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Research Article

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Artificial Neural Network-Based Advanced Algorithm for New Generation Solar PV Systems

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Abstract

Solar PV has been one of the primary renewable energy sources in the current context due to its typical characteristics and sophisticated operation. Most of the time, the output of solar PV has been observed to be irregular and unpredictable; due to this, the load end gets stressed most of the time. Power generation via PhotoVoltaic (PV), due to their benefits such as ease of availability, low cost, negligible environmental pollution, lower maintenance tariff, has been gaining popularity compared to other available renewable resources. In order to minimize the drastic effects of changing environmental conditions over the output of the PV system, the Maximum Power Point Tracking (MPPT) technique has been adopted in most of the areas. It helps to keep track of the panel's maximum power output to increase overall energy generation. Easy design, low cost, good performance characteristics with minimal output power variability, and the ability to monitor changing conditions easily and quickly are significant features of MPPT controllers. An MPPT system based on an improved neural network has been proposed and developed in the current study. As compared to existing software computing technologies and conventional powerpoint monitoring arrangements, the proposed system has a lower transient and steady-state response. Extensive research has been carried out on a standalone solar photovoltaic system for multidimensional performance analysis. The output has been studied, and considerable changes have been highlighted, followed by necessary explanations.

Keywords: Photovoltaic (PV); Incremental Conductance; Matrix laboratory (MATLAB); Particle Swarm Optimization (PSO); Megawatt Peak (MWp); Soft Computing Techniques; Maximum Power Point Tracker (MPPT); Global Maximum Power Point (GMPP)

Introduction

The government of India supports the idea of self-reliance, thus setting an ambitious target of meeting the country's rapidly rising energy demand through clean, green sustainable resources, rather than fossil fuels which have been used intensively since the '90s. The government has targeted to produce 40%of total energy generation through renewable energy or DERs by 2030 [1]. New Delhi has been continuously making an effort to produce 175 GW of renewable energy by 2022 with prevailing solar power, with a goal of 100 GW. Increasing environmental concerns, higher carbon footprints, declining fuel supplies, and increased energy requirements have directed focus towards an aspirational future based primarily on renewable-driven sources and the need for the hour too [2]. In the solar cell photovoltaic power conversion process, two major break throughs have been made. To begin with, light assimilation results in the formation of an electron-hole pair. The gadget's structure isolates the electron and the hole 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 the individual photovoltaic cell value constrains current evaluations [3-5].

Figure 1 depicts the solar cell modeling 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:

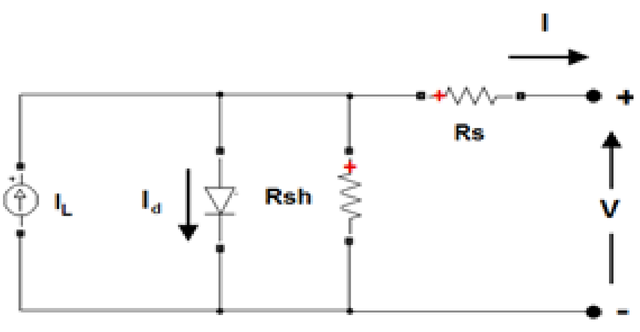

Figure 1: Diode modelling of solar cell.

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

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

Where n is known as the ideality factor and the value of the ideality factor is usually determined by solar cell manufacturing technology. A solar cell is a semiconductor 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 [6]. Solar irradiance is electromagnetic radiation emitted by the sun. The voltage of the solar cell's N/P obstacle layer causes the sum of electrons thumped into the conduction band

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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 [7].

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 [8]. Power is proportional to current voltage. When the sun shines at a rate of 1000 watts/meter2 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. 15% effective 1m 2 square modules 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 the direct current produced by a photovoltaic display [9]. 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 [10]. 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% 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 [11].

MPPT (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 modeling performance. On the other hand, double diode displays have a more complicated and mathematical charge in parameter extraction. In electrical equivalent circuits for the solar photovoltaic system shown in Figure 2 the performance equation for a single diode model is as follows.

