

Comparative Study of ANN and Incremental Conductance MPPT for Solar Water Pump

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ABSTRACT- For measuring the peak power output of PV panel, maximum power point tracking (MPPT) method based on artificial neural networks (ANN) and Incremental Conductance (INC) is describe in this paper. It is precise to use MPPT for the measurement of maximum possible power point as the weather variable such as temperature and sun irradiation changes. The research design and simulation of PV Array with MPPT controller are presented in this paper. The goal of this study is to develop an MPPT controller using an artificial neural network approach for PV applications. A comparison between an ANN-based MPPT controller's performance and that of the conventional INC MPPT method is made. The MATLAB software is used to run simulations and analyze the results. In this article, MATLAB simulation design of the ANN and INC MPPT for obtaining maximum output power and voltage is discussed in detail and coupled with a boost converter.

Keywords—Solar PV Array, Boost Converter, MPPT, Incremental conductance, Artificial Neural Network.

I. INTRODUCTION

PV power seems to be a workable solution to the world's ongoing demand for fresh energy sources to lessen its reliance on fossil fuels. the sun's energy is green, clean and best energy application in context of renewable energy. Photovoltaic energy is unrestricted, clean and less costly, mark it ideal for a range of remote applications like telecommunications, battery charging, meteorological measurement equipment, satellite feeding, and water pumping because a PV system's efficiency depends on both temperature and sun irradiation [1].

Maximum power is extracted using the MPPT approach [2]. Primitive MPPT circuit has only simple DC converters between the output and input energy sources, which may be any renewable source [3]. Presently, different types of method have been proposed for extracting maximum power, such as perturb & observe (P&O), Incremental Conductance (INC), Fractional Open-Circuit Voltage (FOCV), Fractional Short-Circuit Current (FOSC), Hill-Climbing (HC), and many more which are reviewed in [4]. These methods, however, suffer from a number of shortcomings, slower response time, large steady-state fluctuations, and poor efficiency under rapid shifts in solar irradiance [6].

Artificial intelligence (AI) has recently grown in popularity in PV system MPPT control systems. Fuzzy logic (FL)-based MPPT controllers were proposed in [7]. MPPT performance is enhanced when FLC and hill-climbing algorithms are combined [8]. The P&O method-based fuzzy logic FLC

controller's quick and reliable results are shown in [9]. In [10], applying the genetic algorithm (GA), the global MPP tracking was enhanced, which is especially beneficial for partial shading. Some approaches, including hybrid MPPT [11]– [12], combine conventional techniques with artificial intelligence. [13] and [14] report on the classification and comparative study of classical and artificial languages.

As a reliable, quick, and effective method, MPPT based on artificial neural networks (ANN) is frequently used [16]. The main benefits of using the PV systems that use ANN technology are its capacity to identify nonlinear correlations involving both independent and dependent variables and the fact because a full understanding of the core system characteristics is not necessary [17].

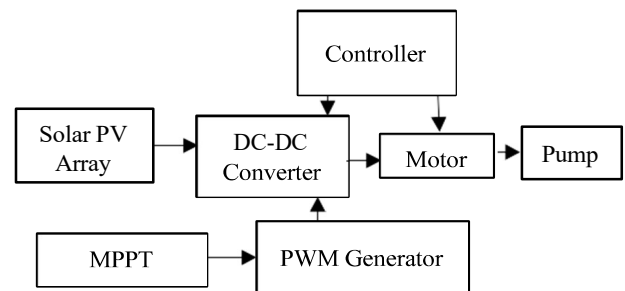


Fig1: Block Diagram of System

II. STUDY AREA AND DATA SET

India is a country that completely lies on the imaginary Tropic of Cancer line. The Intertropical Concept has moved farther south than usual this season, which has an effect on the Indian weather and the Asian monsoon. This is primarily why India has a diverse climate and weather. The three main springs of India's climate are summer, winter, and rainy.

In this study, hourly solar data from New Delhi over a year is used to predict the amount of sun irradiation. In this study, solar temperature and sun irradiation are main study-relevant characteristics.

