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Numerical Simulation and Performance Assessment of ANN-INC Improved Maximum Power Point Tracking System for Solar Photovoltaic System Under Changing Irradiation Operation

Ashish Raj[1], Manoj Gupta[2]

[1]PhD Scholar, Department of Electrical and Electronics Engineering, Poornima University, Jaipur, Rajasthan, India
[2]Professor, Department of Electrical and Electronics Engineering, Poornima University, Jaipur, Rajasthan, India

Abstract— The Government of India has set itself the ambitious target of meeting the country's rapidly rising demand, which is mainly met by coal and oil. Government has targeted to produce 40 percent of total energy generation through renewable energy by 2030. New Delhi works hard to produce 175 GW (GW) of renewable energy by 2022 with prevailing solar power, with a goal of 100GW, and wind power. Increasing environmental concerns, declining fuel supplies, and increased energy requirements have directed our focus towards an aspirational future based entirely on energy supply technologies for renewable sources and non-polluting sources. Power generation via photovoltaic (PV), due to their benefits such as ease of available, low cost, negligible environmental pollution and lower maintenance tariff, is increasingly becoming popular in comparison with other renewable resources. To minimise the effects of changing environmental conditions and improve the power provided by the PV system, the Maximum Power Point Tracking (MPPT) technique was used. It keeps track of the panel's maximum power output in order to increase energy generation. Easy design, low cost, good performance characteristics with minimal output power variability, and the ability to monitor in changing conditions easily and quickly are all features of MPPT controllers. In the current study, an MPPT system based on an improved neural network was created. As compared to existing software computing technologies and conventional power point monitoring methods, the proposed system has a lower transient and steady state response. On a standalone solar photovoltaic system, extensive research has been conducted and a model for system analysis has been created. The proposed system displayed less transient and a steady state response as compared to conventional power point monitoring methods.

Keywords:- *Photovoltaic (PV), Incremental Conductance, Matrix laboratory (MATLAB)), Particle Swarm Optimization (PSO), Mega Watt Peak (MWp), Soft Computing Techniques, Maximum Power Point Tracker (MPPT), Global Maximum Power Point (GMPP)*

I. INTRODUCTION

In photovoltaic power conversion into solar cells, two major breakthroughs have been made. To begin with, light assimilation results in the formation of an electron-hole pair. The electron and the hole are isolated by the gadget's structure. The electrons go to the negative terminal, while the holes go to the positive terminal. The power is provided based on the distribution of holes and electrons. The perfect terminal voltage and current are set using photovoltaic solar picture displays that are combined similarly, arranged, or mixed. The arrangement string configuration allows for a higher voltage level, but current evaluations are constrained by the individual photovoltaic cell value.[11]

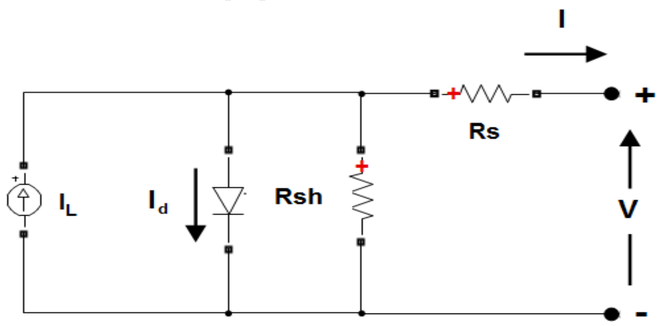

Fig. 1: Diode Modelling of Solar Cell

Figure 1.1 depicts the solar cell modelling diode. The solar cell diode model is used to calculate the I-V and P-V characteristics of solar cells. The controlling equations for the diode model are discussed, taking into account the Rs and Rp effects:

$$I = I_{sc} - I_{01}\left[e^{q\left(\frac{V+I.R_s}{kT}\right)} - 1\right] - I_{02}\left[e^{q\left(\frac{V+I.R_s}{kT}\right)} - 1\right] - \left(\frac{V+IR_s}{R_p}\right) \quad (1.1)$$

