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Grid integrated PV system with different controlling MPPT techniques

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Abstract – *This paper presents the knowledge about the solar photovoltaic (PV) system which connected with the grid and how we can establish or how we can enhance the power regarding to our requirement. This possibility achieved by means of the maximum power point tracking (MPPT). MPPT is connected in between solar PV output and boost converter output to control voltage and current. There are various MPPT methods available for tracking maximum power from this we going to discuss some of the methods the compare the regarding to power output and gives the best suitable method from all of them.*

Keywords – *MPPT; perturb & observation (P&O); incremental conductance (IC); Fuzzy logic; Neural network*

I. INTRODUCTION

As we know that day by day the requirement of the electrical energy is being increase with the increasing manner of the population. As the demand increase our conventional sources not capable to fulfil that huge kind of energy requirement. To consider this fact we must be find some new way for satisfy energy need. Various non-conventional resources available for produce electrical energy but some of them having less efficient to energy conversion. So concentrate on all factors for those sources, solar energy gives the best approach. Solar PV also some time lack in energy output so one mechanism known as maximum power point tracking (MPPT) is applied on it to increase power output.

Solar PV panel is the current controlling device also constant current. The output of solar PV voltage is some time change with change the input of solar PV known as irradiance and the temperature. Solar PV is having non-linear characteristic, so we should making simulation model for understanding its output in MATLAB [1]. There are two ways for tracking maximum power one is by mechanical tracking by adjusting the PV panel and second one is electrically in this we get maximum output by control the duty cycle of the boost converter or by controlling the switching frequency of the inverter.

MPPT is actually giving the point which is at maximum from reference of the open circuit voltage and short circuit current in I-V characteristics. That can be controlling by the value of the duty cycle of the converter. So in this paper clear cut performance in MATLAB Simulinkfor MPPT techniques. Also the grid integration is also done through the dqo-abc transformation in closed loop system. Observe is to be done in various changing irradiance and study for comparison of different technique for chose best one [2].

II. SOLAR PV MODULE

PV module is generally p-n junction material in which two material combine with some of impurities, the process known as doping. Solar PV is a module which working on photovoltaic phenomenon. Here sun power 305-WHT module is being used and its parameter is shown below in table 2 also it I-V and P-V characteristics shown in figure 1.

Table 1.Parameters of Equation

t	diode current (A)
V_d	diode voltage (V)
I_0	diode saturation current (A)
nI	diode ideality factor, a number close to 1.0
k	Boltzman constant = 1.3806e-23 J.K-1
q	electron charge = 1.6022e-19 C
T	cell temperature (K)
Ncell	number of cells connected in series in a module

