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Application of Artificial Neural Network Based Improved MPPT System for Solar Photovoltaic System Under Variable Irradiation Condition

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Abstract— The Indian government has set an ambitious goal of satisfying the country's fast expanding demand, which is currently fulfilled primarily by coal and oil. By 2030, the government wants renewable energy to account for 40% of total energy generation. New Delhi is working hard to develop 175 GW (GW) of renewable energy by 2022, with an aim of 100 GW of solar power and 100 GW of wind power. Increasing environmental concerns, dwindling fuel supplies, and rising energy demands have shifted our focus to an idealistic future based solely on renewable and non-polluting energy supply technology. Photovoltaic (PV) power generation is becoming more popular in contrast to other renewable energy sources due to advantages such as ease of access, low cost, less environmental contamination, and lower maintenance costs. The Maximum Power Point Tracking (MPPT) methodology was utilised to reduce the impacts of changing external conditions and improve the power delivered by the PV system. In order to enhance energy generation, it keeps track of the panel's maximum power output. MPPT controllers have a simple design, low cost, strong performance characteristics with minimum output power variability, and the ability to monitor in changing situations easily and rapidly. An MPPT system based on an enhanced neural network was developed in the current study. The suggested system provides a lower transient and steady state response than existing software computing technologies and traditional power point monitoring approaches. Extensive study has been undertaken on a freestanding solar photovoltaic system, and a model for system analysis has been developed. In comparison to traditional power point monitoring approaches, the suggested system had a lower transient and steady state response.

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), Artificial Neural Networ*

I. INTRODUCTION

Two big breakthroughs in photovoltaic power conversion to solar cells have been made. The production of an electron-hole pair occurs as a result of light assimilation. The gadget's construction separates the electron and the hole. The holes go to the positive terminal, whereas the electrons travel to the negative terminal. The dispersion of holes and electrons is used to generate power. Photovoltaic solar picture displays that are joined identically, organised, or mixed are used to set the perfect terminal voltage and current. Although the arrangement string layout allows for a larger voltage level, current assessments are limited by the value of each solar cell. [11]

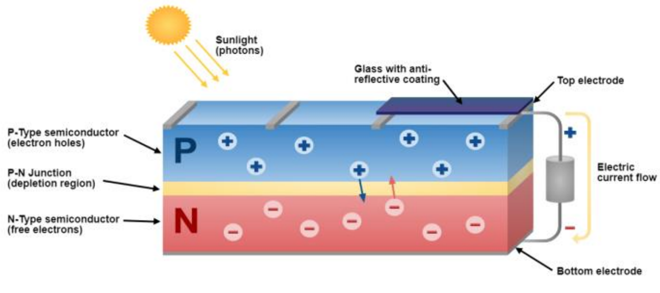

Fig. 1.1: Structure of Solar Cell

When photons from the sun reach a PV cell, they are absorbed, causing electrons in the cell's atoms to travel to the cell's holes[Ashley, 1992]. This is the process of changing the physical location of electrons and holes in order to generate electricity. Fahrenbruch and Bube (2012) cite electricity as one example. To put it another way, the photovoltaic effect is the name given to the physical process of converting sunlight into energy. via the photovoltaic cell A single PV cell can produce between 0.5 and 0.8 volts, or 2 volts. watts of power and can't power a wristwatch or a pocket calculator They require a minimum of 1 to 2 volts in either case. The power output, on the other hand, can vary. By connecting numerous PV cells to make a module, the total amount of energy produced can be increased. This may be the case. Solar panels, which are larger units, are used to generate electricity. A large number of panels are linked together. Arrays are a type of data structure. Solar cells are another name for photovoltaic cells [Nguyen]. [Lehman, 2006] and Lehman, 2006]. Two critical processes are involved in converting solar energy into photovoltaic cells [Razykov et al., 2011]. The schematic diagram of a PV Cell is shown in Figure 1.1. The absorption of light is first caused by a pair of electron-holes. The electron and hole are then separated by the semiconductor chip's structure. The electrons are separated into negative and positive terminals, whereas the holes are separated into positive and negative terminals. The hole spins as the devices remain stationary. As a result, an electron quits its hole and enters the empty location of another hole, and potential electrons do the same. The solar cell then turns into a conductor, absorbing electricity from the silicon wafer [Baeg et al., 2013]. However, the dopants, which are impure atoms, are required for the solar cell to function. The most frequent dopants utilised in PV cells are boron and phosphorus. When doped with Phosphorous, the Silicon Solar Cell becomes a negative type (n-type), however when doped with Boron Positive (p-type), the cell stays a negative type [Cotter et al., 2006].

