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Artificial neural network for maximum power point tracking used in solar photovoltaic system

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ABSTRACT

Nowadays, non-conventional energy sources like solar, wind, geothermal, and small hydro play a vital role in generating electricity. Among these, solar energy is utilized in urban and rural areas. When the sunlight falls on the solar plate, the PV cell produces charge carriers that produce an electric current. A photo voltaic cell is used when it works at the maximum power point. Traditional maximum power point tracking (MPPT) techniques are easier to structure and apply but perform worse than AI-based systems. The main objective of this paper is to develop an intelligent system to determine the maximum power point using artificial neural networks. This system uses the radial basis function network (RBFN) architecture to improve MPPT control for PV systems. The response characteristics of the photo-voltaic array are non-linear due to insolation, temperature variation, the incident light angle, and the solar cell's surface condition. Hence, this must be checked to develop the system's most significant amount of power. The MPPT controller's response can be recycled to monitor the DC-DC boost converters for maximum efficiency.

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1. INTRODUCTION

The abundance of sunshine over a broad portion of the earth's surface allows various photovoltaic (PV) system uses. PV panels are solar-powered arrays of cells that transform solar energy into electricity. The current and voltage available at the PV terminals can be used to charge the battery connected to the PV array and feed dc loads directly [1]. However, because the power output of a PV panel varies with changing climatic circumstances such as irradiance level, temperature, cloudiness, and so on, it is impossible to connect the DC load and the battery directly to the solar panel [2]. When a battery is used in a system, a solar charge controller becomes necessary. A charge controller protects the battery from being overcharged owing to panel voltage fluctuations. It also prevents battery discharge at night when the battery voltage exceeds PV panel voltage [3]. Solar charge controllers use two different methods. They are pulse width modulation and maximum power point tracking. Tragically, PV age frameworks have two significant blemishes: electric power age change proficiency is lesser (9-16%), predominantly under low illumination conditions, and how sun-based clusters produce much electric power differs persistently with weather patterns. Maximum power point tracking (MPPT) regulators should work around the maximum power point to collect the most extreme power from PV modules (MPP). A most extreme power point tracker is a high-productivity DC to DC converter that identifies and converts the most excellent power to highlight the heap voltage's appraised esteem. By using an algorithm-driven control circuit, the maximum power point tracking

MPPT system determines this point so that the converter circuit can extract the maximum amount of power from a PV cell [4].

Because the maximum power operational point (MPOP) of a photovoltaic (PV) system change with changing meteorological conditions, maximizing load output and measuring the MPP is complex (e.g., solar radiation and temperature), although the algorithms used so far have been effective, their effectiveness suffers when external conditions change. Various improved optimization techniques such as fuzzy logic control, particle swarm optimization (PSO), and ANN are used to reduce the convergence time, computational complexity, and overall accuracy of the process. P&O and incremental conductance are two of the most widely used algorithms, both of which are simple but do not provide proper tracking. Multiplayer perceptron neural networks (NN) and fuzzy logic are more precise than the other applied techniques but are also more sophisticated [5]. Traditional methods are more exclusive and timewasting to implement. Radial basis function network (RBFN), on the other hand, has a more specific neural network topology and achieves faster convergence than other networks. In RBFN, the response value is determined using a weighted sum approach, similar to fuzzy-logic systems. RBFN also contains self-adjustable features and the ability to control non-linear and time-varying dynamic systems.

2. MAXIMUM POWER POINT TRACKING

Usually, manufacturers of PV panels do not provide robust data about the PV panel. Therefore, constructing the mathematical model of any PV panel must be adequately identified using an efficient system identification or parameter extraction method. For operating the PV panel at MPP, it is essential to find the MPP using a suitable tracking algorithm known as the MPPT algorithm [6]. The MPPT tracking algorithm is made up of a DC-DC converter. MPPTs are usually implemented by using buck or boost DC/DC converters. To modify the duty cycle of the DC/DC converter, operate a PV panel under constant voltage and power reference.

