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An ANN-P&O-based hybrid MPPT Controller to Enhance Photovoltaic System Efficiency

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Abstract-- Solar energy is a promising energy source in Myanmar, and its use is growing. To gather this kind of energy in a solar PV application, a photovoltaic module is required. The I-V and P-V characteristics of the PV module are nonlinear. The maximum power generated is affected by both irradiance and temperature. Maximum efficiency is gained when PV operates at its maximum power point, which may be accomplished by applying an appropriate MPPT algorithm. The majority of PV systems use traditional MPPT techniques such as incremental conductance (IC) and perturb and observe (P and O). Intelligent control methods are widely employed in all domains due to advancements in control technology. Under normal circumstances, a traditional MPPT controller maximises conversion efficiency but fails under abnormal situations. This paper proposes an intelligent ANN-P&O MPPT controller for the Boost converter that uses the effective regions of both the ANN and P&O methods to identify the global maximum point in order to improve the conversion efficiency of a PV system, as well as a comparative simulation study of three MPPT algorithms: I perturb and observe, (ii) artificial neural network (ANN), and (iii) NN - P&O. The MATLAB/SIMULINK programme is used to evaluate and compare how well the controller performs in odd conditions.

Keywords *- Maximum Power Point Tracking, Perturb and Observe Method, ANN Method, Boost Converter, Hybrid NN – P&O.*

I. INTRODUCTION

Spotless and sustainable power sources like photovoltaic (PV) control is played a significant job in electric power age, and become basic nowadays because of deficiency and natural effects of customary powers. The sunlight-based vitality is straightforwardly changed over into electrical vitality by sun based photovoltaic modules. As a result of nonlinear I-V and PV qualities of PV sources, their yield power is principally relied on the ecological conditions and nature of burden associated. Thus, these conditions will be influenced the general productivity of the PV frameworks [1]. But the productivity of the sun-based PV module is low. Because of the mind-boggling expense of sun-based cells, a most extreme power point tracker is expected to work the PV cluster at its greatest power point. Subsequently the greatest power is extricated from the PV generator depends on three variables: insolation, load profile (load impedance) and cell temperature (surrounding temperature). To get the most extreme power from PV, a greatest power point tracker (MPPT) is utilized [2]. There are so many methods and algorithms for tracking of the MPP of the PV systems. In this paper, comparative investigations of Perturb and observe (P&O) algorithm and artificial neural network (ANN) technique algorithm using dc-dc converter is done in terms of the maximum power transfer capability of these algorithms.

II. STAND -ALONE SOLAR POWER SYSTEM

The solar PV system consists of a PV module, the dc/dc boost converter, the maximum power point tracking algorithm and the load. Radiation (R) is incident on the PV module. It generates a voltage (V) and current (I) which will be fed into the load [3]. The voltage power characteristic of a photovoltaic (PV) array is nonlinear and time varying because of the changes caused by the atmospheric conditions. When the solar radiation and temperature varies the output power of the PV module also changes. In order to obtain the maximum efficiency of the PV module, it must operate at the maximum point of the PV characteristic. The most extreme power point relies upon the temperature and irradiance which are non-direct in nature. The greatest power point following control framework is utilized and work viability on the non-straight varieties in the parameters, such as temperature and radiations [4]. A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load. A dc/dc converter (boost converter) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the load and the module. The dc/dc converter with maximum power point tracking algorithm and the load is shown in Fig. 1. By changing the duty cycle, the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power. Therefore, MPPT techniques are needed to maintain the PV array's operating at its MPP [3]. In this paper, two most popular of MPPT technique (Perturb and Observe (P&O) methods and artificial neural network (ANN) methods and dc-dc converter will be involved in comparative study.