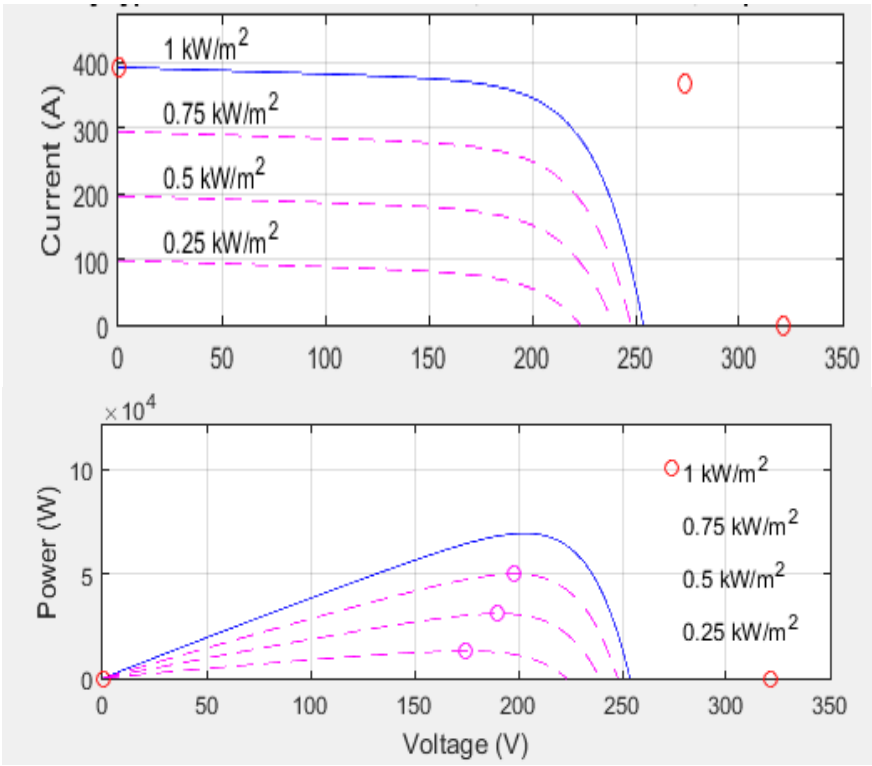


Figure 1. I-V and P-V characteristics of solar PV

$$I_d = I_0 \left[\exp\left(\frac{V_d}{V_t}\right) - 1\right] \quad (1)$$

$$Vt = kT*nl*cell \quad (2)$$

Equations (1) and (2) are used to define solar PV module characteristics.

Table 2.Parameters of PV Module

Maximum power Pmax	305.22 W
Open circuit voltage (Voc)	64.2 V
Voltage at maximum power point (Vmp)	54.7 V
Cell per module (Ncell)	96
Short circuit current (Isc)	5.96 A
Current at maximum power point (Imp)	5.58 A

III. MAXIMUM POWE POINT TRACKING

Generally, the power is a product of voltage and current. Here as we seen in PV characteristics the maximum power is track at certain value of the voltage and current. So it is beneficial for us that we track maximum power in any condition like variation in environmental factors and also at different places.

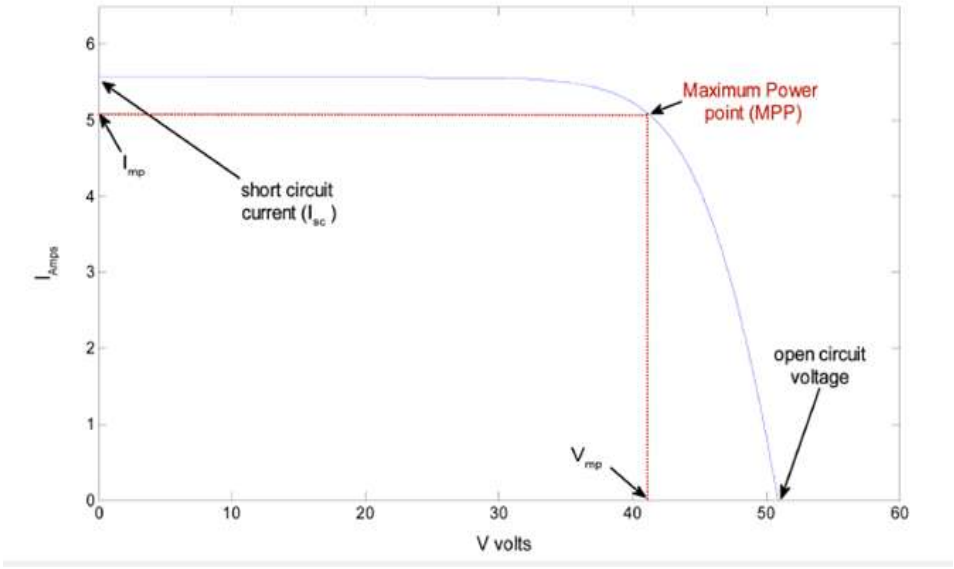


Figure 2.MPP in I-V Characteristics

This phenomenon controls the switching of the duty cycle. For example if output voltage of boost converter is less then it increases the value of duty cycle and vice versa.

List of MPPT methods which going to discussed

- Perturb & Observation (P&O)
- Incremental conductance (IC)
- Fuzzy Logic controller
- Artificial Neural Network

A. PERTURB & OBSERVATION

This method is having its flexible nature hence it used widely in solar PV application. The other name of this method is 'Hill climbing'. As name suggest it working on perturbation so it take the value of output from the solar PV (Vpv) and provide perturbation on it and noticed that what happening on the module output. It measure the value Vpv and Ipv and define Ppv(k) at the interval of k. compare this value with the previous value Ppv(k-1) and see that if the value of the power is increase then it take continuous its perturbation in same direction and adjust the value of Vpv. If the value of power isdecrease then the perturbation going to reverse direction and adjust the value of Vpv. So by doing this changes it try to make oscillate the power near to its MPP[3].

