International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 11 | Nov 2025 www.irjet.net p-ISSN: 2395-0072

A Matlab Modelling of a PV Array for MPPT Using ANN

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Abstract - *Solar power stands out as one of the most plentiful forms of renewable energy available today. significant and rapidly expanding. Getting the most electricity out of solar PV while minimizing losses is of the main design objectives of a PV system. Numerous methods for monitoring the PV system's peak performance point have been documented in various literatures in order to accomplish this. Theoretical information on creating and deploying an artificial neural network-based Maximum Power Point Tracking (MPPT) controller for a standalone Photovoltaic systems are implemented. MATLAB/Simulink is used to create a 5KW solar PV array. The neural network is trained and evaluated using real-time data regarding shifting environmental variables, such as temperature and irradiance changes. Simulation results are shown under rapidly fluctuating load circumstances, temperature, and sun radiation.*

Solar photovoltaic (PV) systems, neural networks, and maximum power point tracking (MPPT) are the keywords.

1.INTRODUCTION

The solar energy that sustains life on Earth is also a limitless and sustainable source of power. Over the past 50 years, a large number of research have been conducted to examine various aspects of photovoltaic (PV) cell design and performance characteristics. The ultimate objective has been to develop fully integrated PV modules which may successfully contend with conventional energy sources.

There is a growing trend toward the usage of solar cells in both industrial and domestic applications as solar energy is anticipated to play a significant part in future smart grids as a distributed renewable energy source. 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.

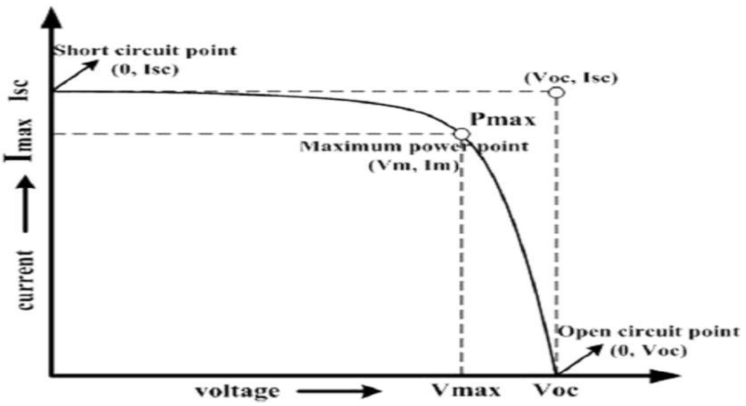

Figure 1: V-I Characteristics of solar PV array

1.1 History of Solar Energy in Karnataka

Karnataka has been instrumental in forward solar energy adoption in India, with several key milestones shaping its leadership in the sector. In 2009, the state commissioned a 3 MW solar facility at Yelasandra in Kolar district—recognized as the country's first utility-scale photovoltaic installation. It was also the first in southern India to introduce a comprehensive solar policy, which laid the substance for a wide range of renewable energy initiatives. With an projected solar potential of 25 GW and between 240 to 300 clear days annually, the state possesses favorable conditions for solar power generation.

One of the most prominent developments is the Pavagada solar park in Tumakuru district, which at one point was the largest operational solar power site globally, with a capacity exceeding 2,000 MW. Karnataka endures to expand its solar infrastructure through large-scale installations and targeted programs aimed at powering agricultural pumps and rooftops. The Renewable Energy Policy 2022–27 has additional accelerated this momentum by offering subsidies and encouraging innovations such as floating solar systems on reservoirs and lakes. By early 2025, the state's cumulative solar capacity had crossed 8.9 GW, reaffirming its position as a major contributor to India's renewable energy objectives and its commitment to sustainable electricity generation.

