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A MATLAB/SIMULINK MODELLING OF A PHOTOVOLTAIC ARRAY FOR MAXIMUM POWERPOINT TRACKING USING NEURAL NETWORK

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Abstract: Solar energy is one of the most important and fastest growing renewable energies. One of the main design goals of a PV system is to obtain the maximum output power from solar PV with minimum losses. To achieve this, various techniques for tracking the peak performance point of PV system are reported in several literatures. In this paper, the theoretical details for the development and implementation of a Maximum Power Point Tracking (MPPT) controller using an artificial neural network for a stand-alone photovoltaic system are carried out. A 350W solar PV array from MATLAB/Simulink is used. Real-time data about changing environmental conditions, such as changing irradiance and temperature, is used to train and test the neural network. Simulation results are presented under rapid changes in solar radiation and temperature along with changing load conditions, which confirms the effectiveness of the proposed method in terms of efficiency. Small to negligible oscillations around the maximum power point and easy implementation are the main advantages of the proposed MPPT control method.

***Keywords* - Maximum Power Point Tracking (MPPT), Solar photovoltaic (PV) system, Neural Network (NN).**

I. Introduction

The global demand for energy is increasing day by day, and it leads to energy crises. Alternative renewable energy sources are needed to meet the growing demand for energy and environmental problems. India has huge solar energy potential. According to the National Institute of Solar Energy (NISE), the country's solar potential is about 748 GW. The installed capacity of solar energy is 82.64 GW as of April 2024. Earlier solar photovoltaics were very expensive, but today they have become affordable for many consumers thanks to the improvement of technology and the mass production of solar panels.

Solar photovoltaic cells are the basic building block of a PV system that converts solar energy into electricity. But PV cells have poor conversion efficiency and it further deteriorate with increasing temperature and decreasing irradiance level because the output current and voltage of solar PV are a function of solar radiation and panel operating temperature. The V-I characteristic of a photovoltaic cell (Figure 1) provides a non-linear curve and it is observed that there is a point on the curve at which the cell produces maximum power at a given irradiance and temperature. This point is called the maximum power point (MPP) and occurs when the rate of change of power with respect to voltage is zero. Various control techniques known as maximum power point tracking (MPPT) are used to monitor the MPP of solar cells.

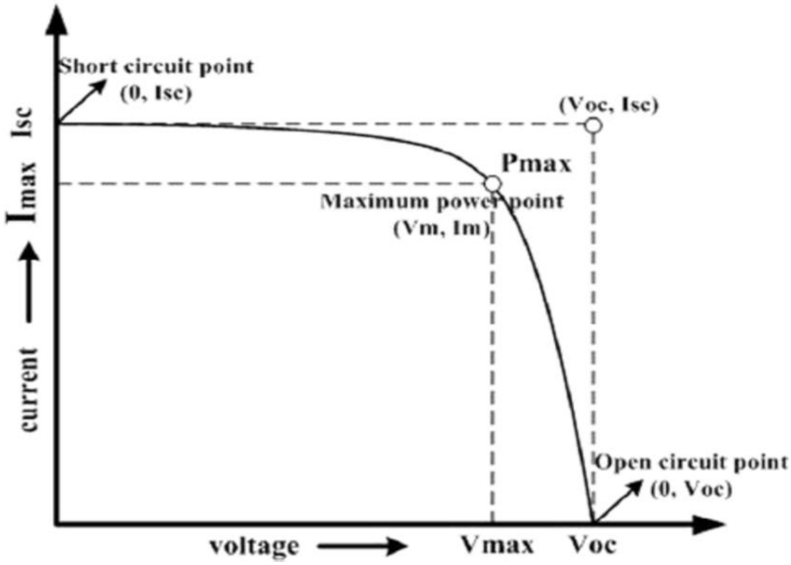


Figure 1: V-I Characteristics of solar PV array

The MPPT technique ensures that the PV operating voltage and current always lie at the maximum power point of the curve. Many techniques have been proposed for MPPT, which differ in speed, complexity, design, and cost, etc. In this paper, an artificial neural network is used to track the maximum performance. It is an artificial network that imitates the behavior of neurons in the human brain. ANN consists of three layers: input layer, hidden layer and output layer. These layers have processing elements called neurons which are interconnected together. The gradient estimation method called "backpropagation" is used to train the neural network. It adjusts the neuron weight by computing the gradient of the loss function. This technique is also called backpropagation error because the error is calculated at the output layer and circulated back through the network layers. Neural networks can adapt to the changing input condition and can generate the best possible results without changing the output criteria.