B. INCREMENTAL CONDUCTANCE

The advantage of this method over the P&O method is that it can track maximum power even in rapidly change in irradiance and temperature. This method check the differentiate of power in terms of voltage and current then it check the condition if the value of MPP is negative on right side and at left side MPP is positive see in figure 3.

$dI/dV = - I/V$ at MPP (3)

$dI/dV > - I/V$ left of MPP (4)

$dI/dV < - I/V$ right of MPP (5)

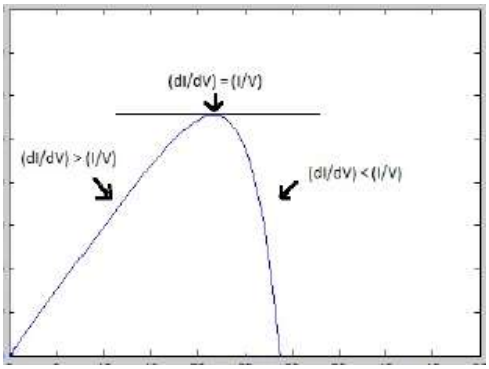


Figure 3.Tracking in IC method

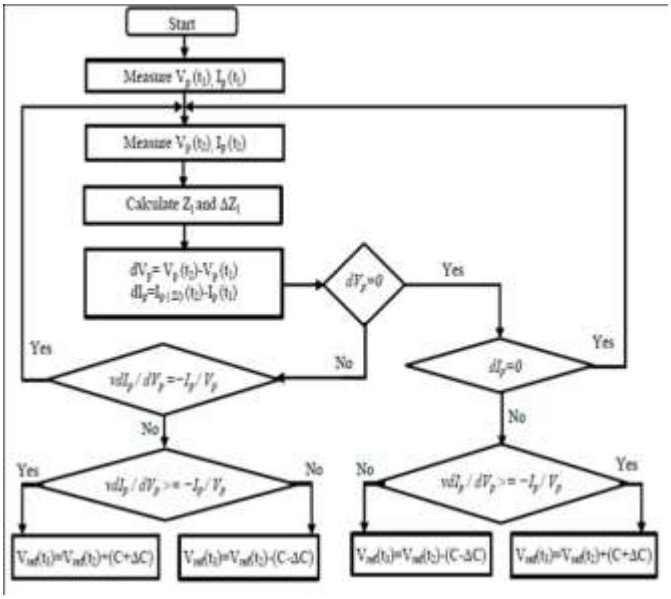


Figure 4.Flowchart of IC method

So by adjusting this differentiates we can track in fraction of time. But there are some fluctuation getting during the tracking which we eliminate by using next method.

C. FUZZY LOGIC CONTROLLER

This one is advanced intelligence based technique and generally most effective with compare to other conventional methods. This having three section like Fuzzification, Inference and Defuzzification, as shown in figure [4].

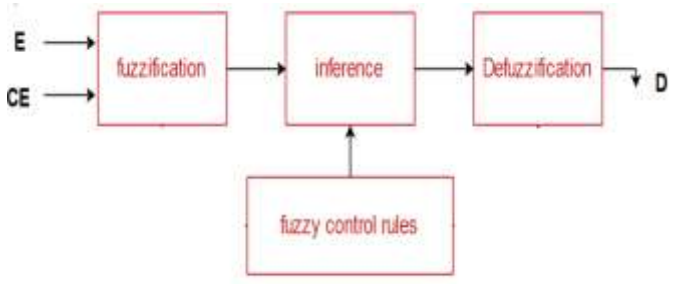


Figure 5. Fuzzy algorithm

$$E(k) = \frac{P(k)-P(k-1)}{(k)-V(k-1)} \quad (6)$$

$$CE(k) = E(k)-E(k-1) \quad (7)$$

- **Fuzzification:** In thisthe intake of value at error and change in error form. It converted into crisp value to the linguistic value which one understands by the system.
- **Inference:** In this blockmamdani fuzzy rules are in working manner. This section takes human decision making process and working for the same.

Table 3.Fuzzy Rule Base

ERROR	CHANGE IN ERROR				
	NB	NS	ZE	PS	PB
NB	PS	PB	NB	NB	NS
NS	PS	PS	NS	NS	NS
ZE	ZE	ZE	ZE	ZE	ZE
PS	NS	NS	PS	PS	PS
PB	NS	NB	PB	PB	PB

- **Defuzzification:** This is one of the last processing unit. This section gets the value from the fuzzy rule based and regarding centre weight gravity method. It gives the output which controls the duty cycle of the boost controller.