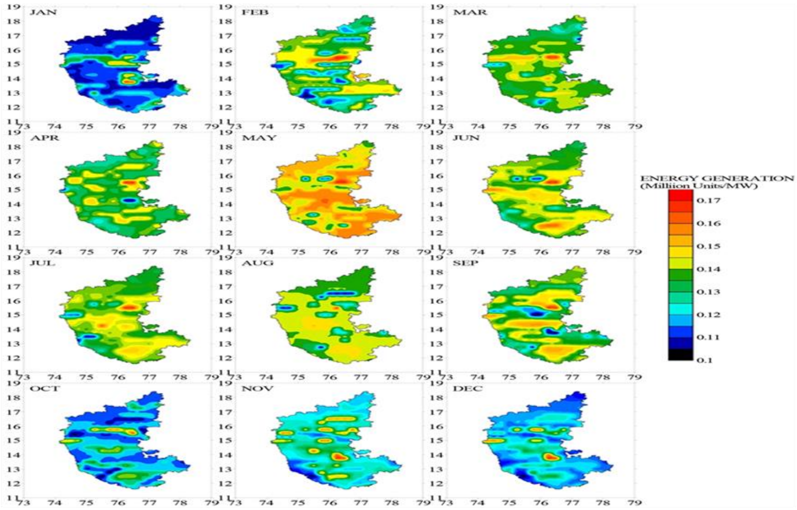

Fig 2:- Seasonal Energy Generation.

2. Methodology

At the forefront of the neural network-based MPPT system block diagram lies the solar photovoltaic (PV) array, responsible for converting incident sunlight into usable electrical power. The array's output voltage and current are notably influenced by environmental variables, particularly ambient temperature and solar irradiance. These two factors are fed into an offline-trained artificial neural network (ANN) controller, calibrated using empirical datasets, to predict the reference voltage corresponding to the Maximum Power Point (Vmpp). To ensure efficient energy conversion, the system pays a trained neural controller that determines the ideal operating voltage based on real-time temperature and irradiance inputs.

This controller interprets the nonlinear relationship among environmental conditions and photovoltaic behavior to estimate the voltage corresponding to the maximum power point (Vmpp). The calculated Vmpp is then fed into a pulse-width modulation (PWM) unit, which generates a control signal for the DC-DC boost converter.

The boost converter adjusts its duty cycle according to the PWM input, elevating the array's output voltage to match Vmpp. Its core components include an inductor, a switching device (such as a MOSFET or IGBT), a diode, and an output capacitor that stabilizes the voltage supplied to the load. To maintain consistent concert near the maximum power point, the system uninterruptedly monitors the PV voltage and current, allowing the controller to respond promptly to changes in load demand and solar settings.

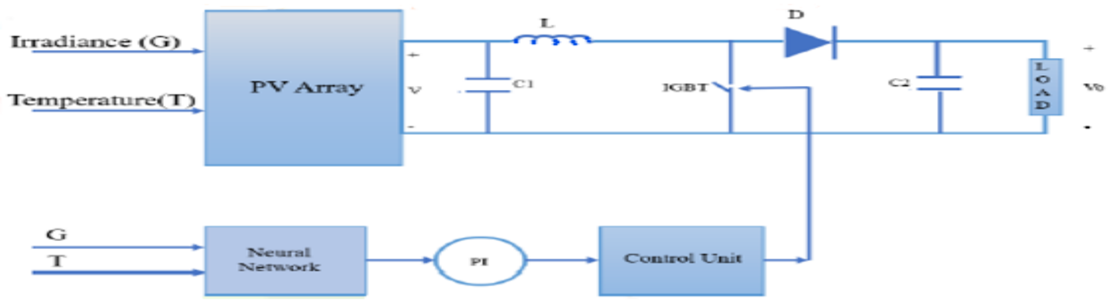

Fig 3 :- Schematic Representation of ANN-Driven MPPT Framework

At the core of any photovoltaic system lies the solar cell, a device engineered to transform sunlight into electrical energy. The electrical output specifically the current and voltage of these cells is influenced by environmental conditions and material properties. are dependent on solar radiation and panel operating temperature, which means that PV cells have a low conversion efficiency that gets worse as the temperature rises and the irradiance level falls, This argument, which is known as the MPP, is reached when the power change rate relative to voltage is zero. The MPPT of solar cells is monitored using A spectrum of management approaches.