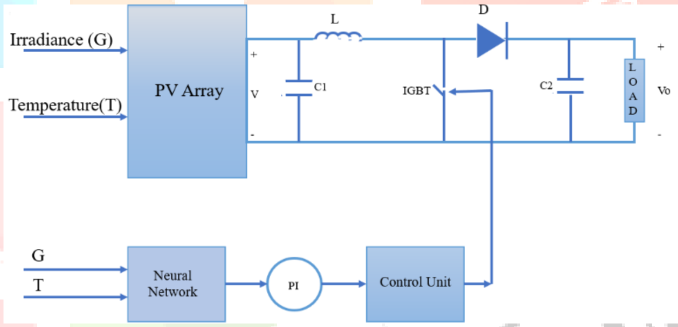


Figure 2: Block diagram of MPPT using Neural Network

II. METHODOLOGY

A typical solar photovoltaic panel converts only 30 to 40 percent of incident sunlight into electricity. A maximum power point tracking technique is used to improve the efficiency of the solar panel. According to the maximum power transfer theorem, the output power of a circuit is maximum when the Thevenin impedance (source impedance) of the circuit matches the load impedance. It is therefore necessary to properly match the solar PV source and load impedance for any environmental conditions to achieve the maximum power point.

MPPT control system consists of a solar PV array, a power conditioner unit to interface the PV output to load and a control unit to regulate the power conditioner. On the source side, we have used a boost converter connected to the solar panel to increase the output voltage. By appropriately changing the duty cycle of the boost converter, we can compare the impedance of the source with the impedance of the load, thus obtaining one working point, i.e., the reference voltage signal Vref with the neural network controller and PWM generator.

III. MODELLING OF MPPT

A Soltech 350 W solar PV array is chosen for the simulation. It consists of one series and parallel strings. The electrical characteristic of the PV array is shown in Table1. Figure 3 and 4 shows the V-I and PV Characteristics of 350W solar PV array with varying irradiation and temperature condition respectively. From the figures, it is observed that with an increase in irradiation level, power increases while with an increase in temperature, power decreases.

Table1: Parameters of 350 W solar PV array

DESCRIPTION	1SOLTECH 1STH-350-WH
Maximum Power	349.59 W
Cells per module	60
Voltage at maximum power point Vmp	43 V
Current at maximum power point Imp	8.13 A
Open circuit voltage Voc	51.5 V
Short circuit current Isc	9.4 A
Temperature coefficient of Voc	-0.36 %/ºC
Temperature coefficient of Isc	0.09 %/ºC
Shunt resistance Rsh	47.9694 ohm
Series resistance Rs	0.22828 ohm
Diode ideality factor	1.045

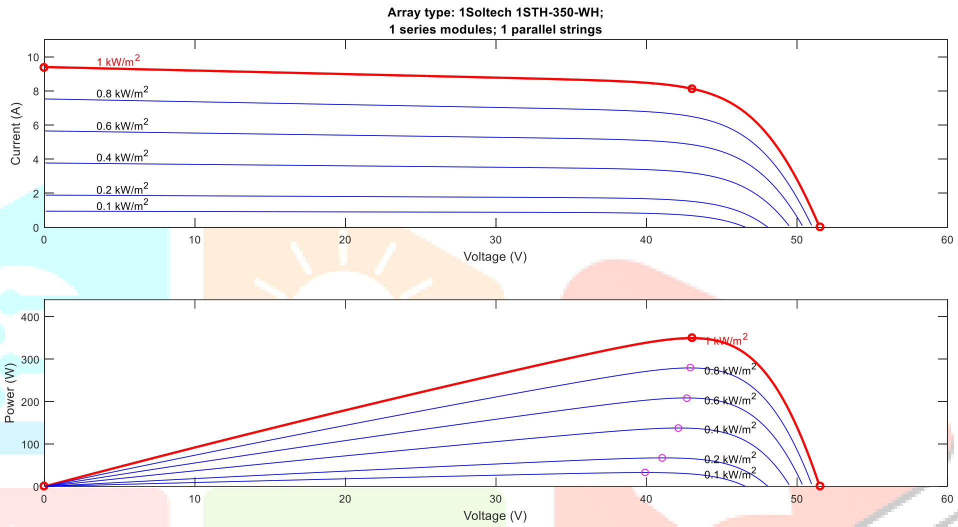


Figure 3: V-I and PV Characteristics of 350W solar PV array with standard and varying irradiation condition