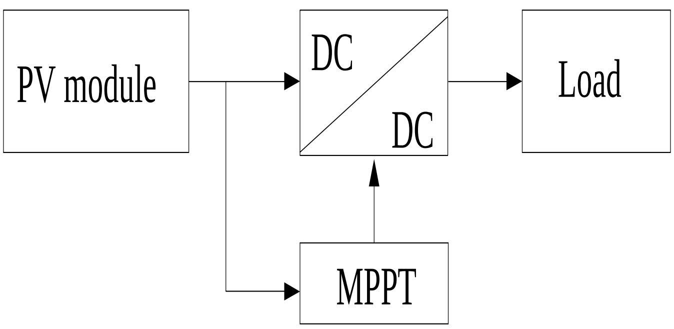


Fig. 1 Block Diagram of PV System with MPPT

III. MAXIMUM POWER POINT TRACKING

Most extreme Power Point Tracking (MPPT) is helpful apparatus in PV application. Sun oriented radiation and temperature are the primary factor for which the electric power provided by a photovoltaic framework. The voltage at which PV module can create greatest power is called 'most extreme power point (pinnacle control voltage). The primary rule of MPPT is in charge of separating the greatest conceivable power from the photovoltaic and feed it to the heap by means of dc to dc converter which steps up/ down the voltage to required size [5]. There are many maximum power point techniques. Among them, two MPPT techniques of ANN, perturb and observe (P&O) have been selected for the purpose of comparison in this paper.

A. DC/DC Boost Converter

The dc-dc converter is used to supply a regulated dc output with the given dc input. These are widely used as an interface between the photovoltaic panel and the load in photovoltaic generating systems. The load must be adjusted to match the current and voltage of the solar panel so as to deliver maximum power. The dc/dc converters are described as power electronic switching circuits. It converts one form of voltage to other. These may be applicable for conversion of different voltage levels. Fig.2 shows the circuit diagram of dc-dc boost convertor [7].

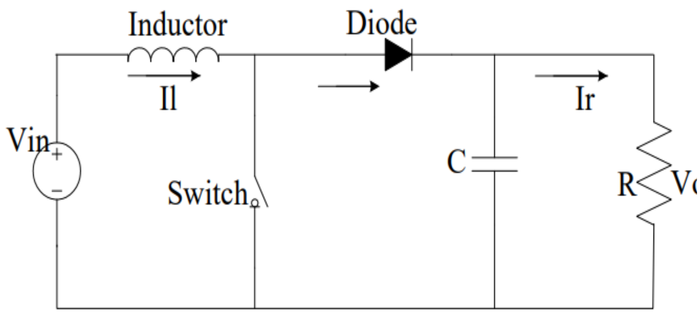


Fig. 2 Circuit Diagram of Boost Converter

The dc-dc boost converter circuit consists of Inductor (L), Diode (D), Capacitor (C), load resistor (RL), the control switch(S). These components are connected in such a way with the input voltage source (Vin) so as to step up the voltage. The output voltage of the boost converter is controlled by the duty cycle of the switch. Hence by varying the ON time of the switch, the output voltage can be varied. The relationships of input voltage, output voltage and duty cycle are as follow:

$$\frac{V_0}{V_{in}} = \frac{1}{1-D} \qquad (1)$$

Where, V_{in}, V_o are the input and output voltage of the converter and D is the duty cycle of the control switch.

B. DC/DC Buck-Boost Converter

A buck-boost converter is a type of dc-dc converter that has an output voltage magnitude either greater than or less than the magnitude of the input voltage magnitude. It's described by a voltage source connected in parallel to an inductor, a reverse-biased free- wheeling diode, a capacitor, and a load of resistance R at the output terminal. In MPPT with ANN technique, Vmppt will be lower than the input voltages in some conditions. Thus buck/boost converter is more favorable than boost converter for ANN technique [7].

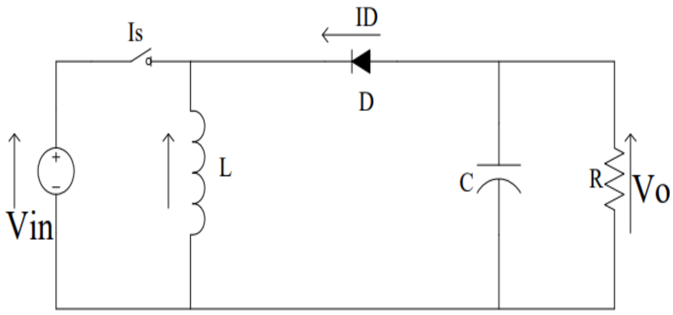


Fig. 3 Circuit Diagram of Boost Converter

$$\frac{V_0}{V_{in}} = \frac{D}{1-D} \qquad (2)$$

Where, V_{in}, V_o are the input and output voltage of the converter and D is the duty cycle of the control switch.