3.MODELLING OF MPPT

A Soltech 5 KW 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 4 shows the V-I and PV Characteristics of 5 KW 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 5 KW solar PV Array

DESCRIPTION	Apollo Solar Energy ASEC-325G65
Maximum Power	324.9897
Cells per module	72
Voltage at maximum power point Vmp	35.99
Current at maximum power point Imp	9.03
Open circuit voltage Voc	45.48
Short circuit current Isc	9.394
Temperature coefficient of Voc	-0.34302
Temperature coefficient of Isc	0.072897
Shunt resistance Rsh	0.99583
Series resistance Rs	0.45886
Diode ideality factor	0.99586

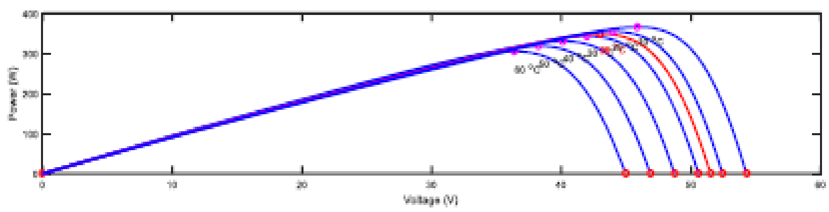

Fig 4: V-I and PV Characteristics of 350W solar PV array with standard and varying Temperature condition

MATLAB/Simulink is used to create the suggested system with a 325 W Apollo solar module. Three main components make up the entire circuit: the ANN-based MPPT controller, the power conditioning stage (boost converter + PWM control), and the PV source.

PV array for solar power

•As the input source, a photovoltaic system generates The direct current output parameters voltage and current are influenced by ambient temperature and incident solar radiation levels.

•Due to the inherent nonlinear characteristics of photovoltaic modules, their operating point shifts in response to fluctuations in temperature and solar irradiance. Without an active control mechanism, the system fails to naturally align with the Maximum Power Point (MPP), resulting in suboptimal energy extraction.

Boost Conversion

A DC - DC boost converter is a device that converts the output of the photovoltaic array into a DC voltage that can be directly converted to the load and allows efficient power transfer.

The main purpose of the converter is to control the Adjusting the output voltage at the photovoltaic terminals to the intended operating threshold which the ANN controller estimates.

The arrangement includes an inductor, a capacitor, a diode and a switching device usually a IGBT- in a way that allows one to easily control conversion of energy.

ANN-Powered MPPT Regulator

•Two real-time lines are fed into the ANN, which are temperature (T) and irradiance (G).

•It was configured to have ten hidden layers and it was trained on historical NASA data.

•In the given conditions, the Vmpp is predicted by the network.

PWM Generator

Mistake is processed to create PWM pulses that control the IGBT of the boost converter.

•The converter causes the PV array to operate at the Vmpp which the ANN predicted through modulating the duty cycle.

Load

•Resistive load (100 30 30 Ω) is connected at converter output.

•The artificial neural network controller is a dynamic control of the system parameters to maintain the photovoltaic array working at maximum power levels, irrespective of the changes in load conditions.

4.SIMULATION RESULTS AND DISCUSSION

The 5KW solar photovoltaic (PV) array's MATLAB/Simulink simulation results show that a neural network-based MPPT controller is remarkably adept at optimizing power extraction under a range of environmental circumstances. The photovoltaic array demonstrated reliable peak power tracking across a wide irradiance range from 1000 W/m² down to 100 W/m² under fixed temperature conditions. When temperature was varied between 20°C and 60°C at constant irradiance, the system showed predictable shifts in maximum power output, mainly due to the inverse relationship between temperature and voltage. In spite of the MPPT controller being configured for steady-state operation, transient fluctuations in output power and current were observed under changing load conditions.

