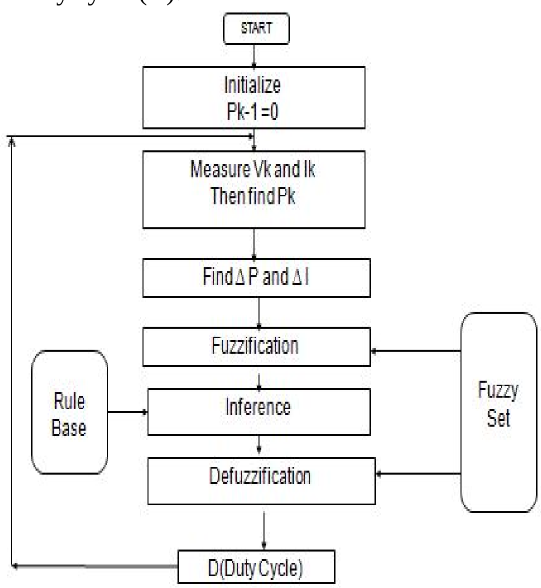


Fig: Flow chart of Fuzzy MPPT

By applying membership function values, the input variables e & ce and the output variable d are transformed into linguistic variables throughout the fuzzification process. These variables are expressed as NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big) in various fuzzy levels. In this work, triangle membership functions are taken into consideration, presuming that there is only one dominant fuzzy subset for each given input. It displays the membership functions for e, ce, and d. Heuristic-defining rules are essential for modeling the FMPPT, and the fuzzy rule base—a collection of if then rules—is utilized to handle fuzzified inputs. Based on experimental knowledge of the issue or PV system characteristics, fuzzy rules are discovered. The number of linguistic variables in the input Membership functions affects how many rules there are. In this study, there are 25 fuzzy control rules in the fuzzy rules. The composition operation carried out by a fuzzy inference system creates a logical choice based on fuzzy rules, from which a control output is produced. In this study, the Mamdani fuzzy inference approach with Max-Min composition operation was applied,depicts the three sections that make up the fuzzy rule database.

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1) Region-1

In this region, the PV curve's slope, or e(k), is negative. This suggests that the PV module's operating point is to the right of the MPP and that the duty ratio needs to be raised in order to follow the MPP. To determine the duty cycle increase's magnitude, utilize the ce(k). The operating point will be moving towards MPP from the right if e(k) is NS and ce(k) is positive. To stop the system from oscillating at this point, the output is set to ZE.

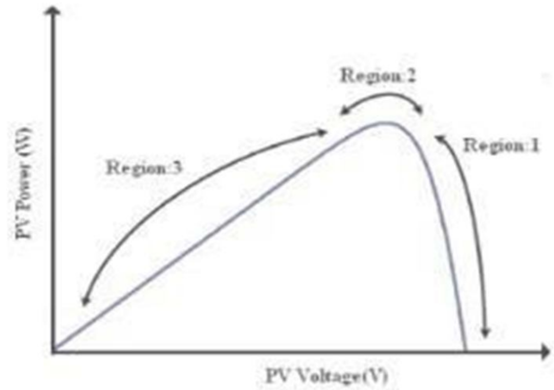

Fig: P-V curve of PV module indicating different regions for fuzzy rule set

e\ce	NB	NS	ZE	PS	PB
NB	ZE	PB	PB	PB	PB
NS	PB	PS	PS	ZE	ZE
ZE	PS	ZE	ZE	ZE	NS
PS	ZE	ZE	NS	NS	NB
PB	PB	ZE	NS	NB	ZE

2) Region-2

E(k) is ZE in this area, indicating that the operating point is around MPP. Therefore, the guiding concept in such circumstances should be to retain the same obligation ratio.

The operational point is moving towards the MPP from the left if ce(k) is NB. Therefore, the duty ratio is reduced. The control rule should be PS to suppress the change in duty cycle magnitude in the opposite direction, preventing the operating point from shifting to the right side of the MPP.

3) Region-3

The operational point is found on the left side of the MPP when e(k) is positive. Therefore, the duty cycle needs to be reduced. The ce(k) is used to estimate how much of the duty ratio should be reduced.