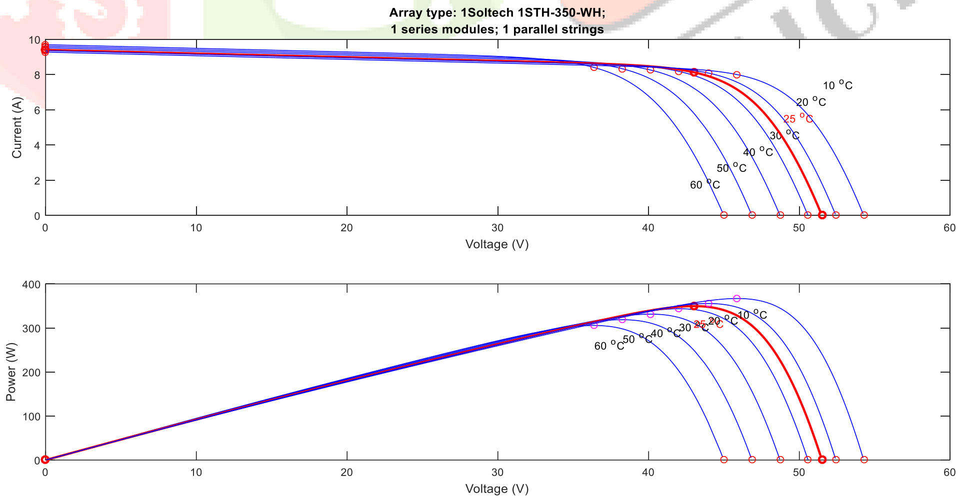


Figure 4: V-I and PV Characteristics of 350W solar PV array with standard and varying Temperature condition

MPPT Using Neural Network

A neural network is used to monitor the maximum output of a simulated 350W solar array. For neural network training, the Levenberg-Marquardt algorithm is implemented in MATLAB, which is a very fast and accurate technique for non-linear operations. Neurons in the input layer obtain the input signal from radiation (G) and temperature (T). The neurons in the hidden layer calculate the output using the tan-sigmoid activation function and pass it to the output layer. The output neuron provides the required voltage at MPP (Vmpp).

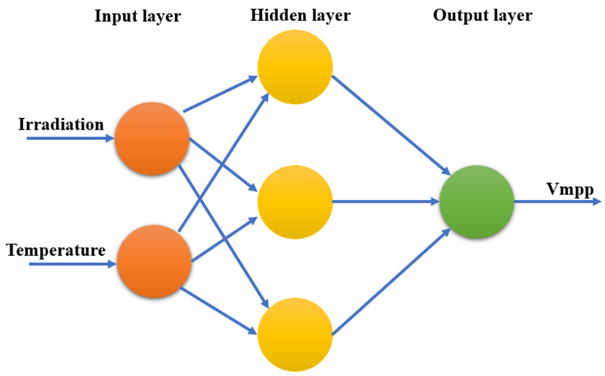


Figure 5: Neural Network

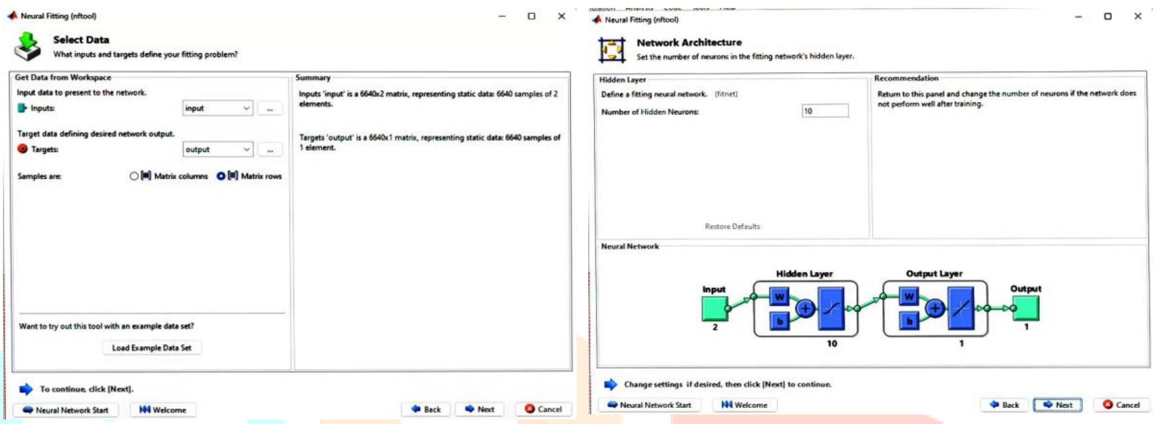


Figure 6: Selected data (input is temperature irradiation and output are maximum voltage) and 10 hidden layers are used

Training and Testing of Neural Network

A neural network requires a set of input and output training data. The real-time irradiance and temperature data near the Thar Desert in India are collected from the NASA website. A total of 6640 sample data are used. From the set of 6640 data points, 4648 data points are used for training and 996 data points each are used for validation and testing of the neural network.