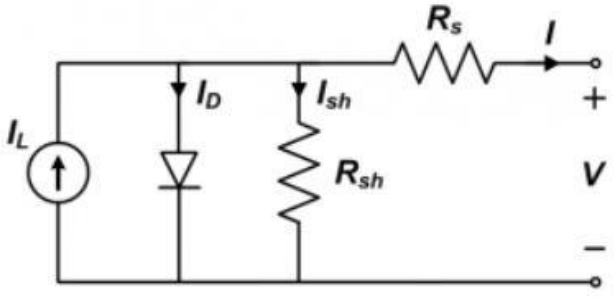

Fig. 1.2: Diode Based Model of Solar Cell

Figure 1.2 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

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

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.

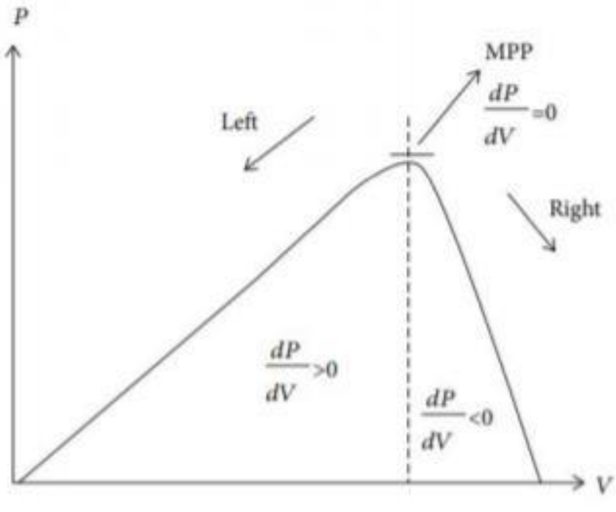

Figure. 2.1 I-V Curve of Solar Cell Characteristics

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 opencircuited 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 powerful tool that can handle even the most challenging jobs. Artificial neural networks are based on an artificially constructed model of the human brain. While it is not now possible to artificially reproduce the human brain in its entirety, there are some restrictions to what present technology can do. Condensed artificial neurons and an artificial neural network can be created. The interconnections of the neurons can be obtained. To simulate the brain, ANNs can be created in a variety of methods. When it comes to recognising simple patterns and tackling difficult challenges, the Artificial Neural Network excels. Because of their extraordinary training abilities, they are artificially utilised in intelligence analysis. Data sets with a substantial amount of data are used to train ANNs. The neural network is trained for the first time with data that includes a variety of image kinds. Even if the given data input surpasses the data gathering capacity of the neural network, the network's input can be categorised and classed once it has been trained. As a result, no direct specification of the properties is required. By obtaining training from a mammal, the network learns to distinguish between mammalian and non-mammalian species. Multilayer feeds, the most popular feed, was chosen to be implemented using ANN. The outputs are based on the value of the input. The following is how an ANN feed is created: The input layer gets the data, and the output layer returns the data, which is then transferred through all hidden levels. [12]