Further improving PV system efficiency, MPPT of the PV system needs to incorporate a controller to take full advantage of the available solar power in fast and wide-ranging environmental changes. For control implementation, field-programmable-gate-array (FPGA) chips can offer more flexibility in the implementation of the control algorithms in real-time compared to microcontrollers, and digital signal processors (DSPs) [7]. Hence, FPGA can be used to execute MPPT in the PV system tracking is the name for this method of tracking. By setting the operational point of the DC/DC converter (either buck or boost) to the corresponding voltage and current of the panel at MPP, MPP can be tracked. Between the PV panel and the load, an MPPT is used to maximize PV power. The MPPT of a PV system is a crucial component. MPPT comprises an algorithm, a controller, a PWM generator, a comparator, and a DC/DC boost converter. The MPPT controller and algorithm must adapt to rapidly changing weather conditions [8]. Photovoltaic cell power is maximum if it is operated at its maximum power point. The Figure 1 represents the power-voltage characteristics of PV cell in which MPP varies with weather conditions.

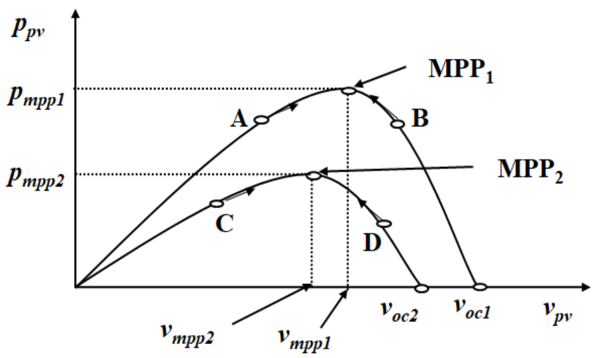

Figure 1. MPP varies with weather conditions

3. SOLAR CELL MODELING

Photovoltaic energy (PV) is a non-conventional source in which solar insolation is the fuel source. The elementary PV device is the PV cell [9]. A PV cell is a semiconductor diode with a light-exposed p–n junction. If the PV cell is short-circuited, light incidence forms charge carriers, which generate an electric current. PV Modules are connected PV cells, while PV arrays are made up of PV modules connected in series or parallel. Technological advancements in semiconductor devices have improved the efficiency of PV modules at a cheap cost [10]. A PV panel model is required for simulation and control applications. PV panel manufacturers rarely disclose the complete information on their products. As a result, any PV panel must be adequately identified using an efficient system identification or parameter extraction method before a mathematical model can be built [11]. It is utilized only when a photovoltaic panel operates at its MPP. To drive the PV panel at MPP, an appropriate tracking algorithm called the MPPT algorithm must be used to calculate the MPP [12]. The Figure 2 represents the equivalent model of solar photovoltaic cell.

$$I_{pv} = \frac{I_{ph}\text{-}I_o[\exp\{(V_{pv}+I_{pv}R_S)/n_sV_t\}\text{-}1]-[V_{pv}+i_{pv}RS]}{R_{sh}} Ipv = Iph - Io\left[\exp\left\{\frac{Vpv+IpvRS}{nsVt}\right\}\right\} - 1] - [Vpv + ipvRS]/Rsh \quad (1)$$

Where:
R_s = Series resistance
R_{sh} = Shunt resistance
I_d = Diode current
n_s = Number of series cells in PV panel
n_p = Number of parallel cells in PV panel

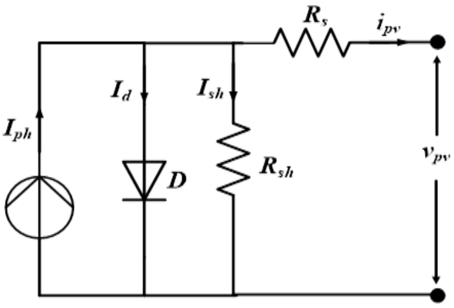

Figure 2. PV panel model

4. BOOST CONVERTER

It is a DC-DC converter for boosting time constant voltage [13]. This converter has a higher response voltage than the excitation voltage and a lower response current than the excitation current. The response voltage produced by the PV array is always less than the response voltage from the boost converter [14]. The circuit diagram of the boost-converter is described [15]. The diagram of DC-DC boost converter is shown in Figure 3.