The operational point is approaching the MPP from the left side when ce(k) is negative at this time. In order to avoid a reduction in duty cycle and oscillation of the system near the operational point, the controller should now set the output to ZE.

The duty cycle of the DC-DC converter changes as a result of FLC. Defuzzification transforms the linguistic value of the output into a clear output value. An aggregated output fuzzy set is used as the input to the defuzzification process, and the output is a single number. There are a lot of defuzzification methods that have been suggested in the literature. The Centre of Gravity (COG) or centroid defuzzification method is the approach that is most frequently utilised . The centre of gravity (centroid) is identified by the defuzzifier in this manner, and the FLC output is based on that value.

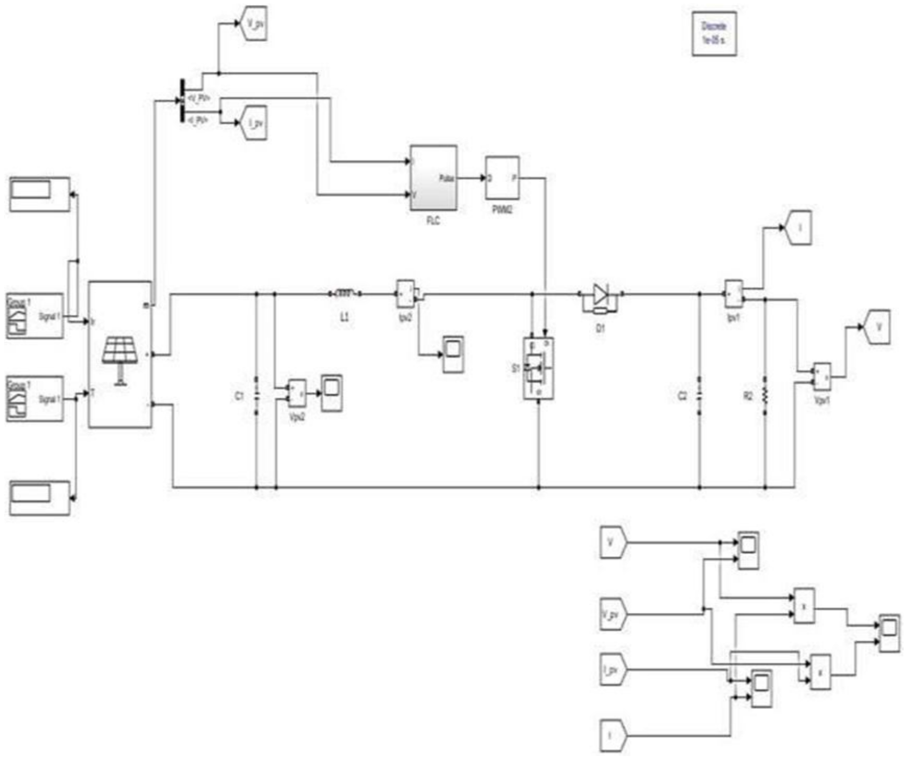

Fig: The figure above shows simulation model of fuzzy technique.