After discussing we can say that when the system is having more rapid changes in the irradiance and temperature then this method is taken the voltage and current in the error form as we discussed. So it is easy to provide contingency for getting MPP. In inference it checks the all best possibilities and triggers out that value which one suite for our requirement [5].

D. ARTIFICIAL NEUREL NETWORK

This controller is human brain based neural controller. It covers all the maximum possibilities for maximum efficiency.It contains three layers known as input layer, hidden layer and output layer. Most of the non-linear dynamic application is working based on this controller.

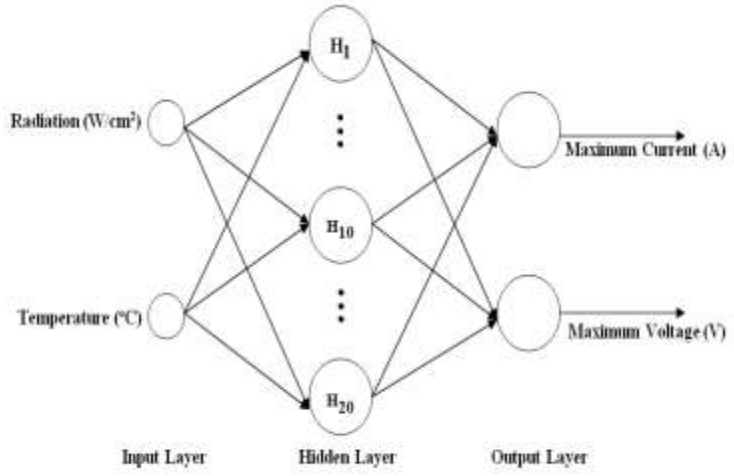


Figure 6. ANN Structure

Input layer take two input known solar irradiance and the ambient temperature then in hidden layer training of the data is achieved by means of the back propagation method and updates the weights of the system. Here we take one optimum output voltage regarding to this in hidden layer the data is updates and try to match that reference optimum voltage and by this comparison also updating going to reduce the error in between actual and optimum value of voltage. This entire process seen in the figure 7 and 8 that how does the neural network is working [6].