III. MAXIMUM POWER POINT TRACKING (MPPT)

MPPT, also known as Power point tracking (PPT), is technique that extract the maximizes energy under all variety of

circumstances by using varying power sources. PV solar systems interact differently with various systems, grids, battery banks, and other electrical loads [2]. The primary goal of MPPT is to solve this issue because the efficiency of a solar PV array is dependent on the irradiance and temperature of the available sunlight, the degree of shadowing, the solar panel's temperature, and the electrical characteristics of the load [3]. As environment changes, the MPPT method modifies the load characteristic. Some MPPT are discussed below: -

1. Perturb and Observe (P&O)

The controller measures the power after slightly altering the voltage from the array, and if it increases, it continues to make little adjustments in that direction until the power stops increasing. The most common approach P&O, may cause oscillations in power output [4]. It is also referred to as the "hill climbing" approach because it depends on the power versus voltage curve increasing below the MPP and decreasing above that point. P&O method may result in top-level efficiency if an appropriate hill climbing strategy is employed with predictive and adaptive [5].

2. Incremental Conductance (INC)

This technique may track shifting conditions more quickly than P&O, despite requiring the controller to complete more calculations. In order to estimate MPP, the Comparing incremental conductance (I/V) is done using incremental conductance approach to array conductance (I/V). The MPP voltage is the resulting output voltage if $I/V = I/V$. $P = IV$ and $dp/dv = 0$ at MPP are the discoveries that form the basis of INC technique [5]. Hence, MPP is achieved when the negative of the instantaneous conductance matches the incremental conductance.

3. Artificial neural network (ANN)

High performance controllers are made using an artificial neural network technique. This structure consists of a large number of neurons that mimic actual brain cells. Each layer in which these neurons are arranged has a sizable number of weights connections with the neurons below it [17]. Each input layer neuron gets data from input data base. An activation function is then used to send this result to the output. The outputs from the hidden layer are then added by each output layer neuron to the bias, and the result is sent via the activation function to create the final output [16]. If the ANN's input is x, its output is y, and w stands for weights and biases in the equation below. The final output of ANN is obtained by linear activation function for the hidden layer and generalized output equation is shown by equation 1 [15].

$$y^j = \sum_{i=0}^n w_{2ji} z^i \quad (1)$$

Where,

$$z_j = f(a_j) = \frac{1}{1+e^{a_j}} \quad (2)$$

$$a_j = \sum_i w_{ji} z_i^h \quad (3)$$

It is important to identify weights that reduces the inaccuracy between the output of the ANN and the desired value the purpose of weight modification during neural network training. The value of mean square error (MSE) is calculated by equation 4.

$$E_{mse} = \frac{1}{N} \sum_{i=1}^N (t_i - y_i^j)^2 \quad (4)$$

where N = trained models value.

IV. SIMULATION MODEL

In this paper a user define solar PV array of 3 strings in which 10 Module are connected in parallel are used whose parameters are shown in table 1

Table1: Parameters of PV Array

Parameter	One Module value	3 Module Value
Maximum Power (P _{max})	200.143 W	600.429 W
Open Circuit Voltage (V _{oc})	32.9 V	98.7 V
Maximum Power Voltage (V _{map})	26.3 V	78.9 V
Current at Short Circuit (I _{sc})	8.21 A	24.63 A
Maximum Power current	7.61 A	22.83 A
Cell per Module	54	162
Coefficient of Temperature at V _{oc} (α)	-(0.35502) (%/°C)	
Coefficient of Temperature at I _{sc} (β)	0.06 (%/°C)	

Output of PV Array is varied with change in solar irradiance and temperature. So, for ANN, solar irradiance and temperature data are considered for study. At every value of weather variable, the values of P, I and V are different. Value of parameters of one Module is shown in the table 2, but the power changes with voltage, as clearly shown by the characteristics of power-voltage and current-voltage in fig. 3

Table 2: Maximum Power at Various Irradiances at 25°C Temperature for One Module

Irradiance (W/m ²)	Maximum Power (W)	Voltage at Max. Power (V)	Current at Max. Power (A)

1000	200.143	26.3	7.61
800	161.50	26.45	6.10
700	414.8	26.52	5.35
600	121.8	26.58	4.58
500	101.6	26.58	3.52
400	81.16	26.51	3.06