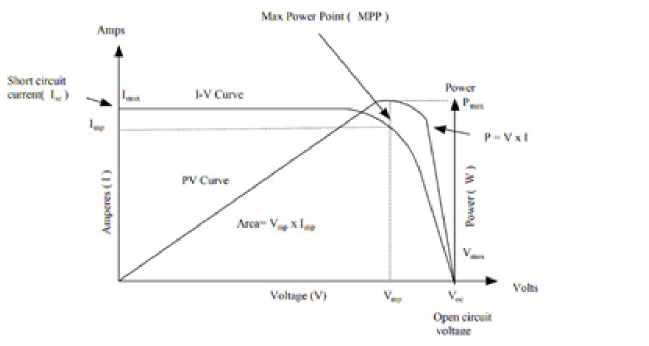

Figure 2: V-I characteristics curve of solar cell.

$$I = I_{pv} - I_0\left(\frac{V+IR_s}{\eta V_T} - 1\right) - \left(\frac{\left(V+IR_s\right)}{R_{sh}}\right) \qquad (1.1)$$

Where,

I_{PV}: Output current PV module

A_{I0}: Diode saturation current, A

I_D: Diode current, A

I_{Sh}: Shunt current, A

R_S: Series resistance, Ω

R_{sh}: Shunt resistance, Ω

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: Temperature, ° C

n: Fill Factor (ideal=1)

Thermal relation is provided with

V_T=KT/q (1.2)

The diode current expression is indicated by

$I_D=I_0(e^{qVd}/n^{kt}-1)$ (1.3)

The current load expression is given by

$I=I_{PV}-I_d-I_{sh}$ (1.4)

Shunt current is given by

$I_{sh}=(V+IRs)/Rsh$

The current phase equation is calculated by

$I_{PV}=I-I_0[\exp(Vph+RshIsh/\ n)-1]$ (1.5)

The current equation is given by the reverse saturation

$I_0=n_pI_{ph}-n_pI_{rs}[exp\ (KV/n_s)-1]$ (1.6)

V-I characteristics represent a relationship between current and voltage in the solar cell under various irradiation and temperature conditions. This curve evaluates the parameters and behavior of certain solar cells. The graph above depicts a standard solar PV cell that operates at a Standard Test Condition (STC). The characteristic curve demonstrates 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 a Short Circuit (SC).

$P_{max}=V_{oc}xI_{SC}$ (1.7)

$P_{mpp}=V_{mp}xI_{mp}$ (1.8)

Where,

V_{oc}: Open voltage circuit

I_{sc}: Short circuit current

P_{max}: Maximum 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 number of losses would occur. The "maximum powerpoint" 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.

ANN (Artificial Neural Network)

A 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 recognizing 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 categorized and categorized 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]

$(x)=(Wn+1\sum l=0W1xi)$ (2.1)

$(x)=1/(1+e25x)$ (2.2)

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

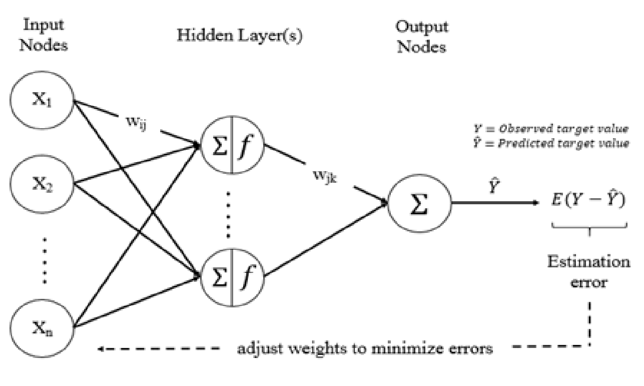

Figure 3: Fully linked multi-layer feed to a hidden layer.

Figure 3 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 inactivation functions are 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 an 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 multi-layer 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. The function will show, regardless of the weight value, whether all inputs are zero.

Methodology

Artificial Neural Network (ANN) (Figure 4) based on information collected from the Incremental (Inc-Cond) method. The neuron-

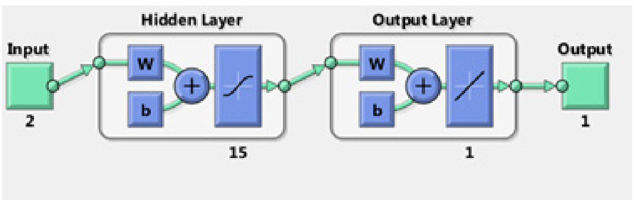

Figure 4: Design of neural network.

based artificial network comprises three layers: input, hidden, and output.

PV voltage, current and solar irradiance can be used to train ANN\ or any combination of these temperatures. Neural network (Figure 5) learning is carried out by feed-forward weight updating. 200000 data collected from the INC algorithm are used for training.