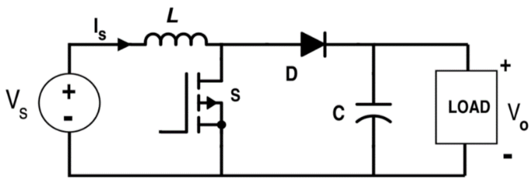

Figure 3. Circuit diagram of boost converter

The conversion ratio is given by (2).

$$\frac{V_0}{V_s} = \frac{I_s}{I_0} = \frac{1}{(1\text{-D})} V0/Vs = Is/I0 = 1/(1-D) \quad (2)$$

Where D is the duty cycle as (3).

$$V_s=\mathrm{V}_0(1\text{-D})\ Vs=V0(1-D) \quad (3)$$

$$Is=I0/(1-D)\ I_s=\frac{\mathrm{I}_0}{\text{1-D}} \quad (4)$$

Knowing V_s and I_s, we can find the excitation resistance of the converter. This is specified by (5).

$$R_s=\frac{V_S}{I_S}=\mathrm{R}_0(1\text{-D})^2 Rs=Vs/Is=R0(1-D)2 \quad (5)$$

Here, R_s varies from R_o to 0 as D differs from 0 to 1 congruently.

5. PROPOSED WORK

Maximum power point tracking is a technology that maximizes power draw under all situations in wind turbines and photovoltaic (PV) solar systems [16]. Maximum power point tracking finds the best load to apply to the cells in order to produce the most efficient output power [17]. Electrical circuits can be built to give arbitrary loads to PV cells, and then other devices or systems can be used to regulate the voltage, current, or frequency [18]. The control law V_{MPPT} is built using a radial basis function network-based MPPT controller with a DC-DC boost converter [19]. The PWM module generates PWM pulses to control the duty cycle [20]. The converter then sends the most power feasible to the load. The Figure 4 represents the block diagram of the proposed work. To construct an efficient MPPT model, an artificial neural network is used. To keep the system simple but speedy, RBFN is employed [21].

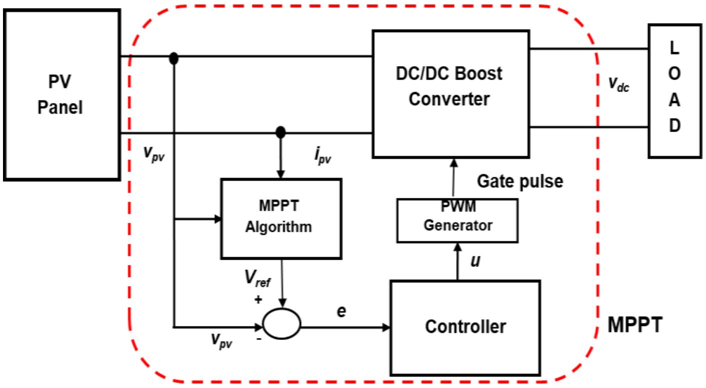

Figure 4. MPPT model

6. ARTIFICIAL NEURAL NETWORK

It is a simulated neural network constructed on biological a network that replicates the structure of the human brain. The artificial neural network is a graph where artificial neurons are nodes [22]. It is best visualized as a weighted directed graph, like a human brain [23]. The link between neuron outputs and inputs can be assessed using weighted directed edges [24]. The basic structure of N-layer RBFN and the proposed structure of RBFN are shown in Figures 5 and 6.

– Supervised learning technique

In Figure 7, supervised learning is defined as the process whereby neural networks are trained using previously defined correct outputs. During supervised training, the hidden unit, c, and weight, w, are updated by means of stochastic gradient descent to lower the error function [25]. The update rule for center learning is (6).

$$h_{xy}(\mathrm{t+1})=\mathrm{h_{xy}}(t)\text{-}\ \eta_1\delta\mathrm{E}/\delta h_{xy} hxy(t+1)=hxy(t)-\ \eta\mathbf{1}\delta E/\delta hxy \quad (6)$$

For x from 1 to 3, y from 1 to n as (7).

$$Wx(t+1)=Wx(t)-\ \eta\mathbf{2}\delta E/\delta Wx\ \mathrm{W_x(t+1)=W_x(t)}\text{-}\ \eta_2\delta\mathrm{E}/\delta\mathrm{W_x} \quad (7)$$

Where the cost function $E = \frac{1}{2}\Sigma\,(kd - k)2 \cdot k^d$ is the MPP voltage. The Figure represents the block diagram of supervised learning technique.