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

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

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

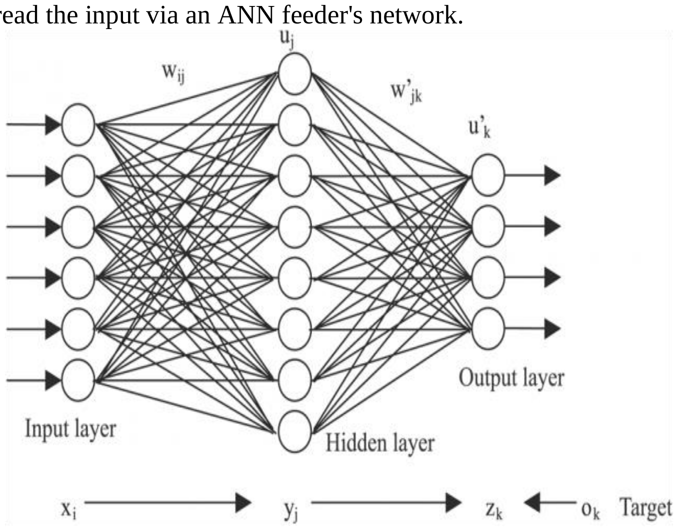

Fig. 3.1 .Fully linked multi-layer feed to a hidden layer

When working with a network that has linkages in all directions (such as the brain) and needs to quantify output, the problem arises. Because linkages are formed within the network, recurrent networks can be used to process these loops. Recurrent networks can code time dependency, whereas forward networks can provide superior feedback on non-time dependent situations.[15]
A multidimensional ANN feed is shown in Figure 3.1, which connects all of the neurons in each layer to the next layer. The ANNs are typically, but not always, totally connected in this network, which is known as a completely linked network. One item is the mass allocated to various inputs, and another is the value in activation functions. When training a single ANN, there are two parameters to adjust. Such a setup is unrealistic, and altering just one parameter will make the gadget more manageable. A bias neuron is created to overcome this problem. The result is still 1, just like with the bias neuron. Only the following layer of neurons is linked to the neural bias, not the prior one. Because the product of a partial neuron is always 1, the weights of the ANN type are always 1 in the initial state. The first layer is the input layer, while the last layer is the output layer. Layers are divided into three categories. A number of layers are linked between the two multi-layer feed forwards. Hidden layers are a type of layer in ANN. The relationship merely progresses ahead from one layer to the next. It's a good idea to feed forward using multilayer. There are two phases to ANNs: The first is known as the learning procedure. A specific output is generated if a specific input is given during the training phase. This is accomplished by the ANN getting continuing training on a set of training data. In the second step of implementation, the total or combined number of remaining weights is explicitly applied and processed via the activation function value. The insertion of the prejudice neuron aids in the deletion of the activation function's t. The weights only need to be replaced if the ANN has been conditioned. Because "t" is the whole value, it cannot be deleted without the use of a bias neuron. Regardless of the weight set, the function will display 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 .

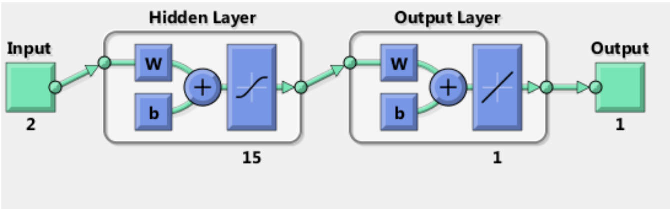

Fig. 4.1. Design of Neural Network

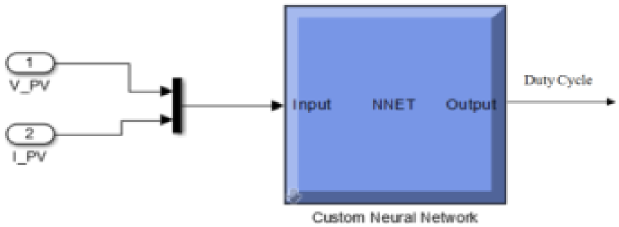

Fig. 4.2 Neuron Model for MPPT System

Figure 4.2 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.

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

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).