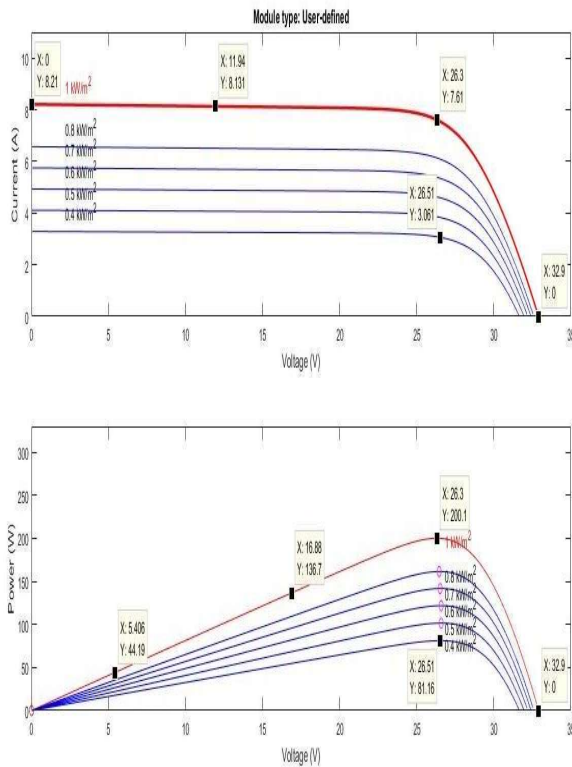


Fig 2: P-V and V-I characteristic of One Module at 25°C temperature

Power of PV is applied to converter that is basically used to boost input voltage of a PV. A boost converter with a specification input capacitor of (C_{in}) 5 mF, an inductor coil (L) of 2.5 mH, and an output capacitor (C_{out}) of 250 F is connected to obtain the maximum voltage from a PV. In this, an IGBT is used, which is connected to two different terminals, and values are recorded for comparing their efficiency and power rating. The methodology used for tuning the IGBT to obtain maximum power is called MPPT

MPPT is technique used to extract maximum value of voltage from solar, wind, or any other source. MPPT technology is used to track and regulate the switching PWM of converter that is utilised to draw power from the PV module. To squeeze the MPP output from solar PV systems, numerous different MPPT techniques are used. In this paper, artificial intelligence-based neural networks and incremental conductance-based MPPT are compared with each other for a converter with the same power rating as a solar PV array.

INC MPPT

Simulation diagram of INC based PV is Shown in fig3. INC MPPT algorithm operates with two values drawn from the characteristic curve depicted in Fig 2. MPPT tracked the peak value of power at a certain irradiance. The IC method's fundamental guiding principle is $\frac{dP}{dV} = 0$.

Then,

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = V \frac{dI}{dV} + I \frac{dV}{dV} \quad (5)$$

In this MPPT algorithm, instantaneous conductance value of $\frac{I}{V}$ and $\frac{dI}{dV}$ are used to obtain the Maximum value of power at this instance of irradiance. Flowchart of working algorithm is shown in fig 4:

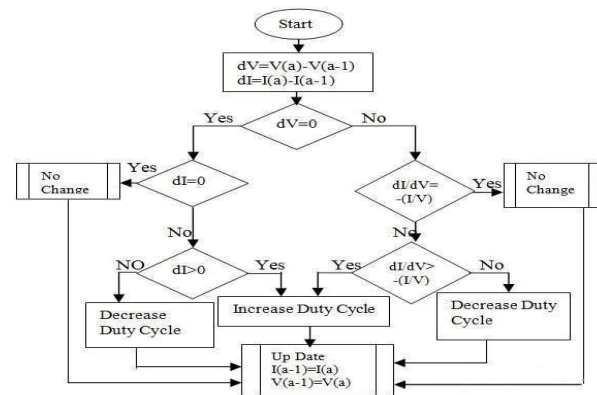


Fig 4: Algorithm flowchart of INC MPPT

The values of power and voltage are tracked and updated at every step. Depending upon this value, the signal is generated, which is given through the DC-DC Pulse Width Modulation (PWM) Generator. The frequency of this PWM generator is 25000 Hz. Generated PWM is applied to the gate of the IGBT, which turns on the IGBT and starts drawing current and voltage depending upon the value of the gate pulse, which is inherent in nature and depends upon signal generated from MPPT.