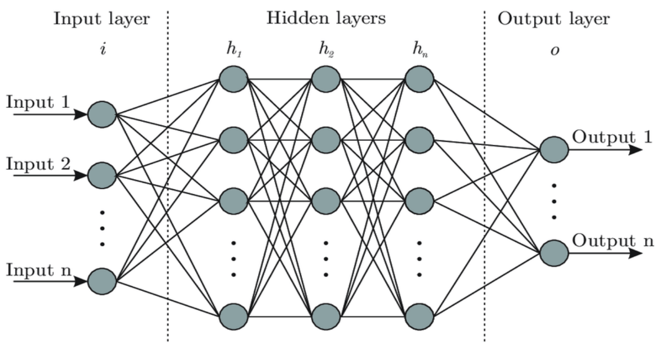

Figure 5. Basic structure of N-layer RBFN

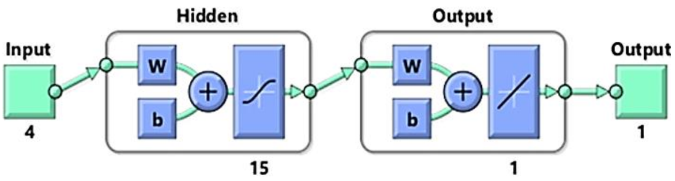

Figure 6. Proposed structure of RBFN

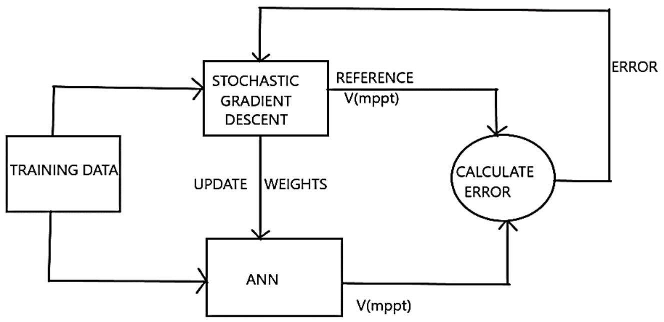

Figure 7. Supervised learning

7. SIMULATION AND RESULT

7.1. Observation of solar PV cell features

Maximum power = 83.2824 W, current at maximum power = 8.07 A, voltage at maximum power = 10.32 V, open circuit voltage = 12.64 V, short circuit current = 8.62 A, and cells per module = 60/3 were the parameters utilized in the analysis. The investigation includes solar irradiation disruptions and temperature changes. Figure 8 illustrates the correlation between changes in maximum power point and changes in temperature and solar radiation.

7.2. Result and simulation of ANN model

As based on Figure 9, the MPPT controller is constructed with a four-layer RBFN NN that produces VMPPT as its response. Excitations for the proposed RBFN include Vpv, Ipv, radiation, and temperature, which are then followed by a V_{MPPT}. As a set of PV module parameters, a 60 W solar photovoltaic module was simulated in MATLAB/Simulink under general testing conditions (25 °C and 1000 watts/m^2). Figure 9 represents the proposed MPPT model using ANN. The proposed MPPT model using ANN's time verses current, time verses voltage, and time verses power characteristics are shown in Figures 10, 11, and 12.