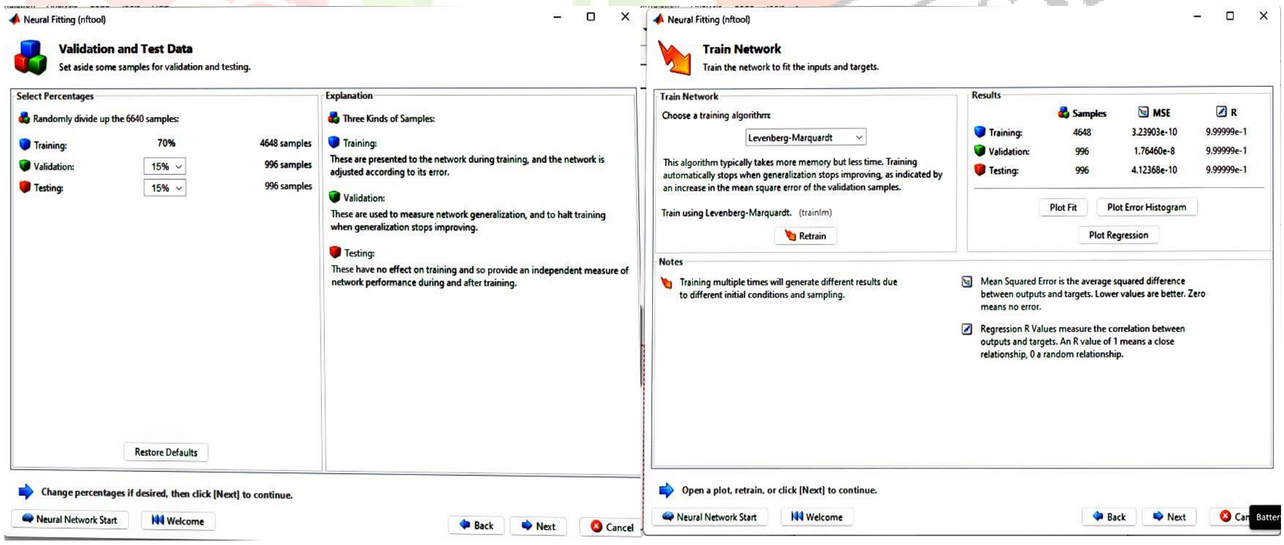


Figure 7: Training, testing and validation Information of neural network.

