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`Comparison of Conventional Maximum Power Point Tracking Algorithm with Artificial Neural Network Based Maximum Power Point Tracking Algorithm with Respect to Change in Load

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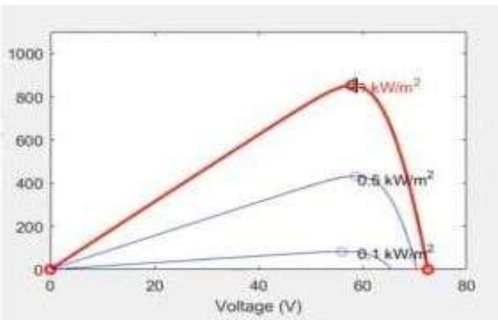
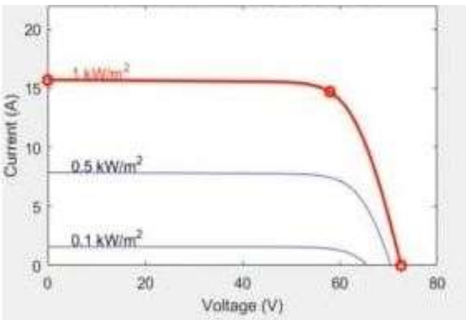
ABSTRACT
In recent times the main source of energy is fossil fuels which is deposited beneath the earth surface years ago. Due to increased population, the deposited fossil fuels have been severely exploited emitting huge amount of toxins in the environment that diminish the quality of human life. This gave birth to explore the renewable energy. The most abundant source of renewable energy available to us is the Solar Energy, but due to inability of the PV cells to track maximum power point due to varying weather conditions and changing load it is necessary to intensify the output power of the Solar Photovoltaic. In this paper artificial neural network based maximum power point tracking algorithm is proposed to enhance the power output of the Solar PV with changing load and comparison between Perturb and Algorithm, Incremental Conductance and Artificial Neural Network has been done to determine the performance. The purpose of the study is to prove the effectiveness of artificial neural network with varying load over the time.

INTRODUCTION

Solar energy is most important eco-friendly and inexhaustible renewable energy resource. Power production based on solar energy is now-a-days attaining more fame because of its benefits. But the dent in its progress is its conversion efficiency which is generally less than 17% [1,2], tracking speed during weather and load change and non-linear reliance on atmospheric parameters. The MPPT technique which is used to extract maximum power point is mainly dependent on temperature and irradiance to get the maximum power. The point at which dP/dV=0 is known as maximum power point or Knee point. The P-V and V-I characteristics are shown in figure 1.





(a) (b)

Fig. 1: *(a) P-V Characteristic of Solar Cell, (b) V-I Characteristic of Solar Cell.*

The PV cells produce current on the basis of photoelectric effect according to which "light energy is directly proportional to electrical energy produced". Adding to it, the amount of solar radiation falling over SPV panels are responsible for the power produced by the SPV panels. In order to get the rated output all, the cells in the panel should have uniform solar radiation which is practically not possible due to many reasons. These problems can be defeated by implementing suitable optimization techniques. Several algorithms are developed and implemented such as Incremental Conductance, Perturb and Observe/Hill Climbing, Fractional open-circuit voltage, Fuzzy logic or neural network etc to track the maximum power point at which the solar PV system should operate [3]. In this paper, the performance of artificial neural network based maximum power point tracking algorithm with changing load has been observed and comparison of the performance with conventional Perturb and Observe and Incremental Conductance algorithm has been done.

VARIOUS MPPT ALGORITHMS

The issue with the MPPT methods is in fetching the voltage Vmpp and current Impp at which the PV array provide maximum power under a given irradiance and temperature [4]. The P&O algorithm depends on the calculation of the PV output power and the change in power by sampling the PV array current and voltage. The tracker operates by increasing or decreasing the voltage of solar array. If the given perturbation results in increase in PV output power then the subsequent perturbation is followed in the same direction similarly if the given perturbation results in decrease in PV output power then the subsequent perturbation followed in the opposite direction. The process is repeated and the duty cycle of the converter is varied until the maximum power point is arrived. The drawback of the algorithm is that the system oscillates around the MPP. By reducing the step size, the oscillations can be minimized but it eventually slower down the MPPT [5].

There is another algorithm which is Incremental Conductance algorithm in which the desired operating point is reached by using the information of source voltage and current. InC algorithm overcomes the drawback of P&O algorithm. From the P-V curve of a PV module shown in figure 1(a), it is clear that slope is zero at maximum point [6]. The formulas are given below:

$$(dP/dV)_{mpp} = d(VI)/dV \quad (1)$$

$$0 = I+V(dI/dV)_{MPP} \quad (2)$$

$$(dI/dV)_{MPP} = -I/V \quad (3)$$

As shown in equation (3), the variance of the output conductance is equal to the negative of the output conductance and this is the condition to achieve the maximum power point [7].

Constant Voltage algorithm considers that at varying irradiance, maximum power point voltage is almost equal which around 76% of Voc.

In recent year’s artificial neural network has developed strongly not only in practical aspect but also in application view point because by implementing artificial neural network, the number of mathematical calculations reduced, it increases efficiency, speed, accuracy and also it holds a smaller number of oscillations. The common ANN is shown in figure 2.ANN is also used to approximate non-linear function [8, 9]. The input and output data of neural network are from model-based simulation results or experimental measurements. For MPPT, input to the ANN can be PV voltages and current and environmental data like temperature and irradiance. The output can be one or more reference signals like duty cycle [10].