ANN MPPT

An ANN MPPT is basically an example of an AI technique. Compared to other standard MPPT approaches, this MPPT provides additional benefits. The main disadvantage of other conventional MPPT is its slow response when sudden change in weather variable occur during PV array application, conventional MPPT frequently fails to tackle MPP of PV array at certain value of temperature and irradiance. When the sun's temperature and irradiance fluctuate, NN will offer a precise duty ratio number to get MPP. Figure 6 depicts a basic overview of ANN.

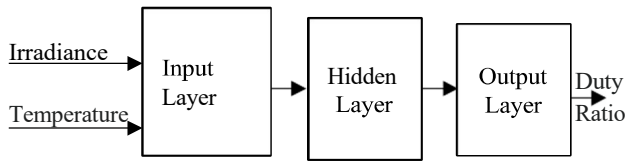


Fig 6: Basic Diagram of ANN MPPT

In this research work, study data set of New Delhi is taken from NASA to train the ANN. Input data is provided by the user from data set, and then the train and hidden layer are calculated on the basis of the input data. Starting with the ANN, a basic if-else programme written on the MATLAB workspace calculates training and target data. The input data is divided into testing data, training data, and target data. Levenberg-training Marquardt's algorithm is used to create the neural network. There are 10 hidden layers that allow the user to generalise the data and weight of the neural network, and ANN will calculate mean square error (MSE) and regression (R) as shown in fig 7.

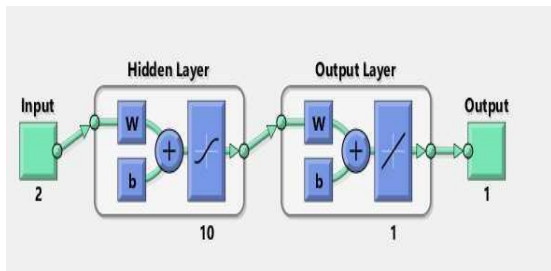


Fig 7: Basic diagram of ANN

It is evident from the trained ANN's performance that mean squared error (MSE) would decrease as epochs rose. At the conclusion of training, A well trained NN will have an extremely low MSE value. The low value of MSE indicates that the output of the NN and the desired output are reasonably close to one another. And the performance curve of ANN is shown in Fig 8.

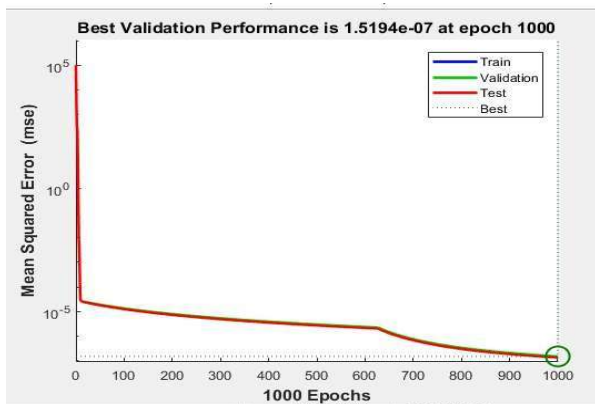


Fig 8: Performance Curve of ANN

The training of data is performed by some basic steps, which are listed in the following flowchart: -