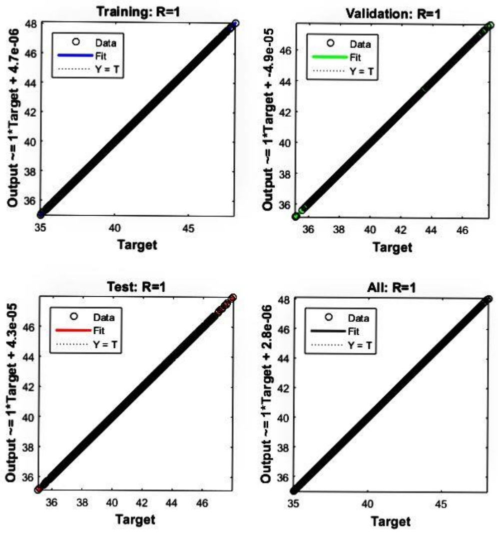


Figure 8: Regression plot

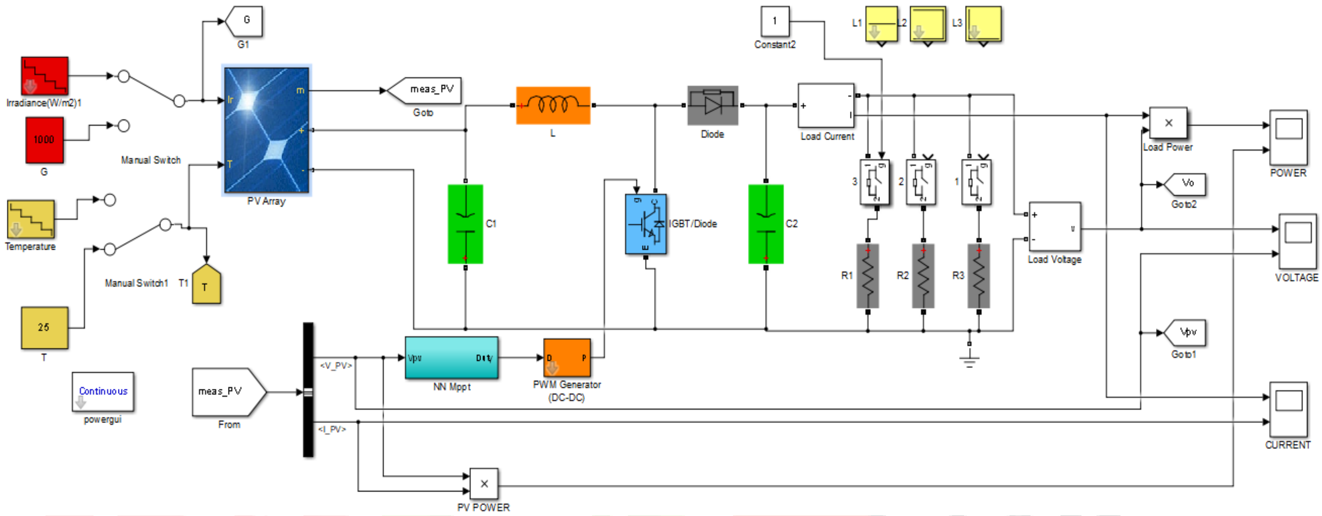


Figure 9: Simulink Model of MPPT using Neural Network

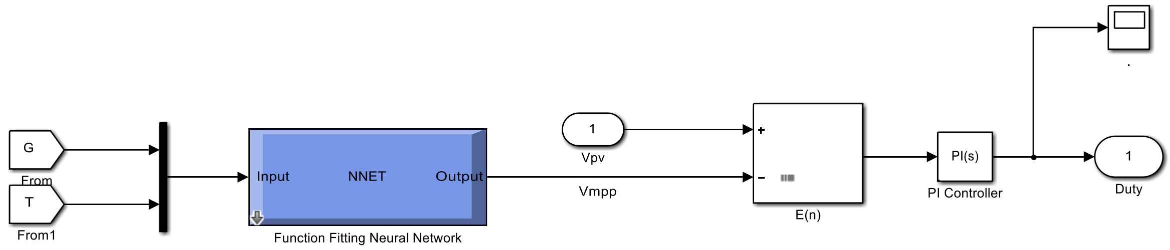


Figure 10: Sub-system of Neural Network

IV. SIMULATION RESULTS AND DISCUSSION

Case 1: Variable Irradiance, Constant Temperature (25°C), Constant Load (100 ohm)