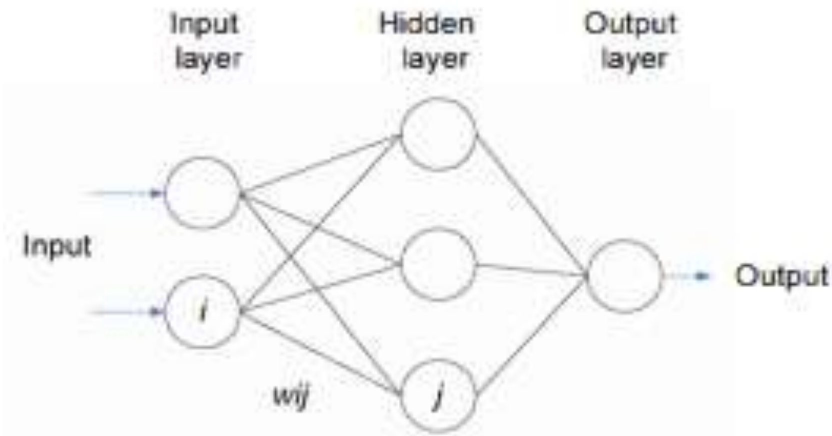


Fig. 2: *ANN Diagram.*

The irradiance and temperature have random variation with weather, by implementing appropriate MPPT optimization technique the efficiency of the system rises whatever is the temperature of the environment and irradiation value. In this research work the execution of MPPT is done with the use of artificial neural network and comparison has been done in between all the three algorithms with varying load.

MODELLING

The proposed model is simulated in MATLAB version 2015. The simulated model includes boost converter, PV array model of 215 KW power, and artificial neural network based maximum power point tracking. input to solar panel is temperature (T) and irradiance (G). The figure 3 shows the schematic block diagram of proposed system [11].

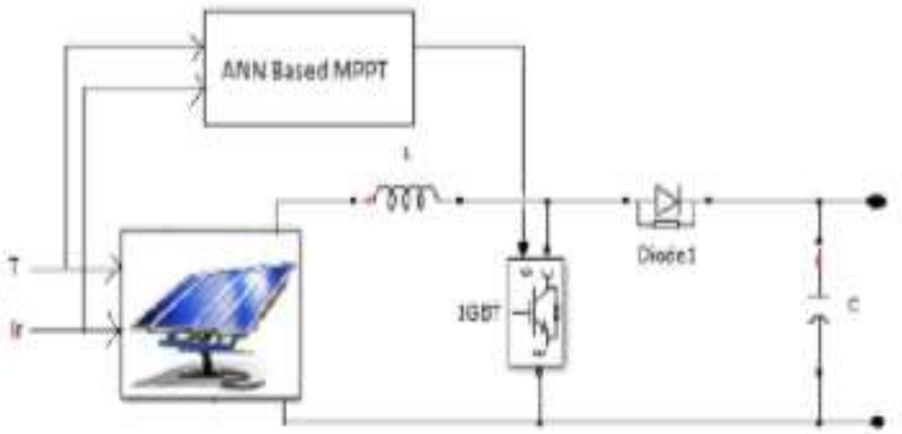
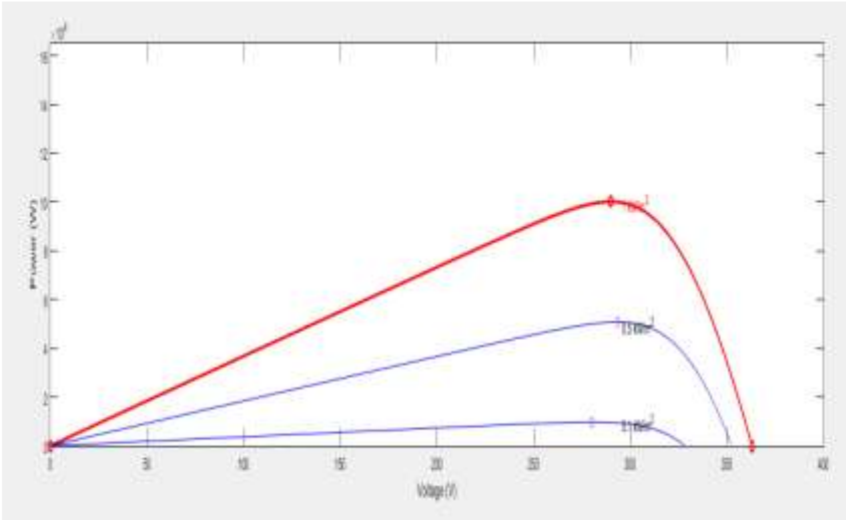


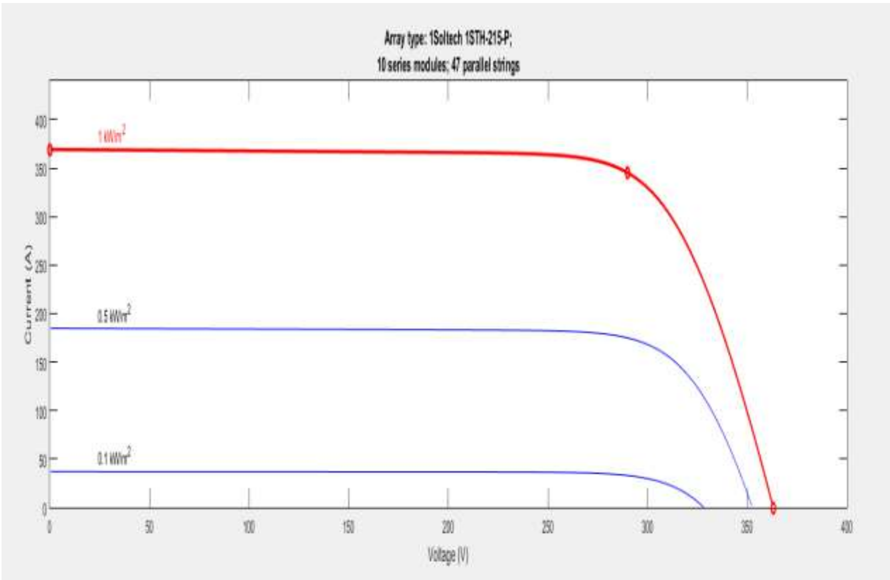
Fig. 3: *The Schematic Block Diagram of Proposed System [11]*