$$I = I_{sc} - I_0\left[e^{q\left(\frac{V+I.R_s}{nkT}\right)} - 1\right] - \left(\frac{V+IR_s}{R_p}\right) \quad (1.2)$$

where n is known as the "ideality factor," and the value of the ideality factor is usually determined by the solar cell manufacturing technology. A solar cell is a semi-conductor that converts sunlight into electricity. Solar cells, for example, will produce electricity using electromagnetic power if the photons' power is high enough to discern electron matches. A single or multi-crystal solar cell produces an electric flux voltage of 0.5 volts. (Solar irradiance is electromagnetic radiation emitted by the sun. The voltage of the solar cell's N/P obstacle layer causes this. The sum of electrons thumped into the conduction band determines the current or amperage of the solar cell. This current is linked to the measurement of solar radiation by the sun. The current of a solar cell can be increased by increasing the solar cell's surface area or by increasing the solar cell's measurement of solar radiation. A solar battery is made up of solar cells. As solar cells are combined, the current stays the same, but the voltage increases at the same time.[1][2]

Solar cells are connected to form a "module" that supplies current and voltage to the system (and therefore power). To frame a 12-volt module, for example, 24 solar cells must be attached in a scheme. A photovoltaic module is also known as a solar cell array. Power is proportional to current voltage. When the sun shines at a rate of 1000 watts/meter^2 and the temperature is 25 degrees Celsius, the power level of a photovoltaic module is commonly referred to as the module's power output. This is an approximation of average sunshine in the middle of a clear summer day. A 15 percent effective 1m2 square module will thus produce 150 Watts in the early afternoon. A photovoltaic (PV) exhibit is a set of power-generating photovoltaic modules. A PV display can be made up of only one module, with output ranging from a few watts to several megawatts, depending on the number and output of the modules. The "heap" is powered by direct current produced by a photovoltaic display. From charging a battery to powering a matching system in a minicomputer to powering a structure or city, batteries are used in a variety of applications. An inverter that adjusts the immediate current in the current should be associated with a PV cluster when it is linked to the utility network. The majority of inverters have a 90% efficiency rating. The advanced inverters generate extremely clean electricity at a constant voltage. Clean power denotes a spinning current that is nearly free of mutilation or harmonics, similar to a sinus wave. Solar panels today are just 30-40 percent electrical. Radiation from the sun. Via maximum power point control, the aim is to improve the operational efficiency of solar photovoltaic systems. The source impedance and load impedance can be adjusted by changing the duty cycle of the corresponding boost converter, allowing for complete power transfer monitoring from the photovoltaic system.[18]

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II. MAXIMUM POWER POINT TRACKING

The standard solar photovoltaic models with one and dual diodes are seen. The single diode model is less complex, but the dual diode model is more advanced in order to increase solar PV modelling performance. Double diode displays, on the other hand, have a more complicated and mathematical charge in parameter extraction. In electrical equivalent circuits for the solar photovoltaic system shown in figure 1.1. The performance equation for a single diode model is as follows.

$$I = I_{PV} - I_0 \left[exp\left(\frac{V+IR_S}{nV_T}\right) - 1 \right] - \left(\frac{V+IR_S}{R_{sh}}\right) \quad 2.1$$

Where,

I_{PV} output current PV module, A
I_0 diode saturation current, A
I_D Diode Current, A
I_{Sh} Shunt Current, A
R_S Series Resistance, Ω
R_{Sh} Shunt Resistance
V_T Thermal Voltage,V
V output voltage of PV array, V
I output current of PV array, A
N_S No.of series cell connected
N_P No. of Parallel cells connected
K Boltzmann constant (1.3806503 x10^{-23} J/K).
q electron charge(1.60217646 x 10-19 C)
T Temp., ° C.
n fill Factor (ideal=1)

Thermal relation is provided

$$V_T = KT / q. \quad 2.2$$

The diode current expression is indicated

$$I_D = I_0\left(e^{qVd/nKT} - 1\right) \quad 2.3$$

The current load expression is given

$$I = I_{PV} - I_d - I_{sh} \quad 2.4$$

Shunt current is given by Shunt

$$I_{sh} = \left(\frac{V+IR_S}{R_{sh}}\right) \quad 2.5$$

The current phase equation is calculated by

$$I_{PV} = I - I_0 \left[\exp\left(\frac{V_{ph} + R_{sh}I_{sh}}{n}\right) - 1 \right] \quad 2.6$$

The current equation is given by the reverse saturation

$$I_0 = n_p I_{ph} - n_p I_{rs} \left[exp\left(\frac{KV}{n_s}\right) - 1 \right] \quad 2.7$$

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I-V characteristics represent a relationship between current and voltage in the Solar Cell under various irradiation and temperature conditions. This curve evaluates the parameters and behaviour of certain solar cells.