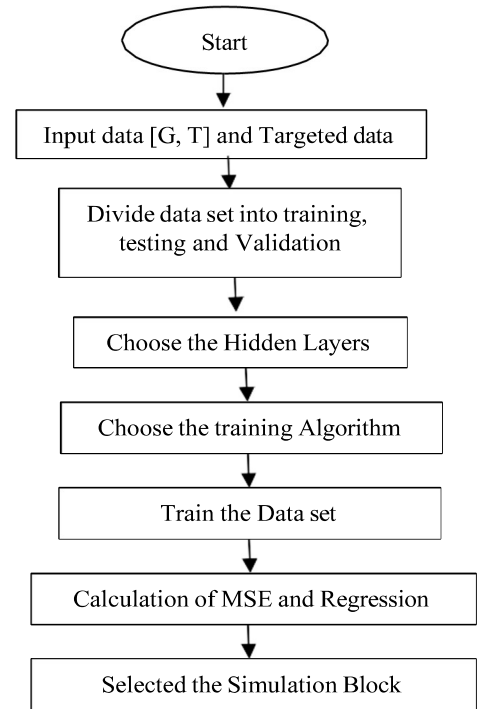


Fig 9: Step Flowchart of starting ANN

V. RESULT AND DISCUSSION:

Figs. 10, 11, and 12 show the output result waveforms of PV cells without MPPT, PV arrays with INC MPPT, and PV arrays with ANN MPPT. It has been discovered that ANN-based MPPT provides a faster response than other conventional MPPT. Without MPPT, the output PV changes with time and weather variable, but it is not constant at any point of operation and does not obtain any stable point, as shown in fig. 10.

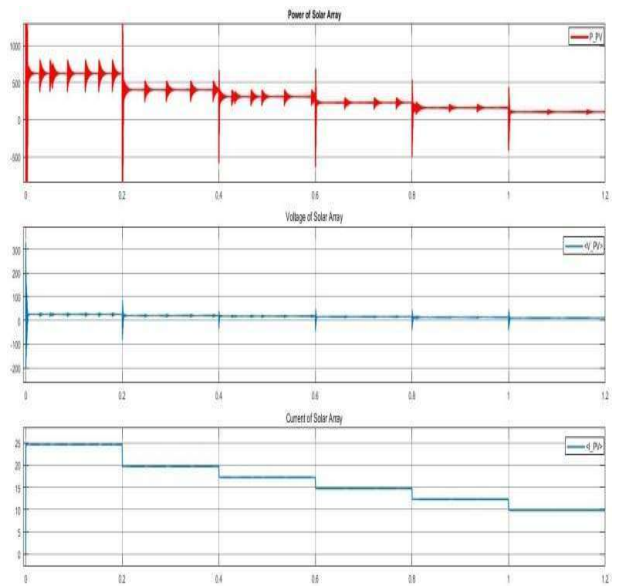


Fig 10: Output of Solar Array without MPPT

It is clear from Fig. 10 that power and voltage are not constant at any point of operation, and maximum power is not obtained at any point. As a result, the varies MPPT are used to obtain MPP of PV.

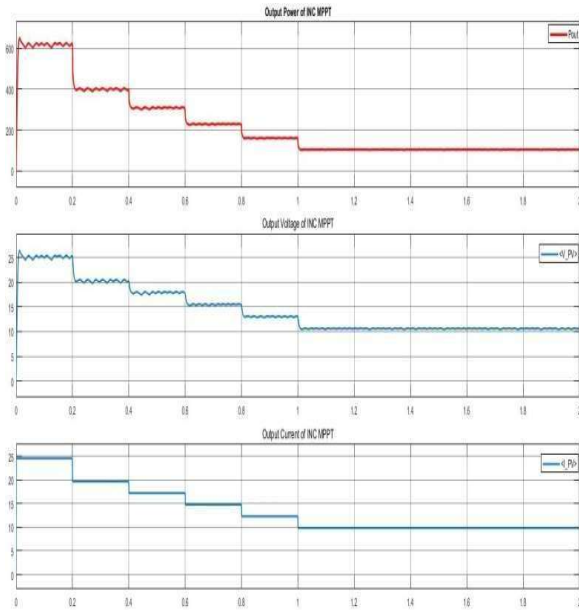


Fig 11: Output of Solar Array with INC MPPT

INC is a more commonly used MPPT than other conventional MPPTs due to its faster response time and the fact that it draws almost constant output power with some transient peaks. Compared to other traditional MPPTs, it is more efficient. Figure 11 clearly shows the power output of PV is approaching its maximum value, but it is not stable at any point.

