Maximum Power Prediction for PV System based on P&O Algorithm

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A b s t r a c t

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This research presents a maximum power point tracking (MPPT) controller for PV systems is proposed. The developing of the proposed controller is based on conventional P&O algorithm and an Artificial Neural Network. The voltage of the optimum PV system is predicted by using ANN as a controller in order to get the maximum point of power (MPP). The three inputs for the modelled ANN are temperature coefficients, ambient temperature, and solar radiation. While, the output voltage represents the ANN output node. The simulation result shows that ANN much faster than P&Q algorithm in which the output voltage prediction is take 4.91 second as compared to conventional P&O algorithm which is 9.69 second.

1. Introduction

Photovoltaic power system (PV) is used to supply a solar power by using photovoltaics. The basic components of PV system are; solar modules to absorb daylight and convert it into electricity, a DC to AC inverter to converts the produced DC current to AC current, and consumer unit to set-up a working system. [1].

Every Solar cell (SC) operation has it's an optimal point which is known as maximum power point. It depends on variation of solar radiation, temperature, and load impedance. However, the MPP is a part located between loads and PV arrays. There are a lot of methods have presented in the previous literatures to find the maximum power for a PV system [2].

A MPPT is proposed in [3] to modify P&O and track the point of maximum power for PV systems.

In addition, the control of direct power and the computation of maximum power are considered the major parts in this modified method. By using this modified method, the maximum power is computed online. Ramaprabha [4] proposed genetic algorithm (GA) to predict the maximum power in the standalone PV system. To train a feed-forward neural network to find the maximum voltage, a set values of temperatures and radiations is used. Youngseok [5] proposed IP&O algorithm in which the hysteresis bandwidth and the reference step size voltage of the PV system under rapidly atmospheric conditions change. Amrouche [6] proposed intelligent MPP tracking algorithm based on ANN. The atmospheric conditions evolution based on comparison between ANN predicted power value with measured value.

This paper focuses on modelling a MPPT controller based on P&O algorithm to increase the tracking

response as well as improve the system efficiency. The converter is controlled by an improved MPPT which is simulated using MATLAB to track the PV system maximum power.

2. PV Cell Model

The SC equivalent circuit is shown in Figure 1. The output current I_{pv} can be calculated [7].

$$I_{pv} = I_{sc} - I_d \qquad (1)$$

Where I_d is the diode current and it is calculated by;

$$I_d = I_o \left\{ \exp\left[\frac{V_{pv}+R_s\,I_{pv}}{V_T}\right] - 1 \right\} - \left\{ \frac{V_{pv}+R_s\,I_{pv}}{R_p} \right\} \quad (2)$$

Where

V_T: thermal voltage; q: electron charge, K: Boltzmann constant; T: cell temperature (Kelvin); R_S: series resistance (solar cell losses); R_P: shunt resistance (diode reverses current).

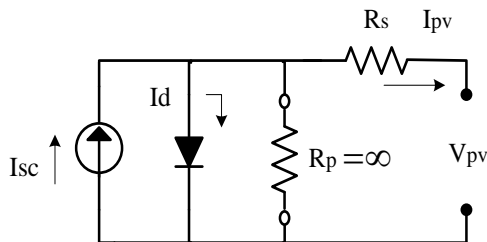Fig. 1: PV cell equivalent circuit

However, if R_p considered infinite value then;

$$I_d = I_o \left\{ \exp\left[\frac{V_{pv}+R_s\,I_{pv}}{V_T}\right] - 1 \right\} \qquad (3)$$

The two following equations can be described the model of a PV module [8],

$$I_{pv\,module} = N_p I_{pv} \qquad (4)$$

$$V_{pv\,module} = N_s V_{pv} \qquad (5)$$

Where $I_{pv\,module}$ and $V_{pv\,module}$ are the PV module current and voltage output. Meanwhile N_p and N_s are parallel and series number cells respectively of the PV module as well.