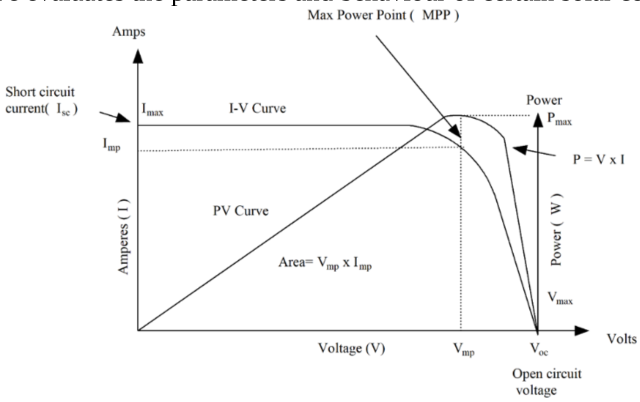

Figure. 2.1 I-V Curve of Solar Cell Characteristics

The graph above depicts a standard solar PV cell that operates at a standard test condition (STC). The charcteristic curve demonstrate the relation of voltage and current which in turn is the result of solar cell power generation. The solar cells are open-circuited and not connected to a load, ensuring that the current is zero and the cell voltage is at its maximum. When the voltage transverse solar cell is zero, the current through the solar cell is known as short circuit (Isc).[16]

$P_{max} = V_{oc} \times I_{SC}$ 2.8

$P_{mpp} = V_{mp} \times I_{mp}$ 2.9

Where,

V_{oc} Open Voltage Circuit

I_{sc} Short circuit current

P_{max} Max Power

V_{mp} High voltage at the point of service

Effect Optimum current at operational condition.

P_{mpp} Highest power at the operational condition.

Maximum power point monitoring methods are used to obtain the maximum value of power in a solar system, allowing the most reliable and maximum amount of power to be sent from the source to the load. We know that solar radiation and temperature fluctuate during the day, so an algorithm that can monitor the MPP is needed. These can have a major impact on the PV system's performance. It is also claimed that if the system's operating point is not closer to MPP, a large amount of losses would occur. The "Maximum Power Point" is the voltage point at which the power value is at its highest. This point, however, varies with solar irradiance and temperature, and the key challenge is determining the optimum voltage and current points for maximum power under varying atmospheric conditions. The majority of MPPT methodologies depend on PV characteristics such as duty cycle management and the use of a look-up table. [15]

III. ARTIFICIAL NEURAL NETWORK

The human brain is a versatile tool capable of completing even the most difficult tasks. Artificial neural networks are built on a model of the human brain that has been created artificially. While it is not feasible to replicate the human brain in its entirety at this time, there are certain limitations to what current technology can do artificially. It is possible to create condensed artificial neurons and an artificial neural network. It is possible to obtain the interconnections of the neurons. ANNs can be produced in a variety of ways to mimic the brain. The Artificial Neural Network performs admirably when it comes to recognising basic patterns or solving complex problems. They are artificially used in intelligence analysis due to their exceptional training skills. ANNs are educated using data sets with a large amount of data. For the first time, the neural network is trained with information comprising various types of images. Even if the given data input exceeds the neural network's data collection, the input provided to the network can be categorised and categorised once educated. As a result, the characteristics do not need to be specified directly. The network learns to differentiate between mammalian and non-mammalian species by receiving training from a mammal. The most popular feed, multilayer feeds, is chosen to be implemented using ANN. The outputs are returned based on the input value. An ANN feed is generated in the following way: The layer receives the input, and the output is returned by the output layer and passed through all hidden layers.[2][3]

$Y(x) = g(W_{n+1} \sum_{l=0} W_1 x_i)$ (3.1)

$g(x) = 1/(1 + e^{25x})$ (3.2)

To get an output, it is easy to spread the input via an ANN feeder's network.