Solar Panel

The solar panel consists of PV arrays connected in series and parallel. In this paper Soltech 1STH-215-P is used having 47 numbers of parallel strings and 10 numbers of series connected modules per string. The peak power of the panel is 215 Watts. The P-V and V-I characteristics of the panel used at standard condition *i.e.* (25°C and 1000W/m^2) is shown in figure 4. The table 1. shows the specifications of panel.



(a)



(b)

Fig. 4: *(a) P-V Characteristic of Soltech 1STH-215-P (b) V-I Characteristic of Soltech 1STH-215-P.*

Artificial Neural Network (ANN)

The artificial neural network is inspired by the working of human brains and it is generally presented as system of inteconnected neurons, these are the processing elements and have some adjustable weights associated to them making neural network capable of learning and adaptive to inputs. The main advantage of ANN is its self-organized and self-learning nature [12-14]. It is basically comprising of three layers i.e. input layer, output layer and hidden layer as shown in figure 2. The input layer is responsible for receiving information; the received data is processed depending on the associated weights between input layer and hidden layer. Similarly, weight is also associated with a link between hidden layer and output layer [15]. The ANN model is performed using MATLAB version 2015.A feed forward neural network with two neurons in input layer, one in output layer and ten neurons in hidden layer is developed.

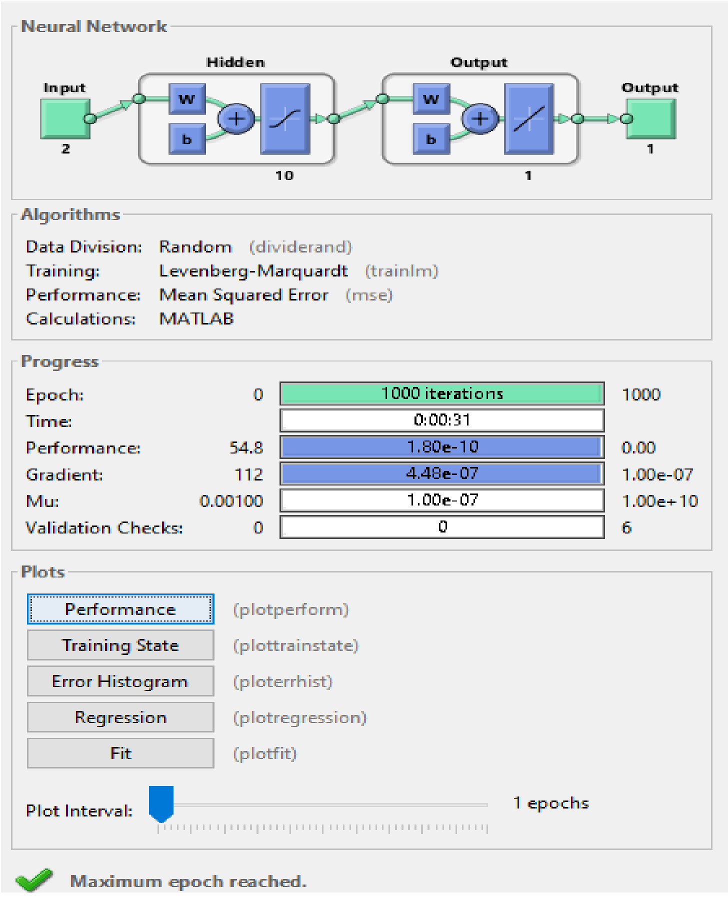


Fig. 5: *Neural Network Layout and its Training Window.*

The input to the ANN is the temperature and irradiance at standard condition i.e. (25°C and 1000W/m^2) and depending on the irradiation and temperature data, the network will provide the maximum power point and corresponding voltage. We need to collect data from PV array for training the neural network in order to implement MPPT neural network algorithm.

According to the input and output data the weights between two layers will be updated or optimized during training of ANN. The Levenberg-Marquardt algorithm is used in the proposed research work. The data for training the neural network is given in table 1. The 'nnstart' tool is used for training of neural network.

Table 1: *Solar Panel Specifications.*

Parameters	**Values**
Open Circuit Voltage (Voc)	36.3 V
Short Circuit Current (Isc)	7.84 A
Diode Saturation Current	2.925e-10A
Diode Ideality factor	0.98117
Light Generated Current	7.864A
Temperature coefficient of Voc	-0.3699%/V
Temperature coefficient of Isc	0.102%/A
Series Resistance (Rs)	0.3938 ohm
Shunt Resistance (Rsh)	313.399 ohm
Maximum Power	213.5 Watt
Number of series connected modules per string	10
Cells per module	60
Number of Parallel Strings	47

The regression and error plot of developed neural network is shown in figure 6 (a) and 6 (b) respectively.