The point of maximum power of a PV cell is affected by the following factors; solar radiation, ambient temperature, and the impedance of the load. Figure 2 shows the I-V line curve of the PV cell [9].

On the other hand, a set triggering signal of duty cycle for DC-DC converter is determined to extract the maximum power of a PV system. Therefore, it is necessary to considered V_{op} and I_{op} by [10].

$$V_{optimum} = K_v V_{oc} \qquad (6)$$

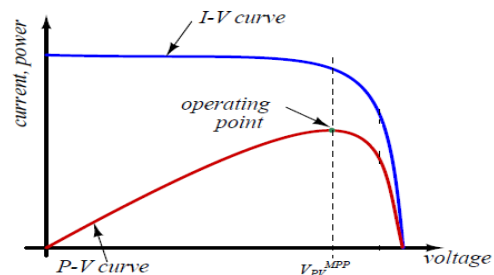$$I_{optimum} = K_i I_{sc} \qquad (7)$$

Fig. 2: PV Cell characterise curve

K_i and K_v are current and voltage gains in the ranges of (0.89-0.91) and (0.74-0.86) respectively.

3. Conventional P&O Method

The PV systems commonly use it due to simplicity and also to obtain MPP. The current and voltage are measuring by it to perturb the operating point [11], as shown in Figure 3.
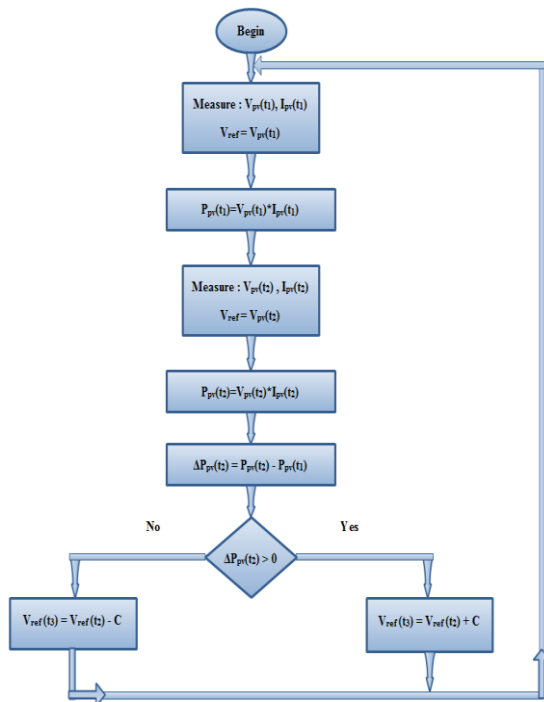
Fig. 3: Flow chart of P&O

It starts with measuring the first sample of the operating voltage V_{pv} (t_1) and current I_{pv} (t_1). After that the second sample of the operating V_{pv} (t_2) and I_{pv} (t_2) are measured. Depending on measured values of the current and the voltage ,ΔP_{pv} is calculated (which means the changing of the PV power module).

If ΔP_{pv} is positive, the operating voltage perturbation should be in the same direction of the increment. If it is negative, the operating point moves away from the maximum power point and the operating voltage should be decrement. The perturbation of operating voltage is done by a constant C which may have a value equal to (0.1) Volt [12]. The value of the (0.1) Volt is considered as an appropriate perturbation step value in the iteration process.

Furthermore, an oscillation around the maximum power may occurs by P&O techniques when atmospheric conditions rapidly change, and the system response will be slow down [13].

4. Proposed PV System Components

The basic components of the proposed PV system is shown in Figure 4. In this system, the atmospheric conditions, temperature and irradiation are used as inputs to the PV module. Meantime, they are also used as the inputs for the artificial neural network (ANN) to produce the optimum voltage. The optimum voltage (V_{op}) is used as the switching signal of boost DC/DC. A capacitor is used in the converter to reduce the ripple of output voltage [10].