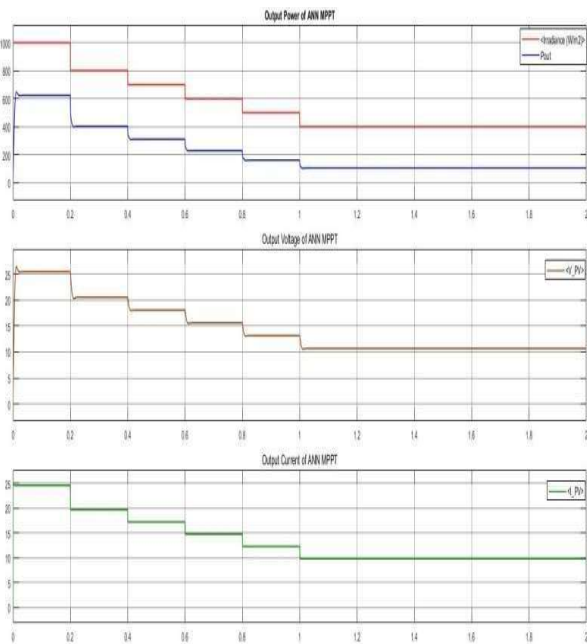


Fig 12: Output of Solar Array with ANN MPPT

In comparison to all other typical manipulation techniques, The ANN MPPT gives more accurate maximum power as compared to other MPPTs because it shows no steady-state oscillation and requires less settling time as seen in Fig-11. Hence, when compared to previous MPPT techniques, the MPPT with ANN algorithm performs better. From PV, the MPP is drawn and it remains constant for a set period of irradiance while the temperature remains constant. When the values of irradiance and temperature change, the values of maximum power also change as shown in the characteristic diagram, and then ANN-based MPPT can make a faster decision to settle the constant with a quick response.

Using ANN controllers has the following benefits:

- Quick reaction for maximum power point tracking.
- Less steady state inaccuracy.
- Because the learning mechanism is built-in, reprogramming is not required.

ANN controller drawbacks include:

- Network requires extensive training.
- The neural network framework occasionally has a complex design.

The overall performance of both MPPT is computed and listed in table 3

Table 3: Performance Comparison of INC and ANN MPPT

MPPT	Irradiance (W/m ²)	P _{out} (W)	P _{in} (W)	Efficiency (%)
ANN MPPT	1000	642.19	648.37	99.04
	800	587.27	594.01	98.94
	700	492.64	497.63	98.99
	600	410.40	414.89	98.91
	500	388.80	397.64	97.77
	400	260.50	263.26	98.95
INC MPPT	1000	604.10	625.70	96.54
	800	388.50	409.10	94.96
	700	296.80	311.20	95.37
	600	217.40	229.80	94.60
	500	150.8	160.20	94.13
	400	96.35	102.70	93.82

VI. CONCLUSION

In this article, MATLAB simulation design of the ANN and INC MPPT for obtaining maximum output power and voltage is discussed in detail and coupled with a boost converter. ANN MPPT gives a constant voltage, power, and current at every instant, and a small change in irradiance or temperature makes

an effect on the output voltage and power, whereas INC-based MPPT does not give a quick response to a small change in irradiance or temperature. It was also observed that the settling time of ANN is about 0.013 s, and after that, it gives a constant maximum power value, whereas the settling time of INC MPPT is about 0.035 s, but after this time, it does not give a constant maximum power value. The average efficiency of ANN is about 98.76%, whereas the average efficiency of INC MPPT is about 94.90%. It means that the efficiency and overall performance of ANN MPPT are much better than those of INC MPPT.

