(Research Article)

Design of Artificial Neural Network based Maximum Power Point Tracking Considering Indore Region Data of 2019-2020

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Abstract

The increasing consumption of energy and growth of environmental problems oil the wheels of exploring Renewable energy sources. Solar energy is one of the mostly used renewable energy and it is definitely a great solution as there are innovative ways to transfer energy using this technology. Efficient operation of solar panel is necessary due to higher cost. In this paper artificial neural network based MPPT algorithm is proposed for Indore region and comparison of Perturb and observe algorithm, Incremental conductance and ANN based MPPT is made using the temperature and irradiance data of 2019-2020 of Indore region, the study shows the Power Output and corresponding Voltage using different algorithms with the input as annual temperature and irradiance of Indore. The output is evaluated using Matlab version 2015. The study shows the effectiveness of artificial neural network as compared to other two algorithms.

Keywords: MPPT, ANN, P&O, InC, Vmp, Imp

1. Introduction

By 2007 only few techniques were available including Perturb and Observe method, fractional open circuit voltage, Incremental Conductance, curve fitting, fractional short circuit current, look up table etc that describes MPPT techniques. And because of these few techniques available for this particular field, Researchers always gets confused while choosing an MPPT technique for a particular application [1]. But now there are many new MPPT techniques including Adaptive Perturbation and Observation, Genetic Algorithm, Particle Swarm Optimization based MPPT, Fuzzy Logic and Artificial Neural Network is one of them that offers comparatively better response in each and every aspect [2]. Maximum Power point tracking (MPPT) is a technique used to get the maximum power which is mainly dependent on solar irradiance, temperature and total resistance.

The output power varies with cell voltage due to non-linear V-I characteristics so it's necessary to develop a technique which will track the available maximum power from sun [3]. Maximum power point is the point at which $dP/dV=0$ in the P-V curve. It is also known as Knee-point. The V-I and P-V

characteristics are as follows:

Figure 1(a). V-I Characteristic of solar cell

Figure 1(b). P-V Characteristic of solar cell

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ISSN 2320-7590

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2. Maximum power point Tracking (MPPT) Algorithms

There are various algorithms to track maximum power point but the problem considered by the MPPT algorithms is to automatically fetch the current I_{mpp} and Voltage V_{mpp} at which the PV array produce maximum power under a given irradiance and temperature [4]. The traditional Perturb and Observe method compares the current operation point and sequential perturbation point to examine the changes in the power and based on the difference obtained in the power, the controller increase or decrease the PV arrays output voltage [5]. The duty cycle of converter increases if the difference observed in the power is weighted positive and similarly the duty cycle of the converter must decrease if the difference observed in the power weighted negative. But if positive and negative weighted, error will occur and maximum power will not reach [6]. The Perturb and Observe method has a disadvantage that it only oscillates around the MPP

Another algorithm is Incremental Conductance which is a technique used in photovoltaic systems for its low cost, good performance and simplicity [7]. InC algorithm overcomes the disadvantage of P&O algorithm by determining when the MPPT reach the MPP and it can also track the rapid change in the irradiation more precisely than perturb and observe method. The only disadvantage of this method is the increased complexity [8].

Constant voltage algorithm assumes that, at different irradiance, maximum power point voltage is approximately equal which around 76% of V_{oc} .

In recent years Artificial Neural Network acquire esteem in tracking maximum power point but it needs to be trained before being used in photovoltaic system [9-11]. It is a impressive technique for plotting the input-output non-linear function [12]. The major advantage this algorithm offers is that it doesn't need to solve the complex mathematical relation between solar temperatures; power output and total resistance and also the outputs are obtained with zero oscillations and in a very less time [13].

To operate the solar panel, Artificial neural network based Maximum power tracking (MPPT) using boost converter is used in this paper so that it can operate at constant voltage across the load for 2019-2020 data of Indore region and also compared the performance of classical and modern methods.

3. Modelling of proposed system

The proposed system is modeled and simulated in MATLAB 2015 version. The simulated model includes PV array model of 215 KW model, dc-dc boost converter and MPPT based artificial neural network trained for real data of Indore region. Input to solar panel is irradiance (G) and temperature (T). The figure 2 shows basic schematic of proposed scheme.[14]

Figure 2. The schematic diagram of proposed system [6]

3.1 Solar Panel: The solar panel consists of arrays of PV cell connected in series and parallel. In this proposed system one array of Soltech 1STH-215-P is used. The peak power of this solar panel is 215 W. The V-I and P-V characteristics at standard conditions (STC @ 25°C) of the solar panel is shown in figure 3. The table I shows the details of solar panel V_{oc} , I_{sc} , V_{mp} and I_{mp} .