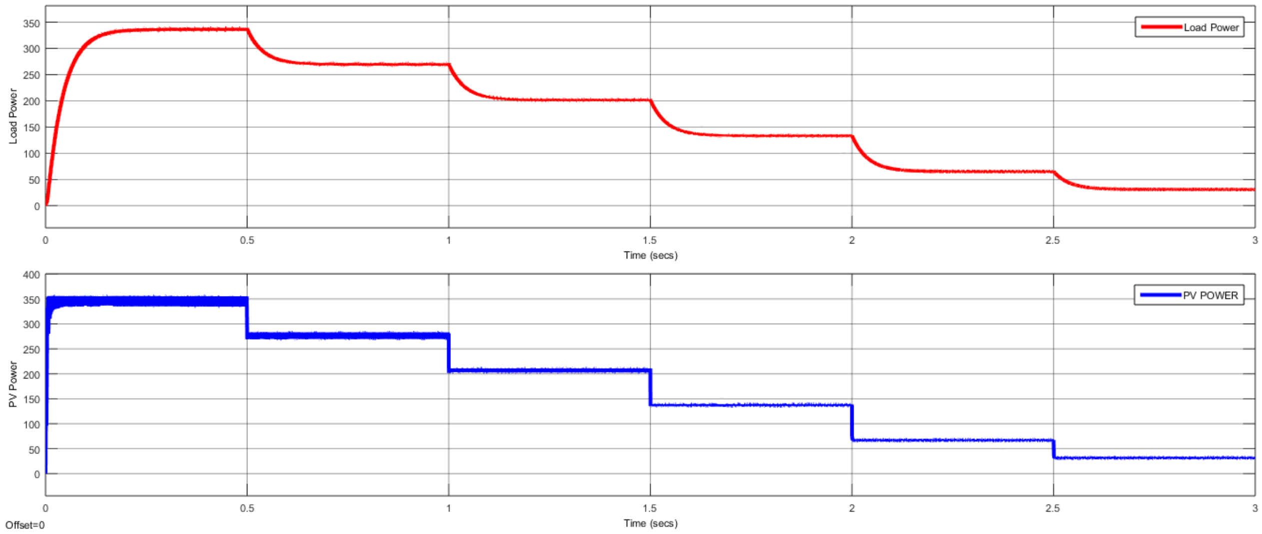


Figure 11: Load Power and PV power vs time curve

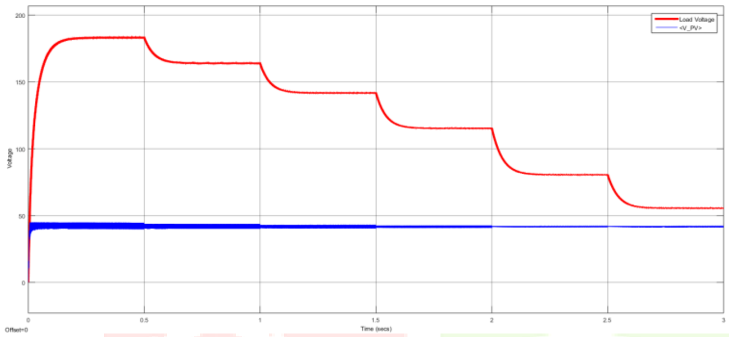


Figure 12: Load Voltage and PV Voltage vs time curve

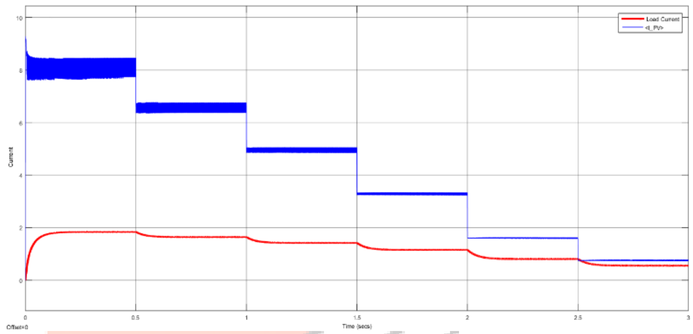


Figure 13: Load Current and PV current vs time curve

Case 2: Constant Irradiance (1000W/m^2), Variable Temperature and Constant Load (100 ohm)