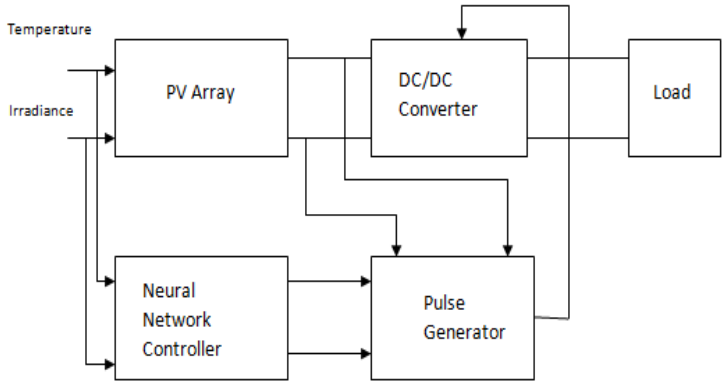


Figure 7. Block diagram of ANN

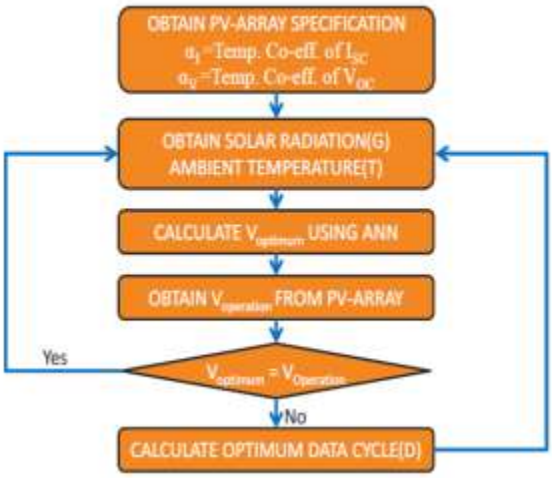


Figure 8. Flow chart of proposed method

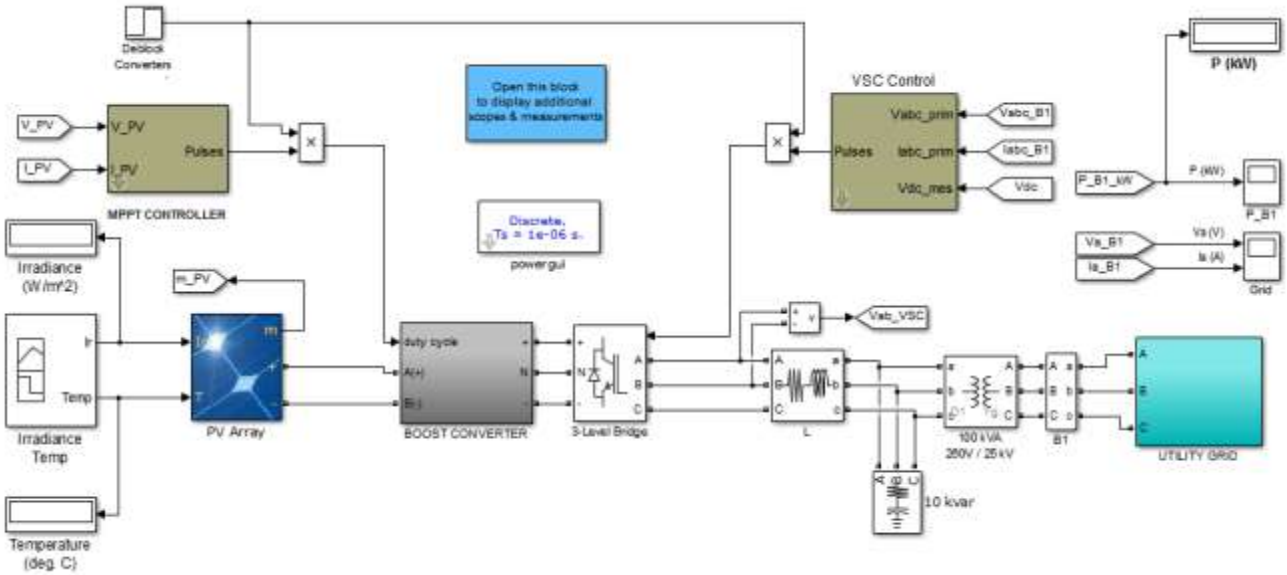
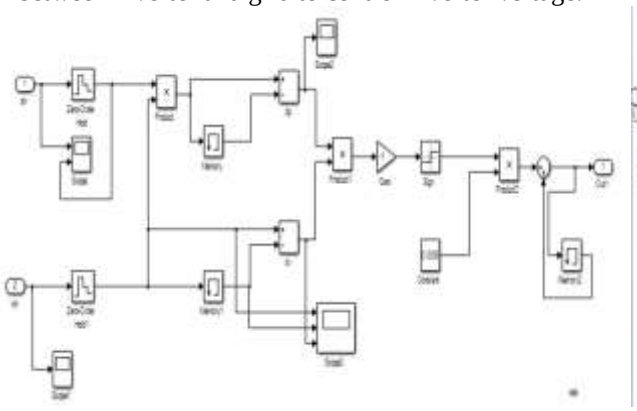


Figure 9. System Model

IV. SIMULATION RESULTS AND DISCUSSION

In simulation with solar PV 100KW grid is connected through 25KV step up transformer. The control of inverter is operated in between inverter and grid to control inverter voltage.



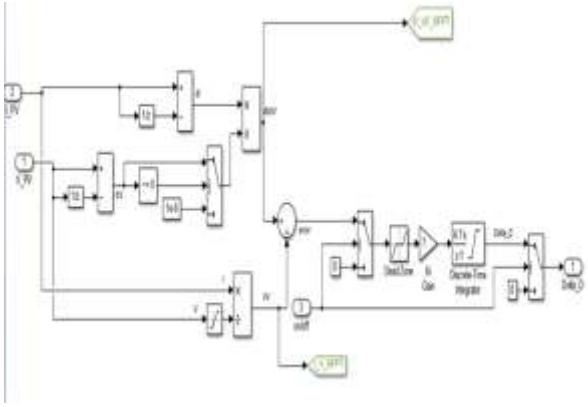
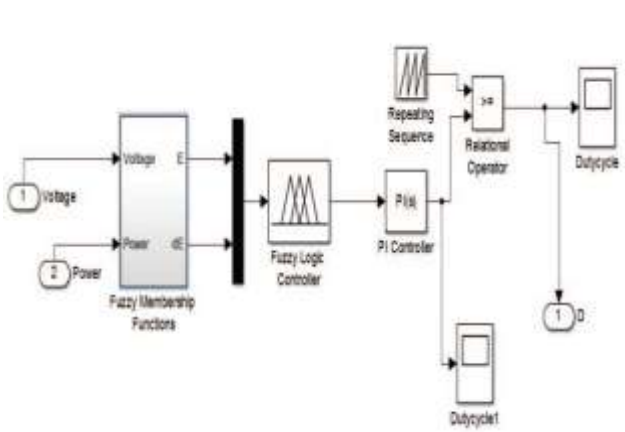