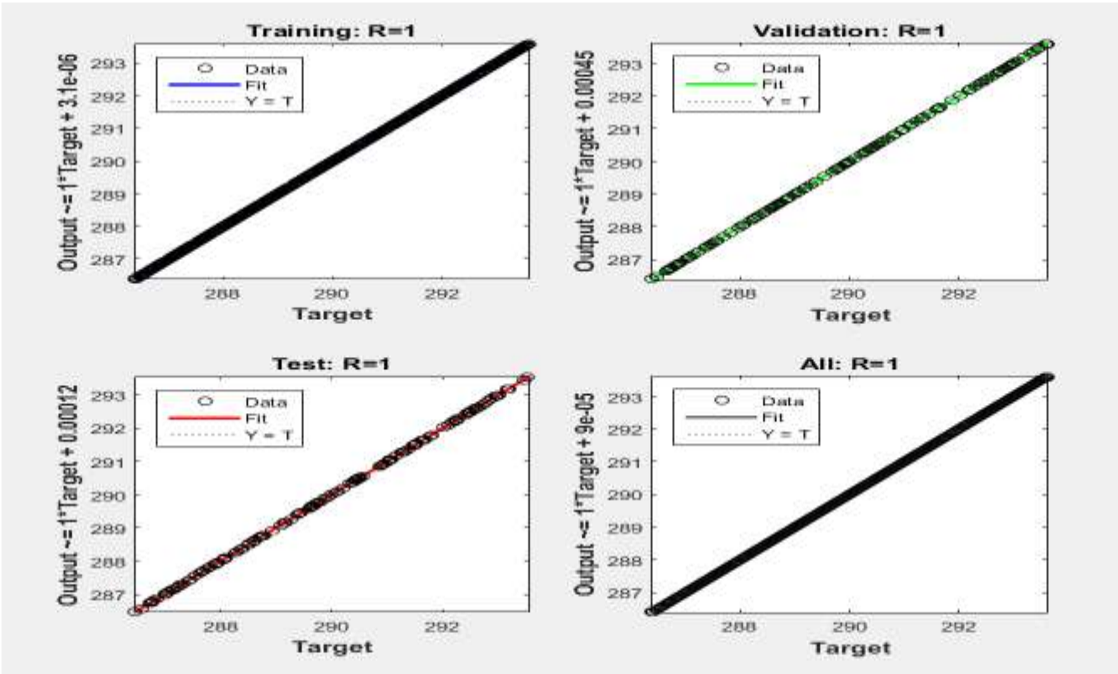


Fig. 6(a): *Regression Plot.*

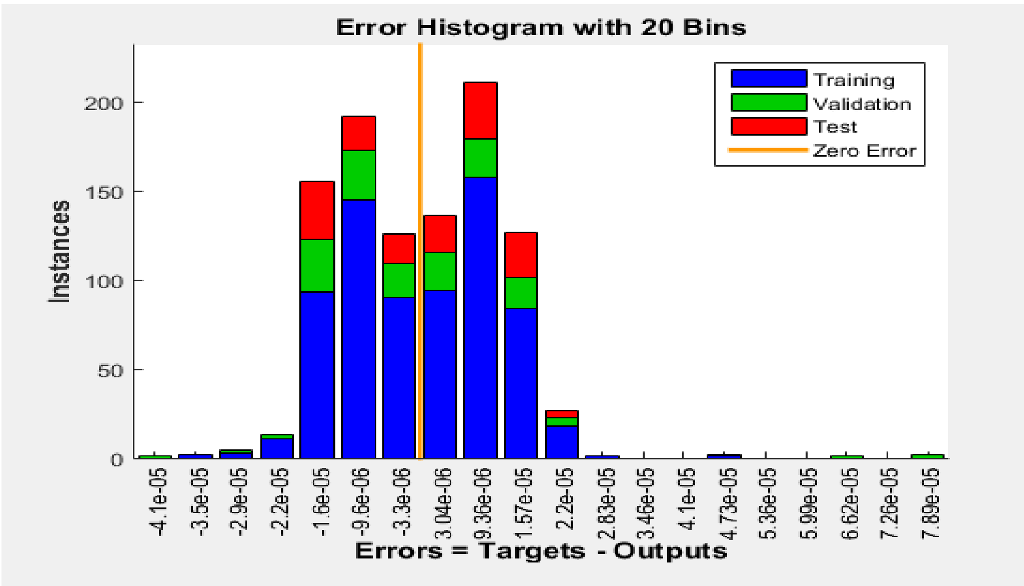


Fig. 6(b): *Error Plot.*

Boost Converter

The boost converters are used to boost-up the DC voltage level. The DC-DC boost converters are used in regulated switch mode DC power supplies. The input of these converters is obtained by PV array and therefore it will be fluctuated due to changing irradiation and temperature. The average DC output voltage must be controlled in these converters to be equated to the desired value but the DC input voltage is changing [16]. The basic circuit diagram of boost converter is shown in figure 7.

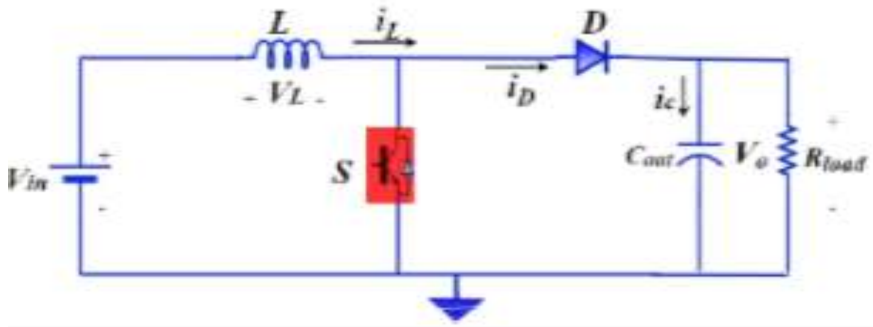


Fig. 7: *Circuit Diagram of Boost Converter. [17]*

The boost converter is a switching converter which operates by periodically ON and OFF state. In the above circuit diagram Vin is the input voltage, inductor (L), controlled semiconductor switch (S) like MOSFET, BJT, IGBT etc. In the proposed research work IGBT is used. Diode (D), capacitor (Cout), loads resistance (Rload).