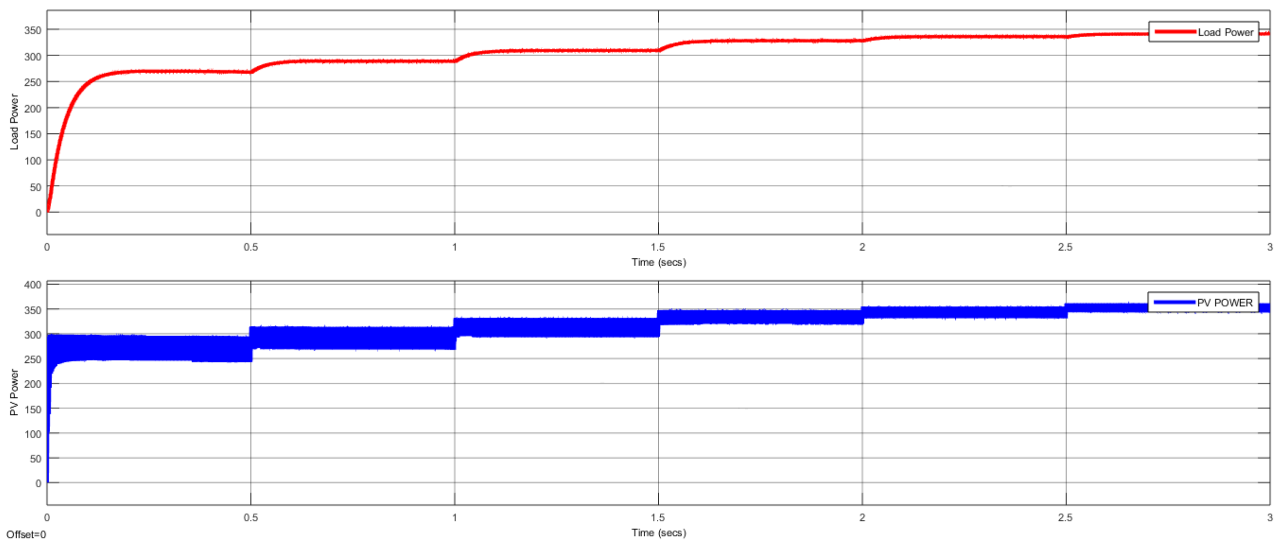


Figure 14: Load Power and PV power vs time curve

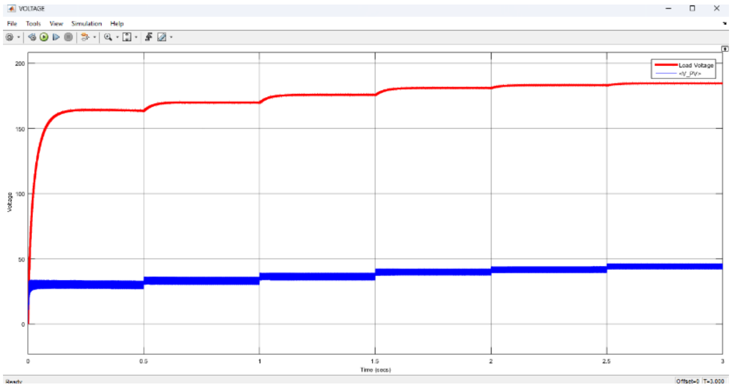


Figure 15: Load Voltage and PV Voltage vs time curve

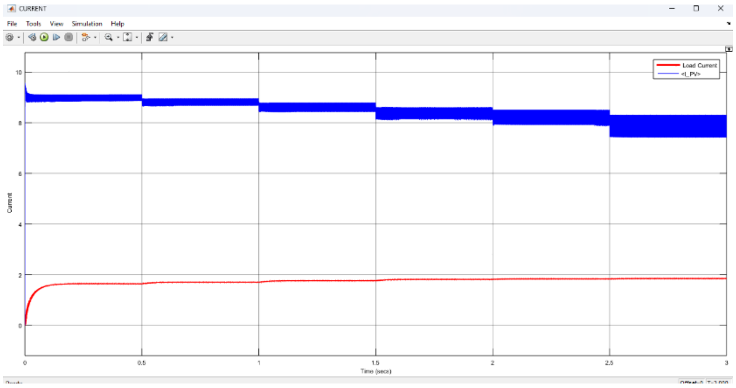
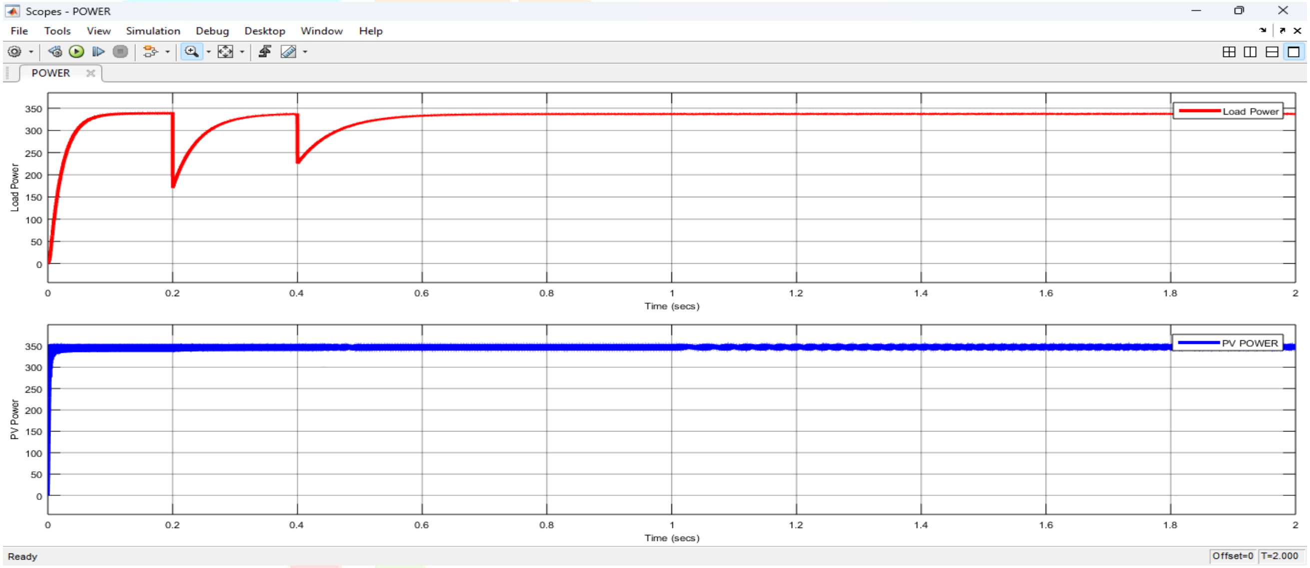


Figure 16: Load Current and PV current vs time curve

Case 3: Constant Irradiance (1000W/m^2), Constant Temperature (25^{o}C) and Variable Load (100 ohm, 200ohm, 300ohm)