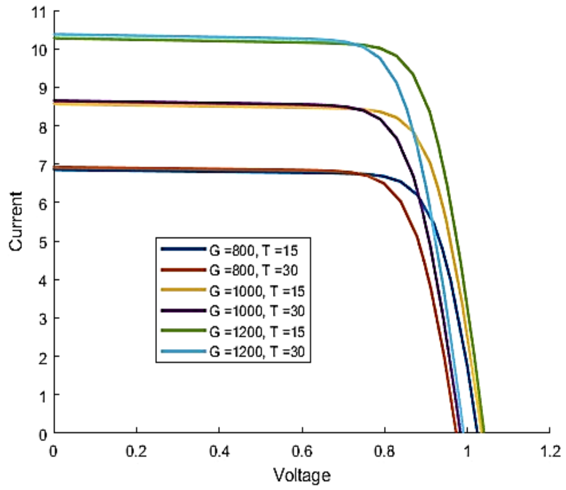

Figure 8. Current-voltage ch

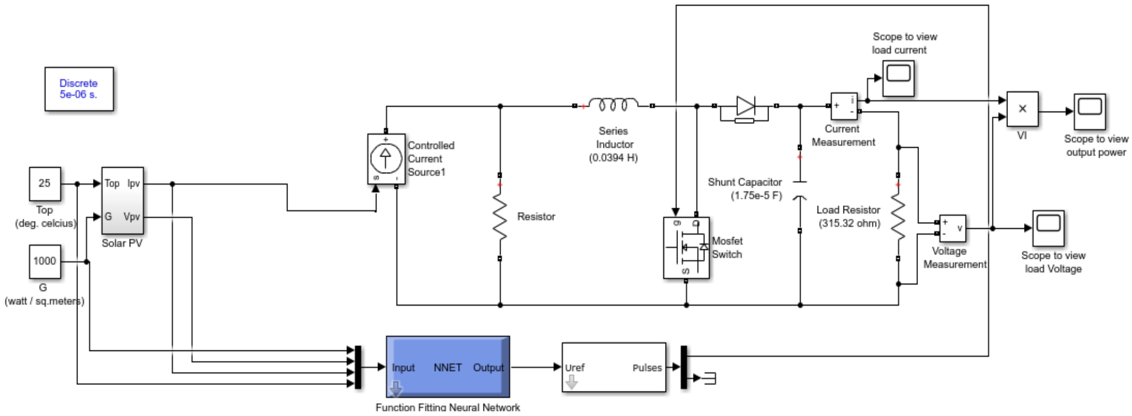

Figure 9. Simulink model

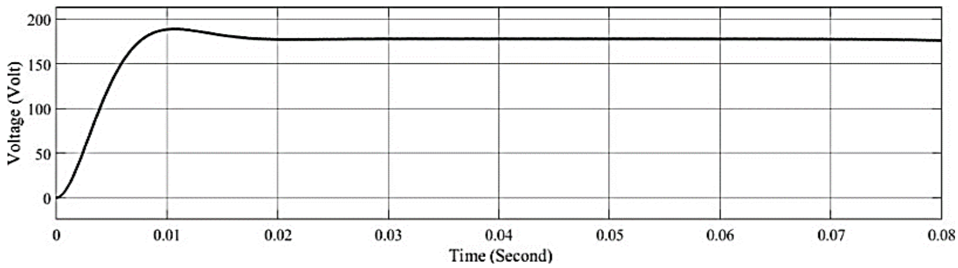

Figure 10. Response current v/s time

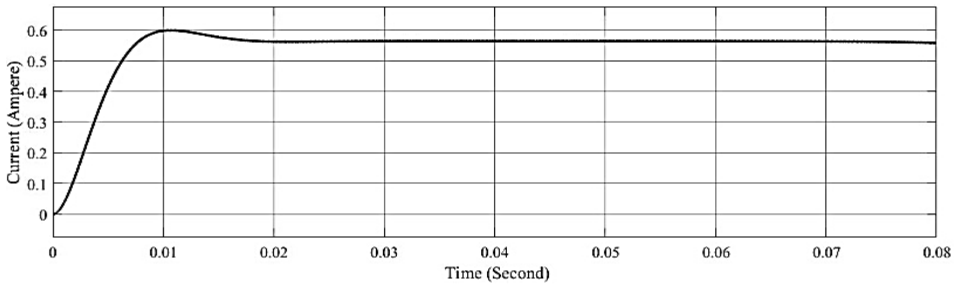

Figure 11. Response voltage v/s time

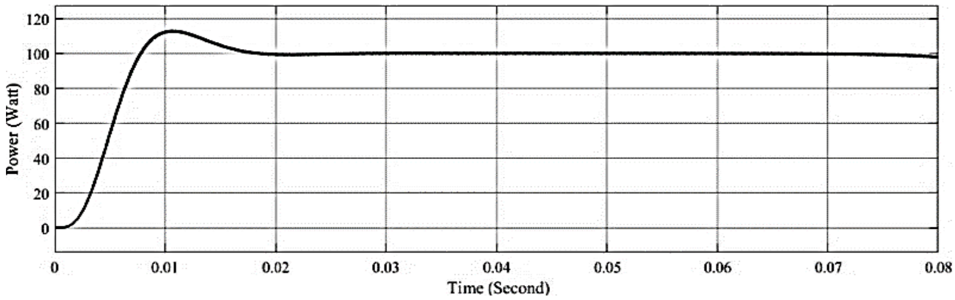

Figure 12. Response power v/s time

8. CONCLUSION

This study discusses the neural network-based MPPT. A neural network is used to quickly and precisely identify the point of greatest power under any change in atmospheric conditions. As the need for renewable energy supplies develops, the model will have a favorable impact on additional advanced MPPT methodologies. The usage of a radial basis function network as the basic neural network decreases complexity while allowing faster tracking, lowering the cost of developing sophisticated MPPT controllers. The system was evaluated and designed, and the system's presentation will be investigated in future research utilizing a tentative system implementation.

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