Figure 10. P&O blockFigure 11. IC block



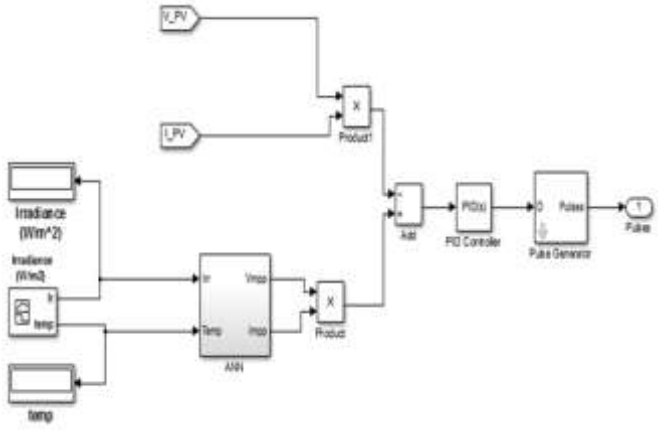
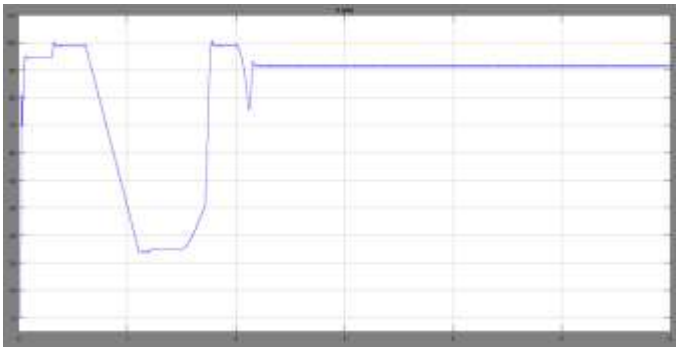


Figure 12.Fuzzy Controller BlockFigure 13. ANN block

Now when the simulation is start then at t=0.3 MPPT is being turn on. The delay of this because of the closed loop system to takes reference data.



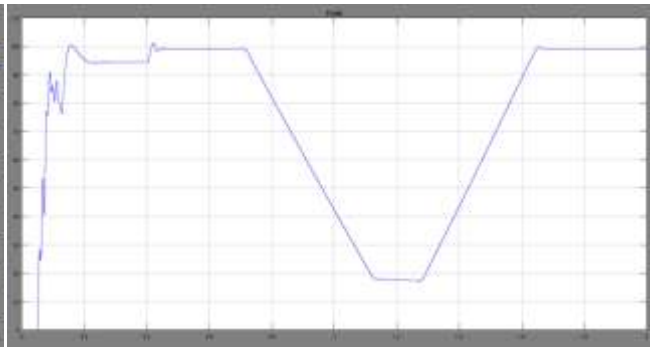
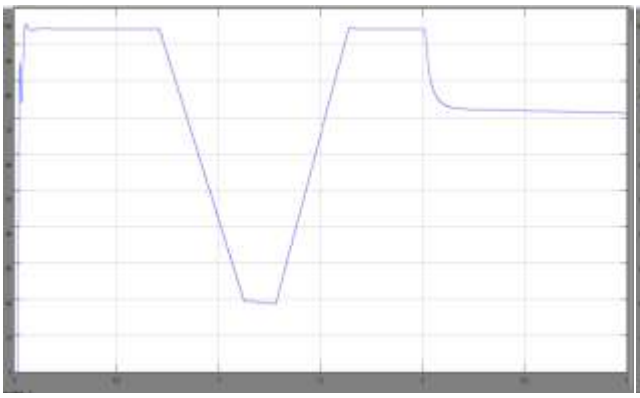