The parameter values for designing the boost converter in MATLAB/Simulink is given in table 2.

Table 2: *Boost Converter Input Data.*

Parameters	**Values**
Input Voltage (V_{in})	250-300 V
Output Voltage (V_o)	600 V
Rated Power	100 KW
Switching Frequency (fsw)	5 KHz
Current Ripple (Δ I)	5%
Voltage Ripple (Δ V)	1%

For calculating the parameters following formulas are used:
Input Current can be calculated as:
I_{in}= Rated Power/Input Voltage--------- (1)
Output Current can be calculated as:
I_{out}= Rated Power/Output voltage------- (2)
Capacitance can be calculated as:
$C = I_{out} \times (V_{out}-V_{in})/(f_{sw} \times \Delta V \times V_{out})$----(3)
Inductance can be calculated as:
$L = V_{in} \times (V_{out}-V_{in})/(f_{sw} \times \Delta I \times V_{out})$------(4)

RESULTS AND DISCUSSION

In this section results of various simulation studies ofperturb and observe algorithm, incremental conductance algorithm and proposed artificial neural network based maximum power point tracking algorithm with 215 watts PV array are shown by taking three different load resistances R1 =20 ohms, R2 =50 ohms and R3 =80 ohms. The three algorithms are simulated individually and similar parameters are set to compare the results. The proposed simulink model of perturb and observe algorithm, incremental conductance algorithm, artificial neural network based maximum power point tracking algorithm and their output are shown in figure 8-13. The entire three MPPT algorithms have two inputs (irradiance and temperature) and one output which is reference output voltage and corresponding maximum power point in the PV characterstics. For the generation of boost converter duty cycle, output of MPPT algorithm is used. Using the reference voltage (Vref), duty cycle for the boost converter is calculated using the formula given in equation:
D = 1-(Vin/Vo) --------------------------- (5)

In the above equation Vin is the instantaneous operating voltage of PV panel and Vo is the reference voltage generated from MPPT algorithm.

By giving input as temperature and irradiance at standard condition (25^0C and 1000W/m^2), the results of the algorithms are evaluated. The simulation results of perturb and observe algorithm, incremental conductance algorithm and artificial neural network based maximum power point tracking algorithm is shown in table 3.