VIII. RESULTS

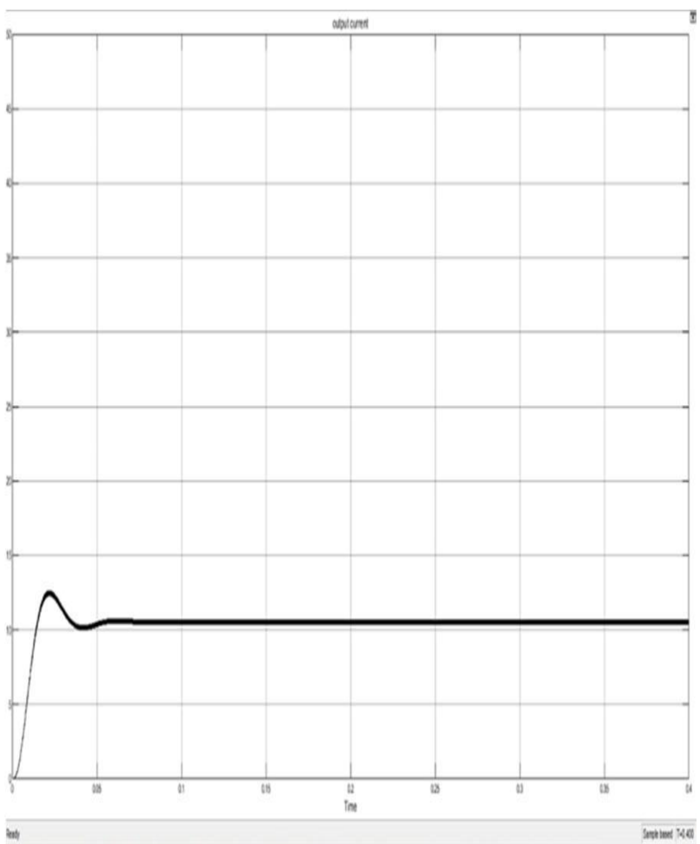

Figure: Output Current form

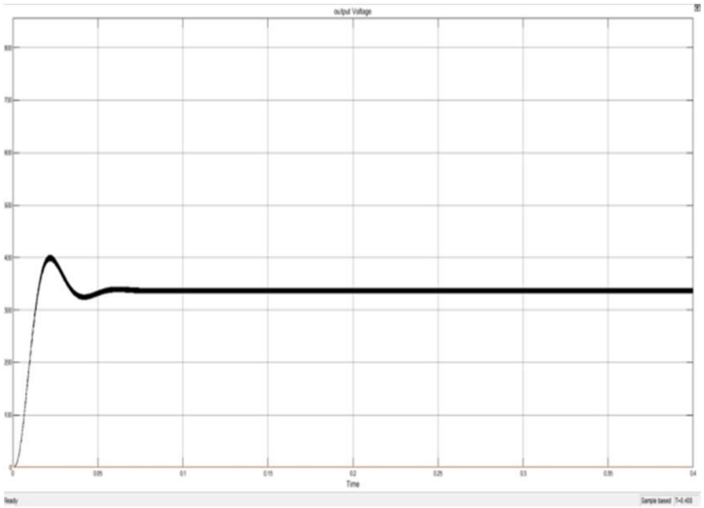

Figure: Output Voltage form

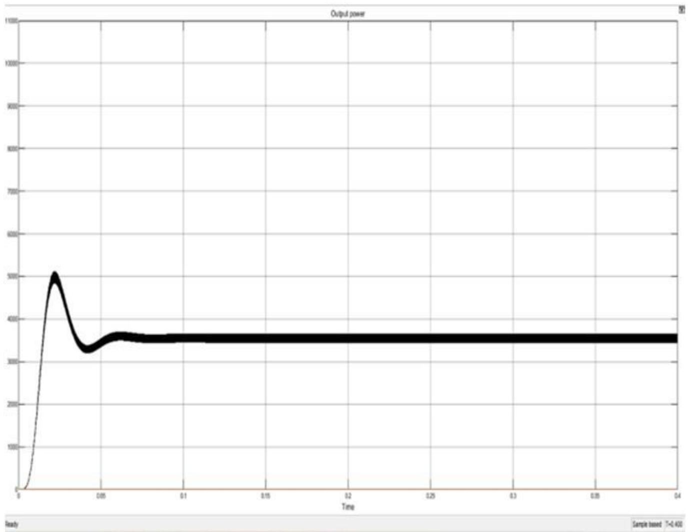

Figure: Output Power form

VIII. COMPARISION RESULTS

Techniques	Temperature (degree)	Irradiance (W/m^2)	Output Power (Kilowatts)
Peturb &Obs(P&O)	25	400	4.1
ICM	25	400	5.2
Fuzzy Logic	25	400	5.69

X. CONCLUSION

This paper presents an evaluation comparision of optimum mppt controllers for pv cell using matlab simulink platform which represents the output power of a photovoltaic (PV) module depends on the solar irradiance and the operating temperature; therefore, it is necessary to implement MPPT controllers to obtain the maximum power of a PV system regardless of variations in climatic conditions which proves Fuzzy controller shows better performance with lower oscillation.

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