Figure 14.Grid output power using P&O controllerFigure 15. Grid output power using IC controller



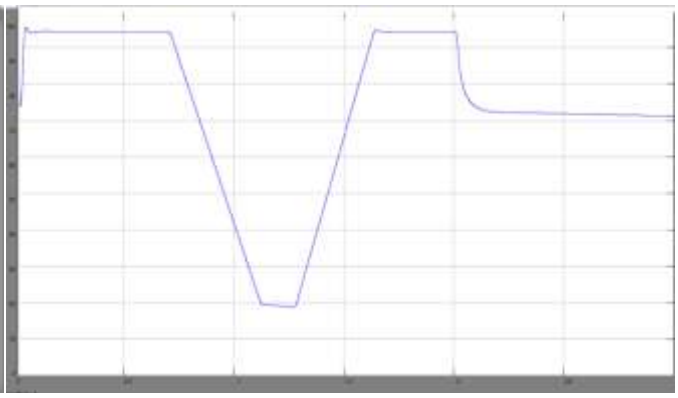


Figure 16.Grid output power using fuzzy controllerFigure 17. Grid output power using ANN controller

Here now compare first P&O and IC waveform at deferent time interval. We can say that there is rapidly change in irradiance. It track MPP without losses and also the oscillation is reduced as compare to P&O. But still some humming take place so we going on fuzzy controller. Fuzzy controller and ANN have the difference is that in ANN the convergence speed is very high and track at 99% of the efficiency.

Table 4. Comparison of All Techniques

Methods	Advantages	Disadvantages
P&O	Mostly used for its cheaper mechanism	Can't track MPP during sudden change of parameters
IC	Improved over P&O	Little bit produced humming during MPP
Fuzzy	Cover all the issues which having conventional methods	Comparable issue when compare with ANN
ANN	Most accurate tracking method without lack of convergence speed	Lack of 1% efficiency

We going to compare fuzzy and ANN in MATLAB then the output power is nearer to same but at starting of controller the ANN is fast tracking as you see in the figure 14 and 15. Fuzzy take some time to take its MPP. P&O is most widely used in application for its simple and easy operation if we don't have any fluctuating load and rapid environment changes then it give best performance and all the disadvantages of P&O are recover in IC controller. IC controller is one type of advance version of the P&O controller. Fuzzy controller is used without having knowledge of any mathematical knowledge of the system. Sometimes fuzzy controller becomes complex because to make rule base system is different for the different system so every time need to set that value regarding our requirement.

In grid connected system the inverter control is most important part because till we not get any actual value of VSC control we can't perform remaining process. In VSC controller abc-dqo transformation used tom make conversion of two phases to three phase system. Boost converter is every time boost up the voltage due to having grid that contain fluctuate load. If we have less demanded load we can used cuk converter instead of boost converter. Generally many systems sometimes require high and sometimes less amount of the voltage at that time we used cuk and boost both of the DC-DC converter to stabilise the voltage to our requirement.

In short we can say that in entire system two control take placed first one is MPPT and other one is VSC control in VSC there are reactive power control also take placed but in my system I take reactive component of Iq = 0 to make power factor unity. So our consideration and working focused only on the active power to control in VSC controller and through PWM it gives to filter and transformer.

Table 5. Comparison in Term of Practical Results

IRRADIANCE	P&O		IC		FUZZY		ANN	
	Pmax	efficiency	Pmax	efficiency	Pmax	efficiency	Pmax	efficiency
1000	91.42	90%	95.42	92%	97.45	94%	98.99	98%
600	70.12	84%	78.33	87%	80.14	89%	84.21	97%
200	35.11	80%	40.15	82%	41.22	83%	45.21	98%
= Actual value = Reference value				1000	100			
				600	85			
				200	46			

V. CONCLUSION

As we discuss earlier that all the MPPT methods having its own speciality. When we talk about the P&O then this method is widely used due to its simplicity and easy control. But when rapid change in irradiance then it worthless. IC method overcome this disadvantage of the P&O and also known as improved version of P&O. but still both this methods have oscillation problem in tracking. Fuzzy controller is eliminating this oscillation but having some complexity to making rule base system. So at last ANN gives best approach on all factors for MPP. Therefore I conclude that ANN is best technique for maximum power point tracking regarding practically and theoretically.

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