REFERENCES

- [1] Y.E. Idrissi, K. Assalaou, L. Elmahni, E. Aitiaz, "New improved MPPT based on artificial neural network and PI controller for photovoltaic applications", *International Journal of Power Electronics and Drive Systems* Vol. 13, Issue 3, pp 1791-1801, 1 Sept 2022.
- [2] N. Karami, N. Moubayed and R. Qutbib," General review and classification of different MPPT Techniques", *Renewable and Sustainable Energy Reviews*, vol. 68, Issue 1, pp 1-18, 10 oct 2016.
- [3] M. A. Abo-Sennah, M. A. El-Dabah and A. El-Biomey Mansour, "Maximum power point tracking techniques for photovoltaic systems: a comparative study", *International Journal of Electrical and Computer Engineering (IJECE)* Vol. 11, Issue 1, pp. 57-73, 17 April 2020.
- [4] G. Sudhakar and J. Surya Kumari, "Design and Analysis of P&O and FLC MPPT Techniques for Photovoltaic System", *IRET Transaction on Power Electronics and Drives (ITPED)*, vol.1, Issue 1, pp 17-23, oct 2013.
- [5] J. Ahmad, "A fractional open circuit voltage based maximum power point tracker for photovoltaic arrays," 2010 2nd International Conference on Software Technology and Engineering, San Juan, PR, USA, 2010, pp. V1-247-V1-250.
- [6] I. Yadav, S. K. Maurya and G. K. Gupta, "A literature review on industrially accepted MPPT techniques for solar PV system", *International Journal of Electrical and Computer Engineering (IJECE)*, Vol. 10, Issue 02, pp 2117-2127, April 2020.
- [7] O. Lagdani, M. Trihi and B. Bossoufi, "PV array connected to the grid with the implementation of MPPT algorithms (INC, P&O and FL method)", Vol. 10, Issue 4, pp 2084-2095, 4 December 2019.
- [8] C. Sharma and A. Jain, ". Performance comparison of PID and fuzzy controllers in distributed MPPT", *International Journal of Power Electronics and Drive System (IJPEDS)*, Vol. 6, Issue 3, pp 625-635, 16 Jun 2015.
- [9] K. H. Chalok, Md. F. N. Tajuddin, T. S. Babu, S. Md. Ayob and T. Sutikno, "Optimal extraction of photovoltaic energy using fuzzy logic control for maximum power point tracking technique", *International Journal of Power Electronics and Drive System (IJPEDS)* Vol. 11, Issue 3, pp. 1628-1639, 29 May 2020.
- [10] Md. Y. Allani, D. Mezghani, F. Tadeo and A. Mami, "FPGA implementation of a robust MPPT of a photovoltaic system using a fuzzy logic controller based on incremental and conductance algorithm", *Engineering, Technology & Applied Science Research*, Vol. 9, Issue 4, pp 4322-4328, August 2019.
- [11] S. Abdourraziq and R. El Bachtiri, "A perturb and observe method using fuzzy logic control for PV pumping systems", 2014 International Conference on Multimedia Computing and Systems (ICMCS), Marrakech, Morocco, 14-16 April 2014.
- [12] A.A. Kulsaksiz and R. Akkaya, "A genetic algorithm optimized ANN-based MPPT algorithm for a stand-alone PV system with induction motor drive", *Solar Energy*, Vol. 86, Issue 9, pp 2366-2375, 31 May 2012.
- [13] H. Attia and K. Hossin, "Hybrid technique for an efficient PV system through intelligent MPPT and water-cooling process", *International Journal of Power Electronics and Drive System (IJPEDS)*, Vol. 11, Issue 4, pp 1835-1843, 16 Jun 2020.
- [14] N. Kacimi, S. Grouni, A. Idir and Md. S. Boucherit, "New improved hybrid MPPT based on neural network-model predictive control-Kalman filter for photovoltaic system", *Indonesian Journal of Electrical Engineering and Computer Science*, Vol 20, Issue 3, pp 1230-1241, 18 May 2020.
- [15] B. Bendib, F. Krim, H. Belmili, M.F. Almi and S. Bolouma, "An intelligent MPPT approach based on neural-network voltage estimator and fuzzy controller, applied to a stand-alone PV system", 2014 IEEE 23rd International Symposium on Industrial Electronics (ISIE), Istanbul, Turkey, 1-4 June 2014.
- [16] S. Motahhir, A. El Hammoumi and A. El Ghzizal, "The most used MPPT algorithms: Review and the suitable low-cost embedded board for each algorithm", *Journal of Cleaner Production*, Vol 246, pp 1183-1189, 10 Feb 2020.
- [17] I. Chtouki, P. Wira and M. Zazi, "Comparison of several neural network perturb and observe MPPT methods for photovoltaic applications", *IEEE 2018 IEEE International Conference on Industrial Technology (ICIT)*, pp 909-914, Lyon, France, 20-22 Feb 2018.