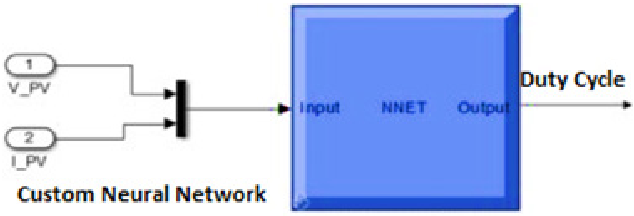

Figure 5: Neuron model for MPPT System.

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

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 tangentially by the sigmoid produces output from the hidden layer while neurons are trained to output layer linearly. Enable the output layer output function. The neural network performance function is analyzed with its Medium Error (ME).

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 (Figure 6) 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.

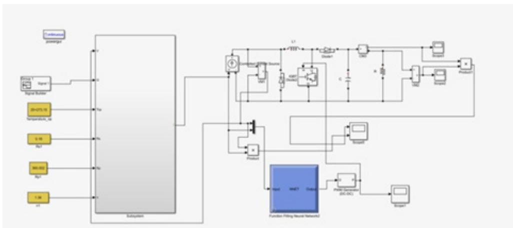

Figure 6: Design of MATLAB simulink model for proposed system.

Results and Discussion

In this exploration, a soft computing-based charge controller was developed to effectively track the maximum V-I (Figure 7) power

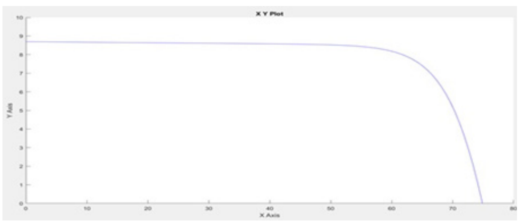

Figure 7: V-I characteristics of solar panel.

points of PV systems with variable irradiances (Figure 8) 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.

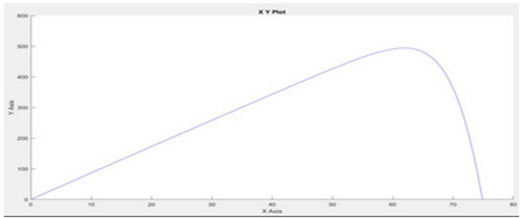

Figure 8: P-V characteristics of solar panel.

The PV modules and battery on the storage system and the inverter are connected to the load controller in high-energy applications. According to current research (Figures 9-11), a photovoltaic solar

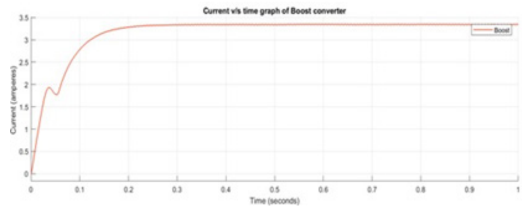

Figure 9: Analysis of current for boost converter.

system's operating performance can be improved by using a powerful power converter with a soft-computer MPPT controller. The addition of an effective charge controller based on an intelligent maximum

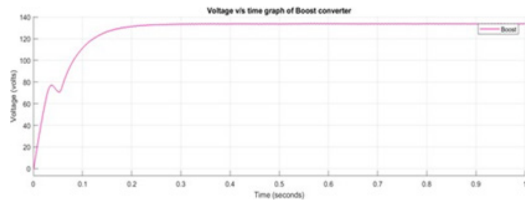

Figure 10: Analysis of voltage for boost converter.

energy monitoring system improves the operating efficiency of solar photovoltaic systems. A battery-contaminated charging controller can

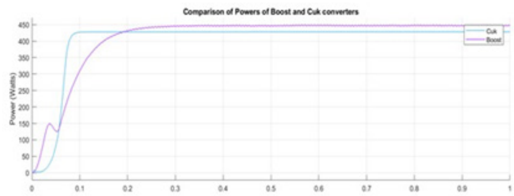

Figure 11: Comparative analysis of power for proposed system.

interact with solar photovoltaic device storage applications and high-power inverters (Table 1).

Table 1: Analysis of results.

MPPT	Power	Efficiency	Ripples
Pando	424W	84.80%	0.083
INC	430W	86%	0.081
ANN-INC hybrid(Proposed)	450W	90%	0.05

Conclusion

The need of the hour is to harness more energy out of the same installed solar PV unit or system by the implementation of a new effective MPPT algorithm 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 and the inverter are all connected to the controller. According to current research, a photovoltaic solar system's operating performance can be improved by using 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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