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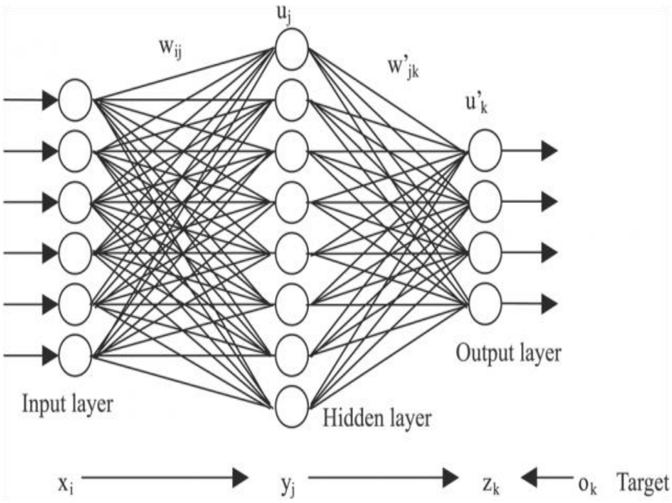

Fig. 1.4.Fully linked multi-layer feed to a hidden layer

The issue occurs when dealing with a network that has links in all directions (as in the brain) and needs to measure output. These loops can be processed with the aid of recurrent networks since links are made within the network. Recurrent networks can code time dependency, but forward networks can better provide feedback on problems that are not time dependent. [15]

Figure 1.4 depicts a multifaceted ANN feed that links all of the neurons in each layer to the next layer. This network is known as a completely linked network, and the ANNs are normally, but not always, fully connected. The mass assigned to different inputs is one thing, and the value in activation functions is another. There are two parameters to change when training a single ANN. Such an arrangement is impractical, and adjusting only one parameter will make the device easier to manage. To solve this problem, a bias neuron is developed. The outcome is still 1 now, as it is with the bias neuron. The neuronal bias is only linked to the next layer of neurons, not the previous one. The weights of the ANN type are always 1 in initial state, since the product of a partial neuron is always 1. An input layer is the first layer, and an output layer is the last layer. There are three different types of layers. Between the two multi-layer feed forwards, a number of layers are linked. ANN has layers that are called hidden layers. The relation moves only forward from the first layer to the next layer. Feeding forward with multilayer is a good idea. ANNs are divided into two phases: The first is referred to as the learning process. If a specific input is given during the training process, a specific output is generated. The ANN receiving ongoing training on a collection of training data accomplishes this. The total or combined number of the remaining weights is explicitly applied and processed via the activation function value similar in the second step of implementation. The prejudice neuron's addition aids in the deletion of the activation function's t. If the ANN has been conditioned, the weights just need to be changed. The meaning "t" is not removed without the addition of a bias neuron since it is the complete value. Function will show regardless of the weight value whether all inputs are zero. [17]

IV. PROPOSED METHODOLOGY

Neural Artificial Network (ANN) based on information collected from the Incremental (Inc-Cond) method. The neuron based artificial network comprises three layers: input, hidden and output .

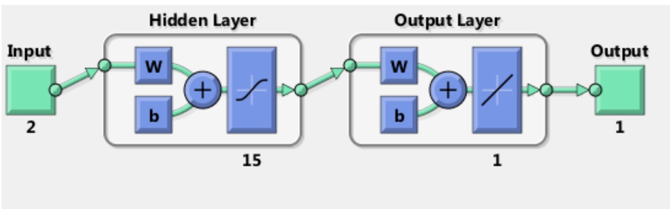

Fig. 1.5. Design of Neural Network

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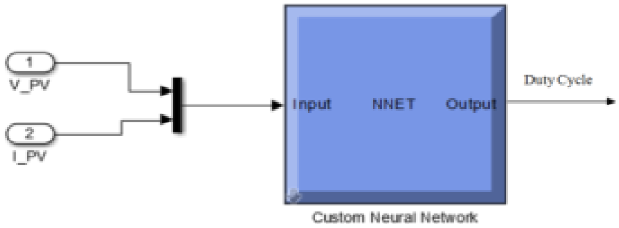