The duty cycle of the converter is considered as a relation between the input and the output voltage of the boost which described by following equation. The V_{pv} is supposed in this research to be the output voltage while input voltage is supposed to be the $V_{pv\ optimum}$.

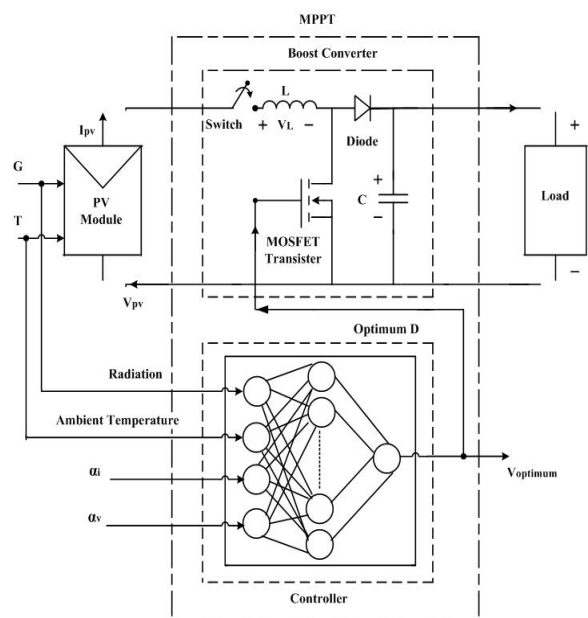$$\frac{V_{pv}}{V_{pv_{optimum}}} = \frac{1}{1-D} \tag{8}$$

Fig. 4: Components of the proposed system

5. Proposed of ANN Controller

A neural network is an adaptive system that tries to simulate its learning process. To do so, MATLAB

is used to model ANN and its training is done using temperature and irradiation values. To predict $V_{pv\ optimum}$, ANN is developed. PV module and P&O algorithm were modelled to calculate the maximum voltage(V_{mp}). Then, the modelled ANN is targeted by obtained voltages. However, the proposed ANN is modelled by three layers as shown in Figure 4. The I_{sc} and V_{oc} coefficients, temperature, and irradiation represent inputs to the first layer. And the predicted voltage represents its output layer which is supposed to be the triggering signal for duty cycle of the converter.
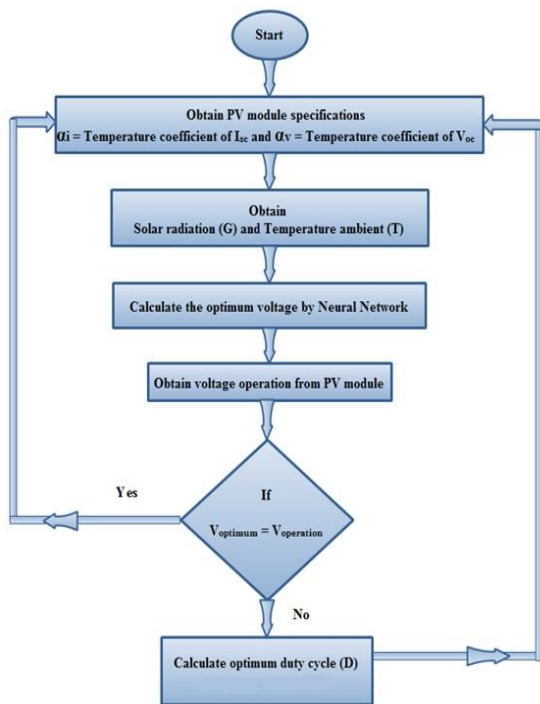

Fig. 5: The proposed ANN algorithm

Figure 5 shows ANN algorithm which begin by determine ambient temperature and solar irradiation, and then optimum voltage is predicted using the developed ANN. To find the PV system is operated as in an optimal case, a comparison is done between the operating voltage and the predicted voltage (8).