Figure 3(a). P-V Characteristic of Soltech 1STH-215-P

Figure 3(b). V-I Characteristic of Soltech 1STH-215-P

3.2 Artificial Neural Network (ANN): Artificial Neural Network is generally presented as systems of interconnected 'neurons' which communicates with each other by sending messages [15]. The connections are associated with weights that can be adjusted based on experience, making neural network capable of learning and adaptive to inputs [16]. The ANN model is performed using MATLAB/Simulink. A feed forward based neural network with two neurons in input

layer, ten neurons in hidden layer and one in output layer is developed. The 'nnstart' tool is used to train the network and Levenberg-Marquardt algorithm is used whose neural network layout and training window is shown in Figure 4.

Figure 4. Neural network layout and its Training window

The input data for neural network is temperature and irradiance of Indore region (2019-2020) and based upon temperature and irradiation the network is going to provide voltage at maximum power point and maximum power at that point. In order to implement MPPT neural network algorithm, we need to collect data from PV array for training. During training the weights between two layers will be optimized or updated according to input and output data. Levenberg-Marquardt algorithm is used in the proposed research work. The data for training the neural network is given below:

Table 1. Parameters of solar panel

Parameters	Values
Open Circuit Voltage (Voc)	36.3 V
Short Circuit Current (Isc)	7.84 A
Temperature coefficient of Voc	-0.3699%/V
Temperature coefficient of Isc	0.102%/A
Diode Saturation Current	2.925e-10A
Light Generated Current	7.864A
Diode Ideality factor	0.98117

Shunt Resistance (Rsh)	313.399 ohm
Series Resistance (Rs)	0.3938 ohm

The error and regression plot of neural network developed is shown in Figure 5(a) and (b) respectively.

Figure 5(a). Error plot of Neural Network.

Figure 5(b). Regression plot of Neural Network.

3.3 Boost Converter: A boost converter is a DC to DC converter which is used to boost-up the DC voltage level. It is

similar to a step-up chopper. The basic circuit diagram using IGBT is given below:

Figure 6. DC-DC boost converter

When IGBT is turned-on, current starts flowing through inductor and IGBT and energy gets deposited in the inductor and when IGBT is turned off then the energy earlier deposited in the inductor is released through the load and capacitor. Duty-ratio is responsible for the amount by which the output voltage gets boosted up.

For designing the boost converter in MATLAB/Simulink following values of the parameters are used as shown in Table 2:

Table 2. Boost converter input data

Parameters	Values
Input Voltage (V_{in})	55-58 V
Output Voltage(V_o)	100 V
Rated Power	213.15
Switching Frequency (f_{sw})	5 KHz
Current Ripple (ΔI)	5%
Voltage Ripple (ΔV)	1%

The formulas for calculating the parameters are given below:

Input Current can be calculated as:

$$I_{in} = \text{Rated Power} / \text{Input Voltage} \text{ ----- (1)}$$

Output Current can be calculated as:

$$I_{out} = \text{Rated Power} / \text{Output voltage} \text{ ----- (2)}$$

Inductance can be calculated as:

$$L = V_{in} \times (V_{out} - V_{in}) / (f_{sw} \times \Delta I \times V_{out}) \text{ ----- (3)}$$

Capacitance can be calculated as:

$$C = I_{out} \times (V_{out} - V_{in}) / (f_{sw} \times \Delta V \times V_{out}) \text{ ----- (4)}$$

4. Results and discussion

In this section result of various simulation studies of incremental conductance, perturb and observe, and proposed ANN MPPT algorithm for 215W PV array are presented considering solar irradiance and temperature data set of Indore region (2019-2020). The three MPPT algorithms are simulated in one Simulink model and similar parameters are set to compare the results. The proposed Simulink model is shown in figure.7. The entire three MPPT algorithms have

two inputs (temperature and irradiance) and one output i.e reference output voltage corresponding to maximum point in the PV characteristics. The output of the MPPT algorithm is used for generation of duty cycle for boost converter. The duty cycle for the system is calculated using the reference voltage (V_{ref}). The duty cycle is calculated using equation 5:

$$D = 1 - (V_{in}/V_o) \text{ ----- (5)}$$

where V_{in} is instantaneous operating voltage at PV panel

V_o is the reference voltage generated from MPPT algorithm.

The Simulink model of incremental conductance (InC), Perturb and Observe (P&O) and ANN-MPPT, methods are shown in figure 8-10 respectively. The maximum power and voltage at maximum point are evaluated through the Simulink model by giving input as average monthly irradiance and temperature of Indore region. The data of Irradiance of Indore region for 2019-2020 is referred from National Renewable Energy Laboratory (NREL) [17]. These simulation results are compared to Perturb and observe, Incremental conductance and artificial neural network based maximum power point tracking and shown in table III and IV.