Fig. 1.6 Neuron Model for MPPT System

Figure 1.6 shown. PV voltage, current and solar irradiance can be used to train ANN. or any combination of these temperatures. Neural network learning is carried out by feed-forward weight updating. 200000 data collected from INC algorithm are used for training. Part of the data used for training is shown in Table below.

$$E_{mse} = \sum_{k=0}^{n} = \frac{1}{12}[m(k) - o(k)]^2 \quad (1.5)$$

Propagation of back Levenberg- Marquardt algorithm with PV and PV current, where m(k) refers to the output measured and o(k) refers to the output required and N refers to the number of training patterns. ANN's input. The hidden layer contains 15 neurons and is activated tangently by the sigmoid produces output from hidden layer while neurons are trained linearly output layer Enable the output layer output function. The neural network performance function is analysed with its medium error (MSE).

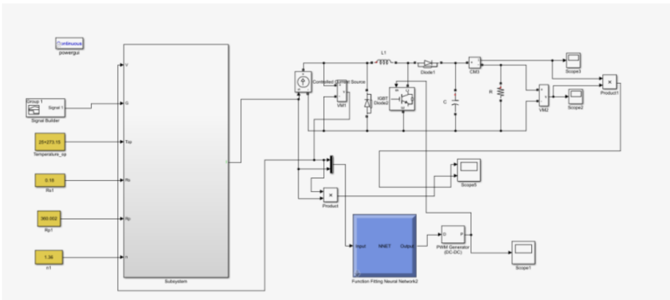

Fig. 1.7. Design of Simulink Model for Proposed System

The benefit of the proposed algorithm is that it takes more time to track MPP. Everyone PV array parameters alter with time, the neural network must therefore be trained To ensure accurate MPP tracking regularly. Input to the subsystem of the PV panel, i.e. Irradiation was as follows varied. quantitatively.

V. RESULTS

In this exploration, a soft computing-based charge controller was developed to effectively track the maximum IV power points of PV systems with variable irradiances and complex working conditions, and soft computer-based control systems with enhanced incremental conductance-based trained artificial neural network configuration and duty cycles were controlled.

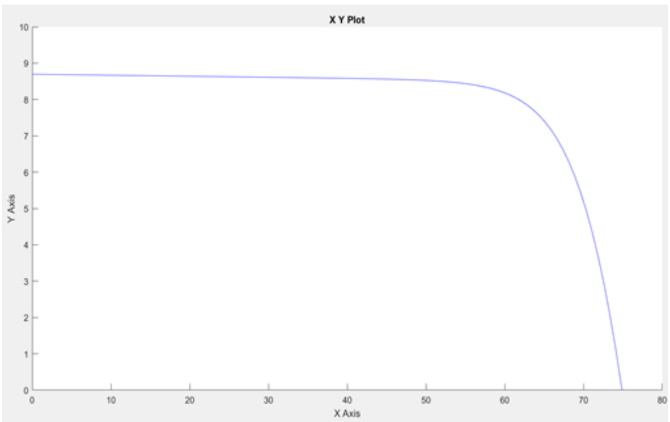

Fig. 1.8 V-I Characterisitcs of Solar Panel

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The PV modules and battery on the storage system, as well as the inverter, are connected to the load controller in high-energy applications. According to current research, the operating performance of a photovoltaic solar system can be improved by the use of a powerful power converter with a soft-computer MPPT controller.