Figure 17: Load Power and PV power vs time curve



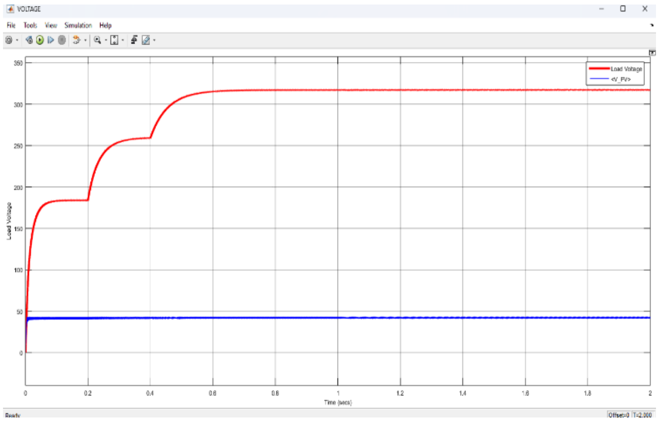


Figure 18: Load Voltage and PV Voltage vs time curve

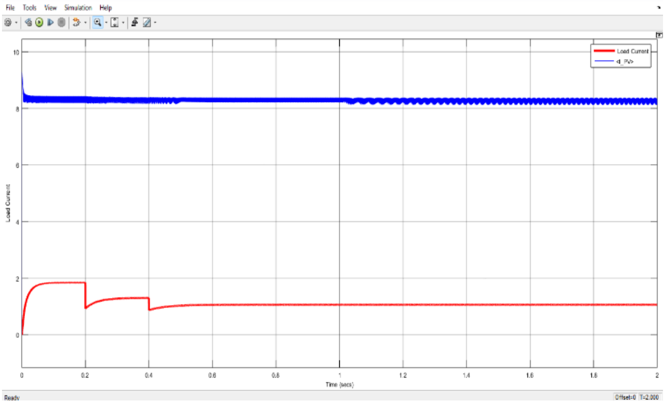


Figure 19: Load Current and PV current vs time curve

Table 2: SIMULATION RESULT

S. No	IRRADIANCE	TEMPERATURE	LOAD	PV POWER	LOAD POWER
1.	Variable irradiance: 1000W/m^2 800W/m^2 600W/m^2 400W/m^2 200W/m^2 100W/m^2 (At an interval of 0.5 seconds)	Constant temperature (25^0 C)	Constant Load (100 ohm)	350W 278W 208W 138W 68W 32W	340W 270W 201W 134W 65W 31W
2.	Constant irradiance(1000W/m^2)	Variable temperature: 60^0 C 50^0 C 40^0 C 30^0 C 25^0 C 20^0 C (At an interval of 0.5 seconds)	Constant Load (100 ohm)	300W 312W 330W 348W 350W 360W	270W 290W 312W 330W 340W 343W
3.	Constant irradiance(1000W/m^2)	Constant temperature (25^0 C)	Variable load: 100ohm 200ohm 300ohm (At an interval of 0.2 seconds)	350W	340W (There are fluctuations when load is added but it settles down quickly)

Considering the effect of solar radiation, temperature and load; the simulation results of load power-PV power versus time, load load-PV voltage versus time, and load current-PV current versus time under different conditions are shown in Figure 11 to Figure 19. The maximum output power is strongly affected by changing solar radiation and temperature. The results are summarized in Table 2. The simulation results show that the neural network is quite accurate and performs well when it is compared to the standard specified values of the Simulink 350 W PV array model shown in Figure 3 and Figure 4.

V. CONCLUSION

Extracting the maximum output from a solar PV array is a critical step in harvesting renewable energy, such as solar energy. The objective of the MPPT technique is to obtain the maximum available power from the solar PV array. Irradiance and temperature are the two main factors that affects the output power of a PV array.

A 350W PV array is selected from the MATLAB Simulink library and real-time input data (Irradiance and Temperature) are collected from a location near the Thar desert in India by using the NASA website for training and testing the neural network. A MATLAB code for a Simulink model is developed to change the PV terminal voltage to monitor the maximum output. A Simulink model of an MPPT control system using a neural network is shown in the figure with different input conditions of irradiance, temperature and load along with their respective results.

The results for changing irradiance, temperature and load conditions are summarized in Table 2. The results show that quite accurate value of maximum power is tracked by the MPPT algorithm within a few seconds with small to negligible fluctuations. Performance was observed to be unaffected by load changes. A slight deviation is observed when the load fluctuates, but it stabilizes quickly. We found that developing a neural network is quite simple and easy. For different temperatures and irradiances, the neural network provides more accurate results, proving the effectiveness of this method.

Future work is done by implementing MPPT technique using Neural Network for real solar PV panel considering partial shading conditions. A neural network can also be used to obtain maximum power in an integrated wind and solar power system.

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