Figure 7. Simulink model of the proposed system

Figure 8. Subsystem of incremental conductance

Figure 9. Subsystem of Perturb and observe algorithm

Figure 10. Subsystem of ANN-MPPT algorithm

This can be observed from the both the tables that maximum power output of ANN-MPPT algorithm is much better compared to the InC and P&O method. This can be interpreted that steady state performance of ANN-MPPT is much better than InC and P&O method. Hence it is clear that the artificial neural network algorithm outperforms the other two algorithms.

The results are also evaluated under the fast changes in irradiance and temperature kept at 25°C. The performance of all the three methods is evaluated by providing sine wave pattern input in which irradiance is changing from 0 to 1000 kw/m² and again 1000 to 0 kw/m². The figure.11 shows the comparative results of maximum power between three algorithms. This can be easily distinguished that ANN is able track MPPT point fast and accurately as compared to the other two algorithms. The ANN can be able to track the MPPT point within 0.1 sec whereas InC and P&O algorithms took 5.8 sec to track the maximum power. Hence it can be observed from the results that ANN had better performance over other two algorithms both in steady and transient states.

Table 3. Maximum power steady state values for average monthly temperature and irradiance of InC, P&O and ANN MPPT algorithms

Month	Average Monthly Temp.	Average Monthly Irradiance	InC O/p Power	P&O O/p Power	ANN O/p Power
Jan	27.5	560	121.4	116.3	154.1
Feb	32	620	130.7	123.2	194.5
Mar	36.5	654	119.5	134.1	192.5
Apr	39.5	720	143.4	143.4	194.4
May	38.3	700	141.8	141.4	194.5
Jun	33.2	598	118.8	118.8	189.6
July	29	450	87.59	89.08	123.9
Aug	29.7	470	80.16	80.16	138.8
Sept	31	580	114	114	151.3
Oct	30.2	550	105.1	110.2	133.5
Nov	27.3	554	113.7	113.7	143.5
Dec	26	523	96.51	103.1	150.6

Table 4. Operating voltage at maximum power for average monthly temperature and irradiance of InC, P&O and ANN MPPT algorithms

Month	Average Monthly Temp.	Average Monthly Irradiance	InC O/p Volt.	P&O O/p Volt.	ANN O/p Volt.
Jan	27.5	560	29.38	29.75	31.62
Feb	32	620	27.83	29.72	30.36
Mar	36.5	654	30.26	28.21	30.21
Apr	39.5	720	28.38	28.38	30.35
May	38.3	700	28.22	28.21	30.35
Jun	33.2	598	25.64	25.64	29.99
July	29	450	25.06	25.57	30.44
Aug	29.7	470	31.78	31.78	29.9
Sept	31	580	30.11	30.11	31.18
Oct	30.2	550	31.22	25.96	31.44
Nov	27.3	554	26.82	26.82	31.66
Dec	26	523	31.73	25.44	31.12

From the presented results it can be interpreted that varying temperature and irradiances and fast changing irradiance, artificial neural network based maximum power point tracking method can efficiently track the maximum power point as compared to other two algorithms.

Figure 11. Output of InC, P&O and ANN MPPT algorithm with fast varying irradiance.

5. Conclusion

As the solar energy source is assumed to be infinite, solar photovoltaic based electricity generation continues to grow. The only obstacle of such PV based solar systems are poor conversion efficiency, MPPT is the technique used to extract maximum output power from PV array at different irradiances. But it also has issue of delivering maximum efficiency, so this paper presented a proposed research work of implementation of artificial neural network with maximum power point tracking and it is concluded that artificial neural network based maximum power point tracking algorithm is more efficient than perturb and observe algorithm and incremental conductance algorithm in tracking the maximum power point as shown from the tables and output of efficiency comparison model. Also it holds less number of oscillations, the controller is fast and comparatively accurate in nature and more robust. In this paper 12 data sets i.e. temperature and irradiance of Indore region (2019-2020) is used but if large number of datasets is used to train the network then also the artificial neural network based maximum power point tracking algorithm proved to be more efficient. The artificial neural network tracks the exact maximum power point whereas other two algorithm hover around that point. The limitation of the proposed work is that it is only restricted to Indore region as the input is the temperature and irradiance of Indore region but the technique can be used to calculate the maximum power and corresponding voltage for any region by considering temperature and irradiance of that particular region.

Nomenclature

MPPT- Maximum Power Point Tracking
ANN-Artificial Neural Network
P&O- Perturb and Observe
InC- Incremental Conductance

V_{mp}- Voltage at maximum power
I_{mp}- Current at maximum power
IGBT- Insulated gate bipolar transistor
PV- Photovoltaic
Kw/m²- Kilo Watt per meter square

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