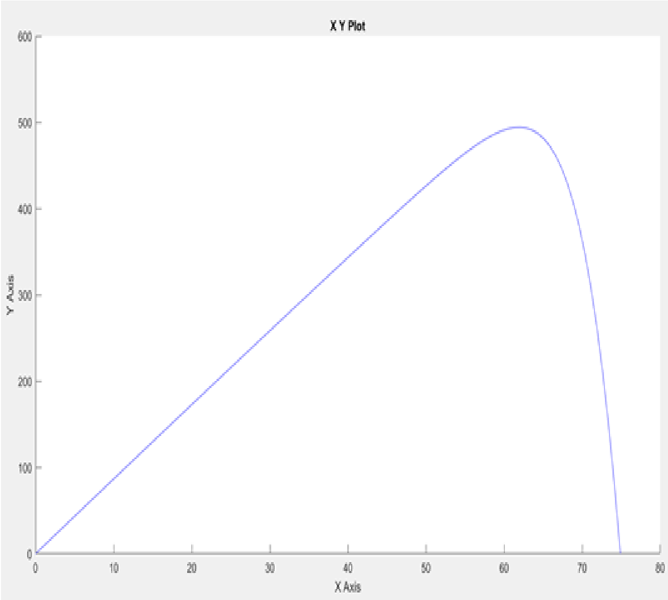

Fig. 1.9 P-V Characterisitcs of Solar Panel

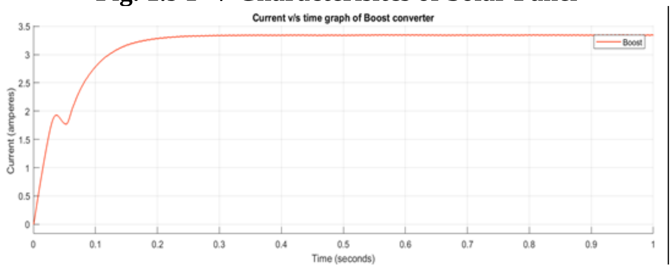

Fig. 1.10 Analysis of Currrent for Boost Converter

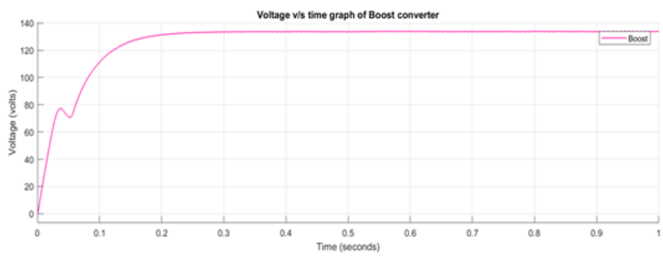

Fig. 1.11 Analysis of Voltage for Boost Converter

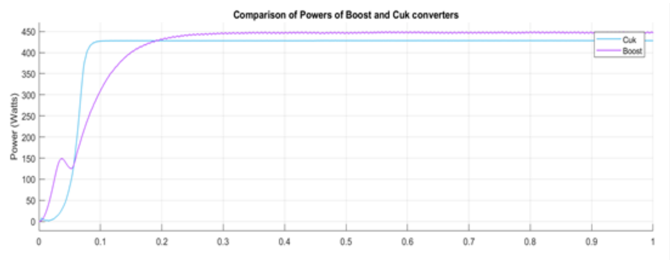

Fig. 1.12 Comparative Analysis of Power for Proposed System

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Table-1 Analysis of Results

MPPT	Power	Efficiency	Ripples
P and O	424 W	84.8 %	0.083
INC	430 W	86 %	0.081
ANN-INC Hybrid (Proposed)	450 W	90%	0.05

The addition of an effective charge controller based on an intelligent maximum energy monitoring system improves the operating efficiency of solar photovoltaic systems. A battery-contaminated charging controller can be interacted with solar photovoltaic device storage applications and high power invertors.

VI. CONCLUSION

ANN-INC based power point controllers were developed during this research to track efficiently with variable irradiance and complex operating conditions. The maximum power point was derived from photovoltaic systems' I V characteristics, and the soft computer program-based controls with boost configuration and operating cycles were controlled using enhanced ANN methodology. The PV modules and battery on the storage system, as well as the inverter, are all connected to the controller. According to current research, the operating performance of a photovoltaic solar system can be improved by the use of a powerful power converter with a soft-computer MPPT controller. The addition of an effective charge controller based on an intelligent maximum energy monitoring system improves the operating efficiency of solar photovoltaic systems. The study could be expanded to include the use of a deep learning convolutional neural network for photovoltaic device design and analysis.

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