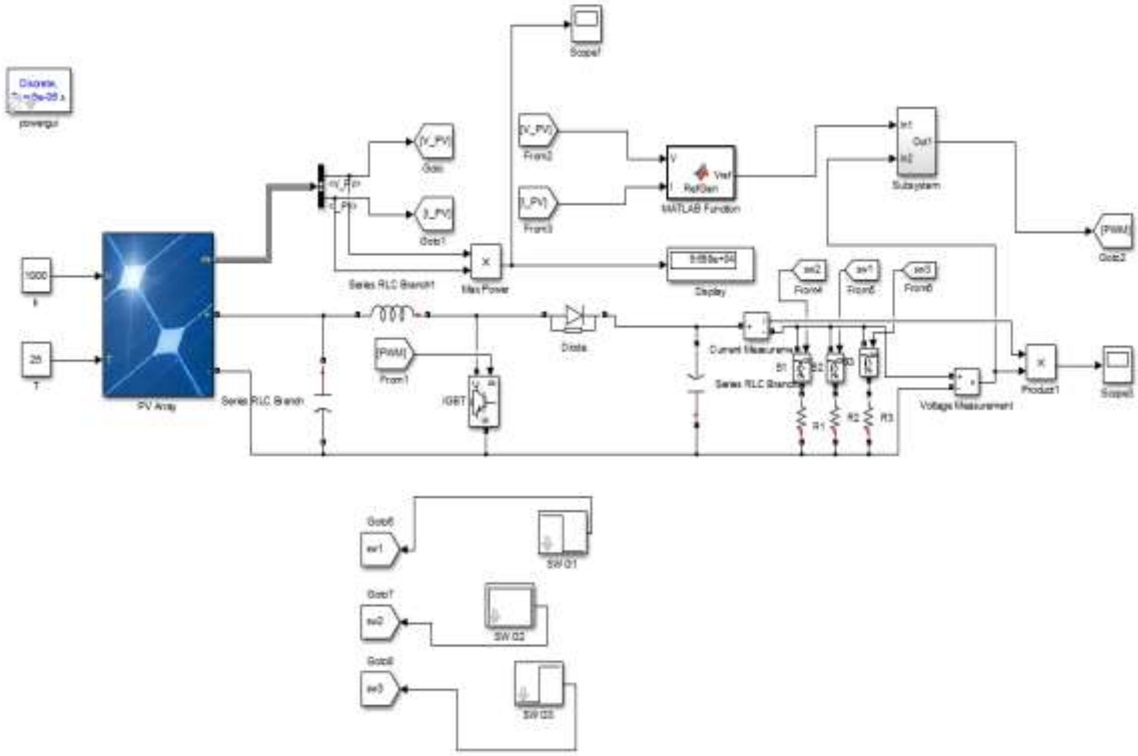


Fig. 8: *Simulink Model of Perturb and Observe Algorithm.*

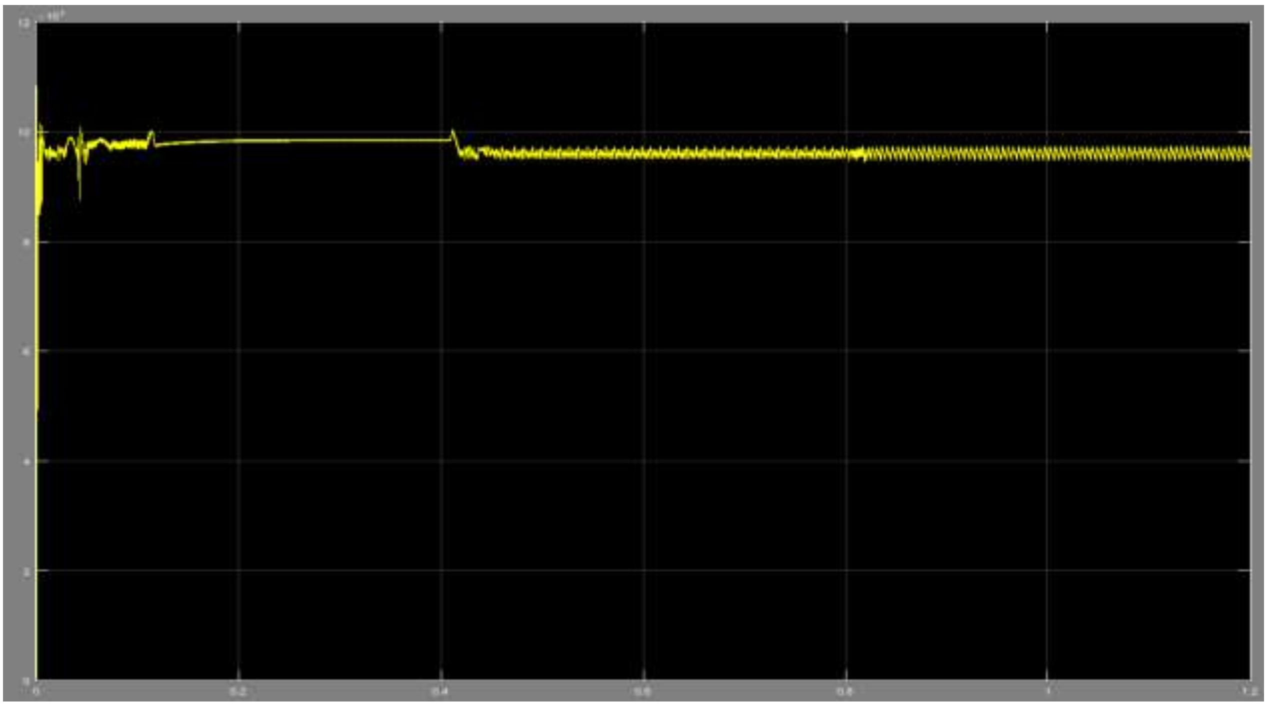


Fig. 9: *Power Output of Perturb and Observe Algorithm.*

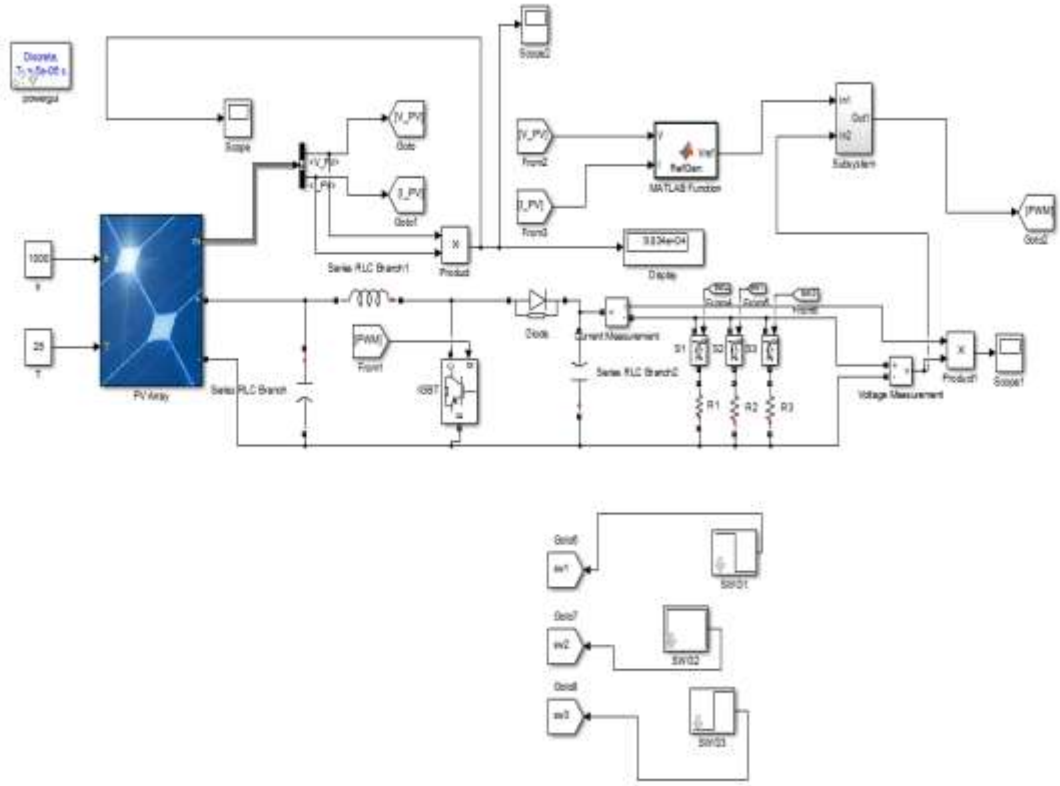


Fig. 10: *Simulink Model of Incremental Conductance Algorithm.*

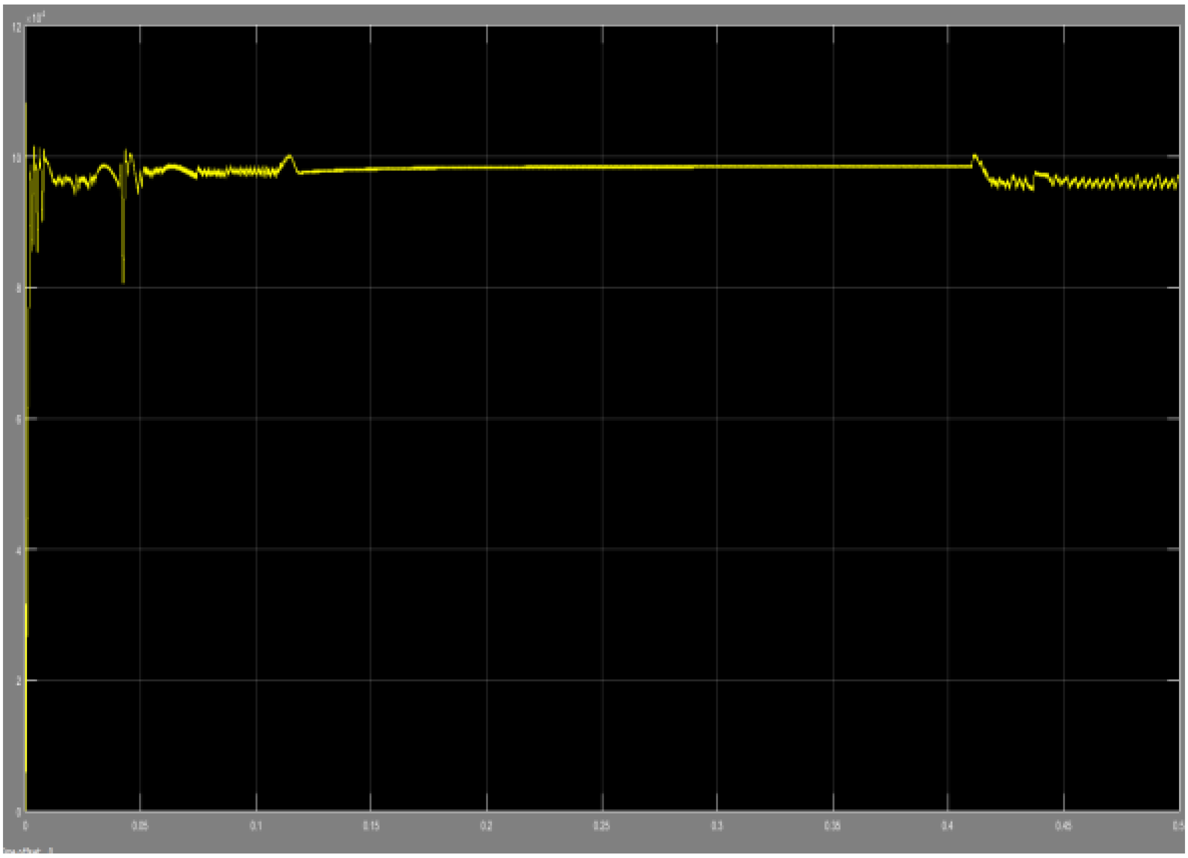


Fig. 11: *Power Output of Incremental Conductance Algorithm.*

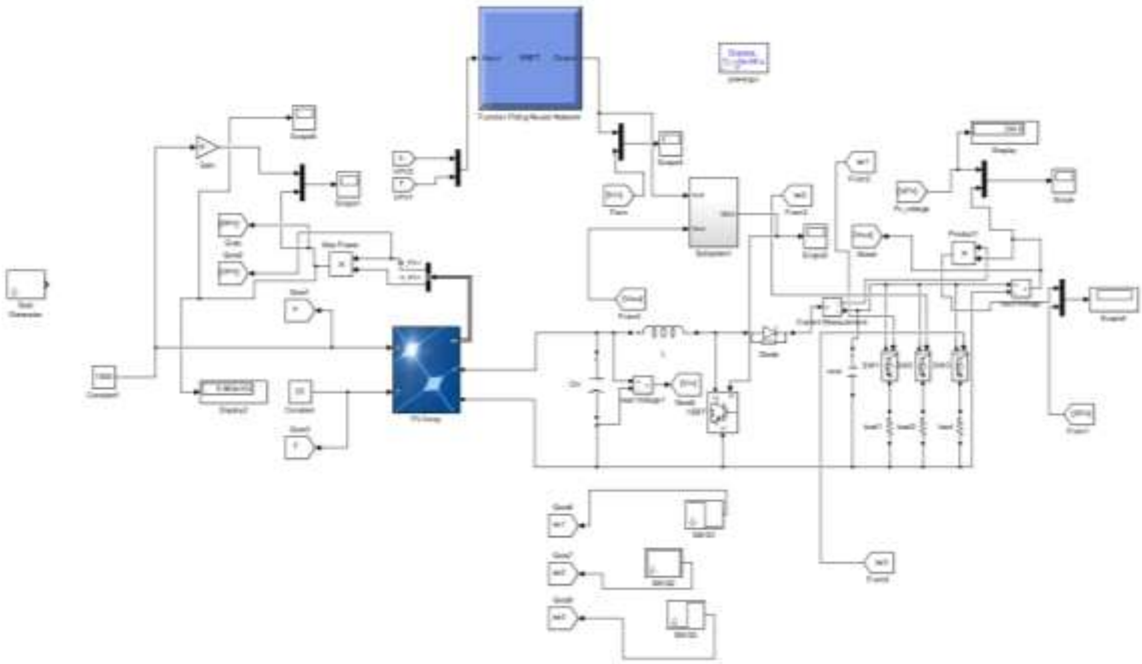


Fig. 12: *Simulink Model of Artificial Neural Network Algorithm.*

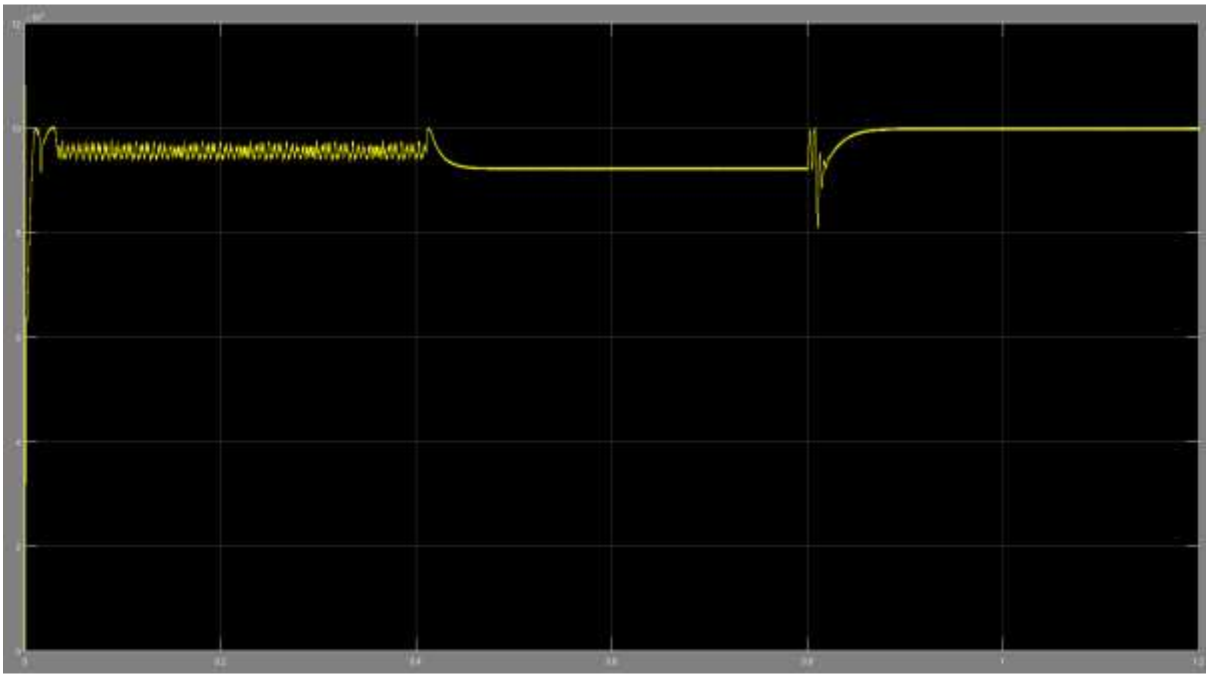


Fig. 13: *Power Output of Artificial Neural Network Algorithm.*

From the table 3, it is observed that the maximum power output of ANN-MPPT is comparatively much better to incremental conductance and perturb and observe algorithm.

The simulation time of the system is 1.2 seconds and the switching time of variable load resistance R1 is from 0 to 0.4, the switching time of