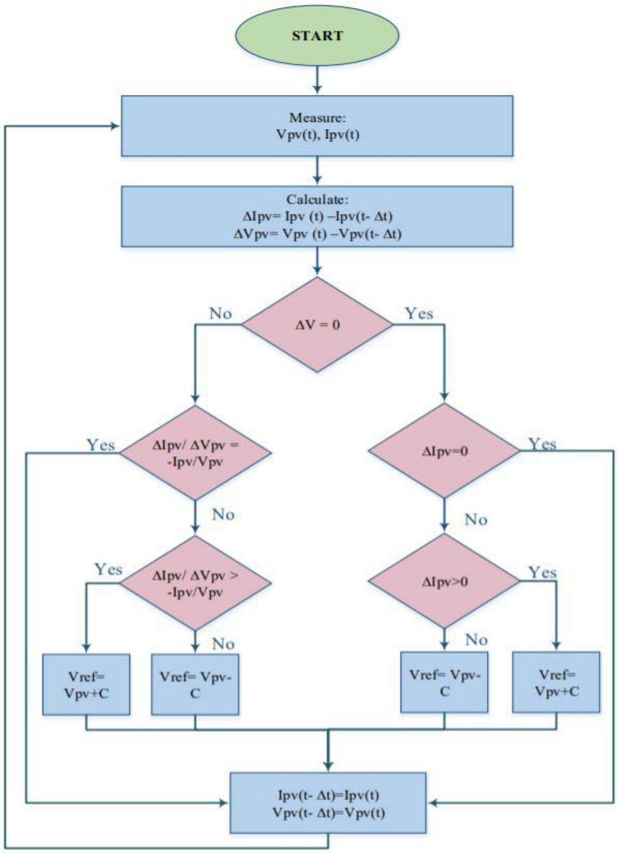

Fig. 4.3 Proces Flow Chart of INC MPPT

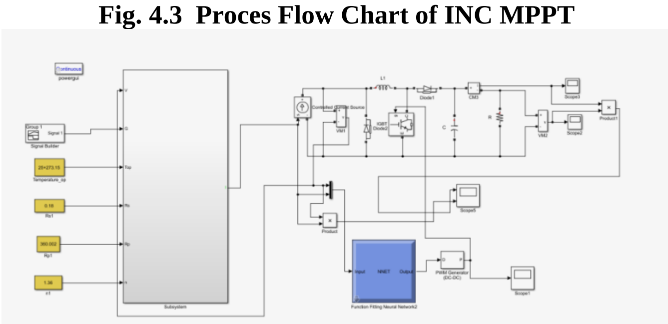

Fig. 4.4. Design of Simulink Model for Proposed System

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.

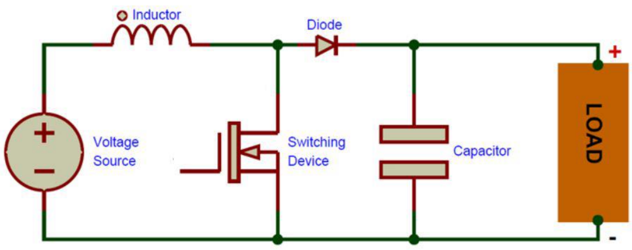

Fig. 4.5 Comparative Analysis of Power for Proposed System

The improved maximum power point system has been developed by training the data obtained from INC algorithm to design an efficient neural network architecture based maximum power point system. The system has been used to control the duty cycle of charge controller with the help of switching circuit. The system has been simulated under variable irrdiation and results have been analyzed to test the accuracy of the designed system.

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.

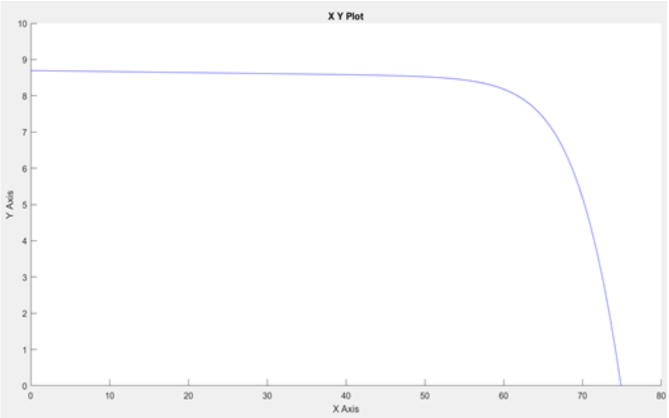

Fig. 5.1 V-I Characterisitcs of Solar Panel

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.