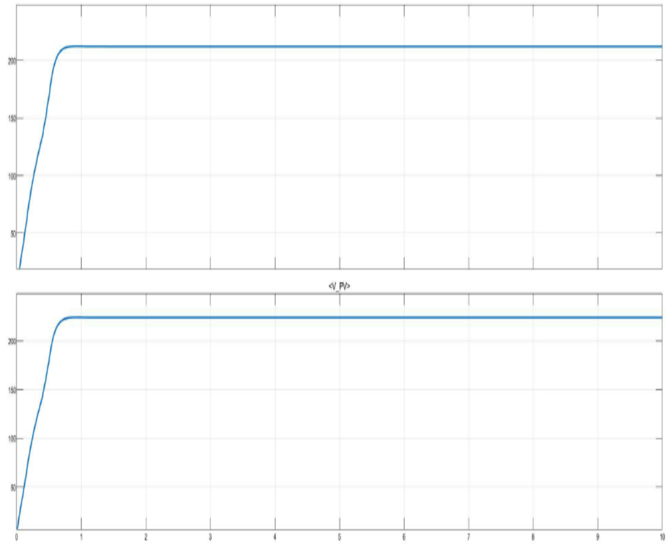

Fig5:- Load voltage and Pv voltage v/s Time curve

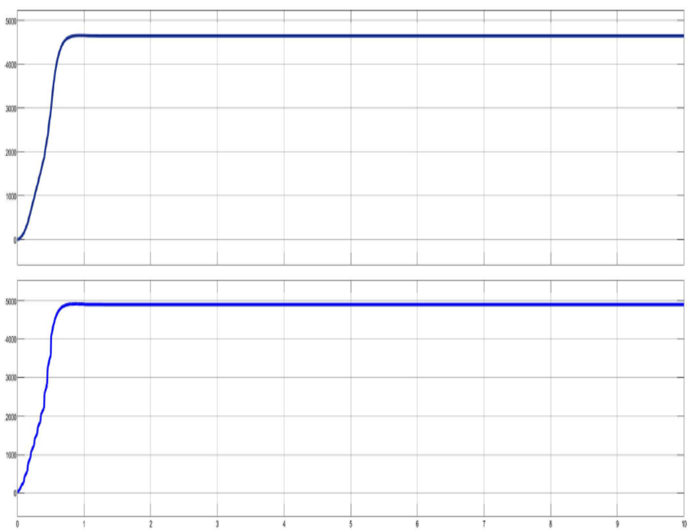

Fig6:-Load power and Pv Power V/S Time curve

The neural controller was trained on an extensive dataset that emulated real world variations in irradiance and temperature. This enabled swift and accurate final estimation of the voltage corresponding to the maximum power point, resulting in improved tracking precision and reduced oscillatory behavior associated to traditional MPPT techniques. The system's adaptability and resilience under dynamic conditions affirmed the suitability of neural-based control for real time PV regulation. Its potential extends to more complex scenarios, including hybrid energy configurations and environments affected by partial shading.

Table 2: SIMULATION RESULT

Case 1:-Normal load

Sl.no	Solar power	Rload	Power	Voltage	Current	Ploss	Error%
1	5027	150	4984	238.1	21.08	43	0.8554
2	5027	160	4715	236.4	21.01	312	6.206
3	5027	140	4723	236.8	22.03	304	6.047

Case 2:-Over load

Sl.no	Solar power	Rload	Power	Voltage	Current	Ploss	Error%
1	5027	1500	79.3	791.34	2.709	49477.7	98.422
2	5027	2000	82.32	643.44	2.043	4944.64	98.3608
3	5027	6000	160.234	296.1	0.541	4866.82	96.8132

Case 3:-Under load

Sl.no	Solar power	Rload	Power	Voltage	Current	Ploss	Error%
1	5027	3	436.54	7.498	22.44	4590.7	91.32
2	5027	8	536.23	12.24	22.45	4490.89	89.33
3	5027	15	808	35.95	22.46	4219	83.926

5. CONCLUSIONS

A critical aspect of harnessing solar energy efficiently lies in extracting the highest possible power from photovoltaic arrays. Maximum Power Point Tracking (MPPT) algorithms are specifically designed to optimize this output under varying environmental conditions. Among the key variables influencing PV performance are ambient temperature and solar irradiance, both of which dynamically alter the array's electrical characteristics. power. Using real-time input data (temperature and irradiance) collected from a position close to home via the NASA website, the neural network is trained and tested on a 5KW solar array selected from the MATLAB Simulink package. A MATLAB code for a Simulink model is developed to change the PV terminal voltage in order to track the maximum output. A neural network-based MPPT control system with changing load, temperature, and irradiance input conditions and their related outputs is shown in the image as a Simulink model. gives an overview of the results under different load, temperature, and irradiance conditions.

Future research will employ a neural network in order to apply the MPPT approach to a realistic solar PV panel considering the effect of partial shading. It is also possible to optimize electricity in a wind and solar power system with the help of a neural network.

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