variable load resistance R2 is from 0.41 to 0.8 and the switching time of variable load resistance R3 is from 0.81 to 1.2. Ideal switch is used for switching of resistances.

Table 3: *Output Power.*

Resistance	Power Output of P&O	Power Output of InC	Power Output of ANN
20 Ohms	9.618e+04	9.637e+04	9.927e+04
50 Ohms	9.579e+04	9.620e+04	9.837e+04
80 Ohms	9.635e+04	9.712e+04	9.904e+04

From table 3 it is easily distinguished that the output power of ANN is much better as compared to other two algorithms.

CONCLUSION

Solar energy is the non-vanishing renewable source of energy. The only scratch of the PV based solar systems is its poor conversion efficiency. The efficiency of the PV panel is influenced by the changing irradiation and temperature, so the implementation of maximum power point tracking (MPPT) is important for such systems. But it also faces issue while delivering maximum efficiency. This paper presented proposed research work of implementation of artificial neural network based maximum power point tracking with variable load resistance and comparison has been made with conventional perturb and observe and incremental conductance algorithm with same set of parameters. The implementation was carried out successfully and the accuracy in tracking the maximum power point (MPP) under varying load resistances was validated by the results. It is concluded that artificial neural network based maximum power point tracking algorithm is more efficient than other two algorithms and also it proves better in terms of speed, accuracy and holds a smaller number of oscillations. From the simulation results of all the three algorithms it can be concluded that better response is found for the proposed algorithm. The obtained output power is higher in case of ANN based algorithm as compared to other two algorithms.

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