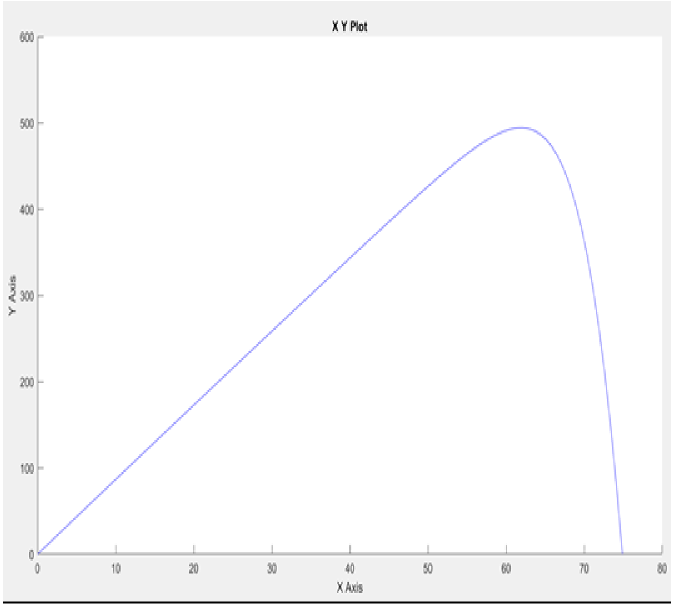

Fig. 5.2 P-V Characterisitcs of Solar Panel

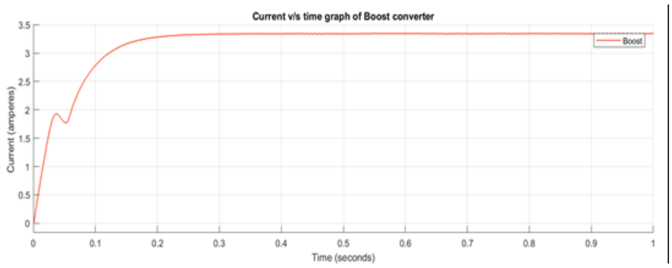

Fig. 5.3 Analysis of Currrent for Boost Converter

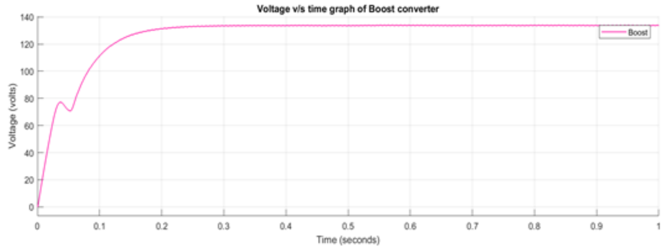

Fig. 5.4 Analysis of Voltage for Boost Converter

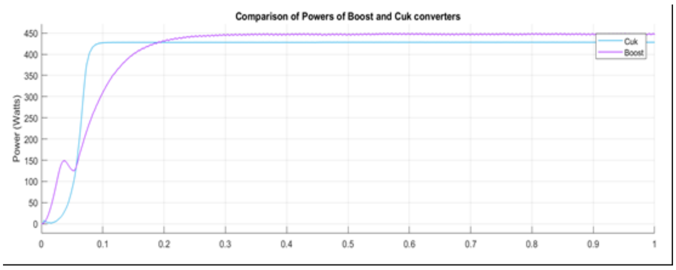

Fig. 5.5 Comparative Analysis of Power for Proposed System

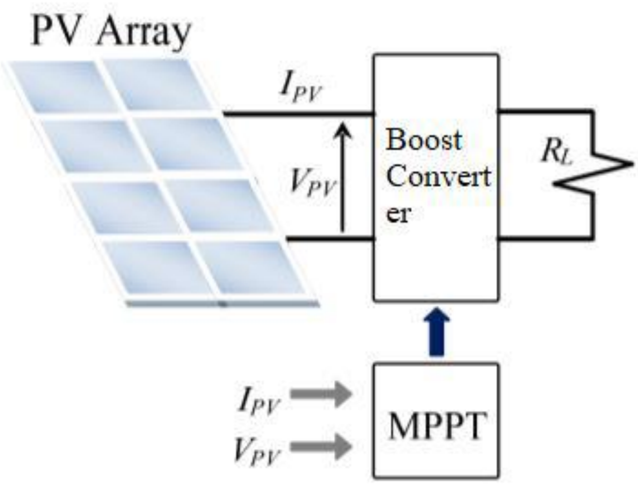

Fig. 5.6 Inteconnection Diagram of Proposed System

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. According to a comparison, the model implemented using the ANN MPPT methodology has a greater efficiency of than the existing perturb and observe MPPT methodology, which has an efficiency of 84.8 percent. In addition, when compared to the P&O model, the ANN model produces considerably fewer voltage and current ripples. Based on the provided characteristics, it is easy to conclude that the suggested hybrid technique provides better performance on the PV system with more power output under difficult operational conditions, as well as superior qualitative performance and quick tracking speed.

VI. CONCLUSION

ANN-INC based power point controllers were developed as part of this study to keep track of fluctuating irradiance and complex operating conditions. The maximum power point was calculated from solar systems' I V characteristics, and upgraded ANN methodology was used to regulate soft computer program-based controls with boost configuration and operation cycles. The controller connects the PV modules and batteries on the storage system, as well as the inverter. According to current research, using a strong power converter with a soft-computer MPPT controller can increase the operating performance of a photovoltaic solar system. Solar PV systems' operation efficiency is improved by adding an effective charge controller based on an intelligent maximum energy monitoring system. The research could be expanded to cover the design and analysis of solar devices using a deep learning convolutional neural network.

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