6. Discussion of the Results

The overall PV system is discussed in this section. The proposed MPPT algorithm has been simulated in MATLAB and its performance has been compared with the P&O algorithm. Figure 6 shows the results of the MPP tracking using two MPPT algorithms by plotting the P-V curves. The calculated result is compared mathematically with the theoretical as;

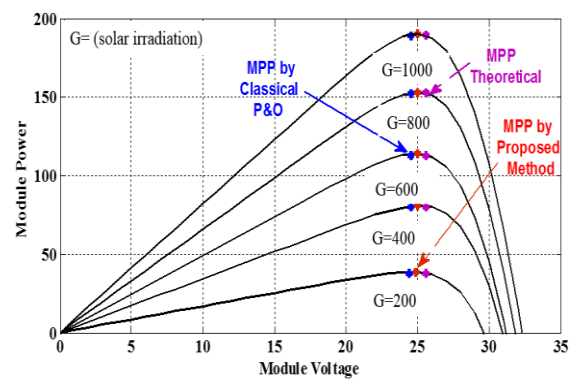$$P_{max} = \frac{G_{now}}{G_{ref}}\ P_{max\ ref} \tag{9}$$

Fig. 6: Comparison of the two MPPT algorithms with theoretical MPP

It is clear that, the location of the MPP for the proposed ANN is more close to the theoretical as compared to conventional P&O.

A comparison between the conventional P&O and ANN controller is done as in Figure 7 to evaluate the performance of them. It is noted that the power by conventional P&O is less than the ANN.
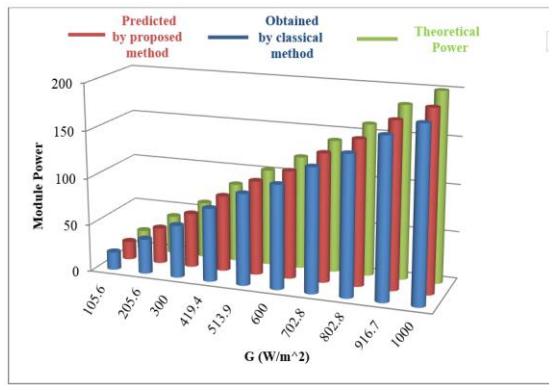
Fig. 7: Power comparison

In terms of efficiency, the efficiency of any maximum power point tracker is defined as the ratio of the output power to the theoretical maximum power. The efficiency of conventional P&O algorithm is calculated by dividing the obtained power to the theoretical maximum power of PV module, while the efficiency of the proposed ANN algorithm is obtained by dividing the predicted power to the theoretical maximum power of PV module [11]. So, the efficiency can be given by,

$$\eta = \frac{P_{obtained\ by\ P\&O}}{P_{maximum\ theoretical}} \%100 \qquad (10)$$

$$\eta = \frac{P_{obtained\ by\ ANN}}{P_{maximum\ theoretical}} \%100 \qquad (11)$$

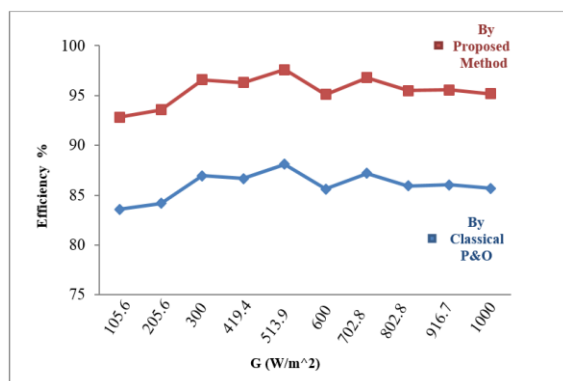Figure 8 shows ANN tracking efficiency is not less than 92% as compared to the P&O method.

Fig. 8: PV system comparing efficiency

7. Conclusion

In this research, MPPT controller is improved to predict PV maximum power by using the factors of irradiation, temperature, and load resistance. The simulation outputs show that the response of P&O is less than the response of MPPT controller. In addition, the tracking efficiency average of ANN is 95.52% as compared to P&O controller 85.98%.

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