C. ANN Technique

The ANN control system has to be trained before being used in the photovoltaic system. The neural network is a powerful technique for mapping the input-output nonlinear function. The network tries to simulate its learning process through the various input fed to it during each cycle of data interpretation. It changes its structure based on the internal and external information that flows in and out of the network system.

The ANN control framework must be prepared before being utilized in the photovoltaic framework. The neural system is an incredible method for mapping the info yield nonlinear capacity. In the proposed structure, a two layer falling neural system method is fused that predicts the PV exhibit voltage at which the most extreme power is achievable. These build up a non-direct connection between the information and yield with a concealed layer that capacities with inclinations like neurons of the our mind. The hidden layer in the model is a two layer neural network. This is then sent to layer 1 with 50 neurons where a process input synthesizes the signal with weights and generates a tangent sigmoid transfer function. The output of layer 1 is the input for layer 2 with another set of 50 neurons that assigns weightage to the values and generates a pure linear transfer function [8].

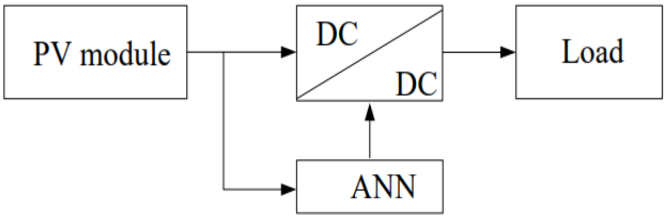


Fig.4. MPPT System with ANN Controller

D. Perturb and Observe (P&O) Technique

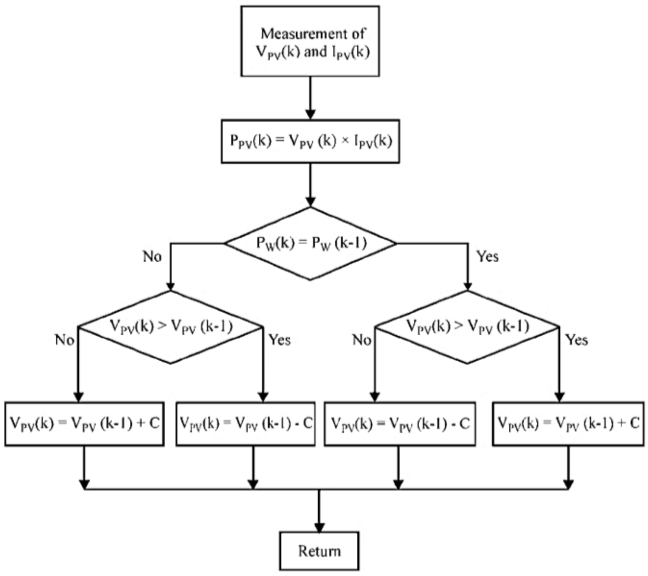


Fig. 5 State-flow Chart of P&O MPPT Technique

P&O is the most often utilized method to follow the greatest power because of its straightforward structure. This method works by intermittently irritating the PV module terminal voltage and contrasting the PV yield control and that of the past annoyance cycle [1]. As shown in Fig. 5 if the PV module operating voltage changes and power increases the control system moves the operating point in that direction; otherwise, the operating point is moved in the opposite direction.

IV. SIMULATION AND RESULTS

After modeling the Stand-Alone PV System, the comparative analysis of Maximum Power Point Tracking Algorithms is analysed. The simulation models for Maximum Power Point Tracking Algorithms are executed with MATLAB/Simulink version R2019a. The simulation results of Maximum Power Point Tracking Algorithms for all the schemes are shown in the following sections.

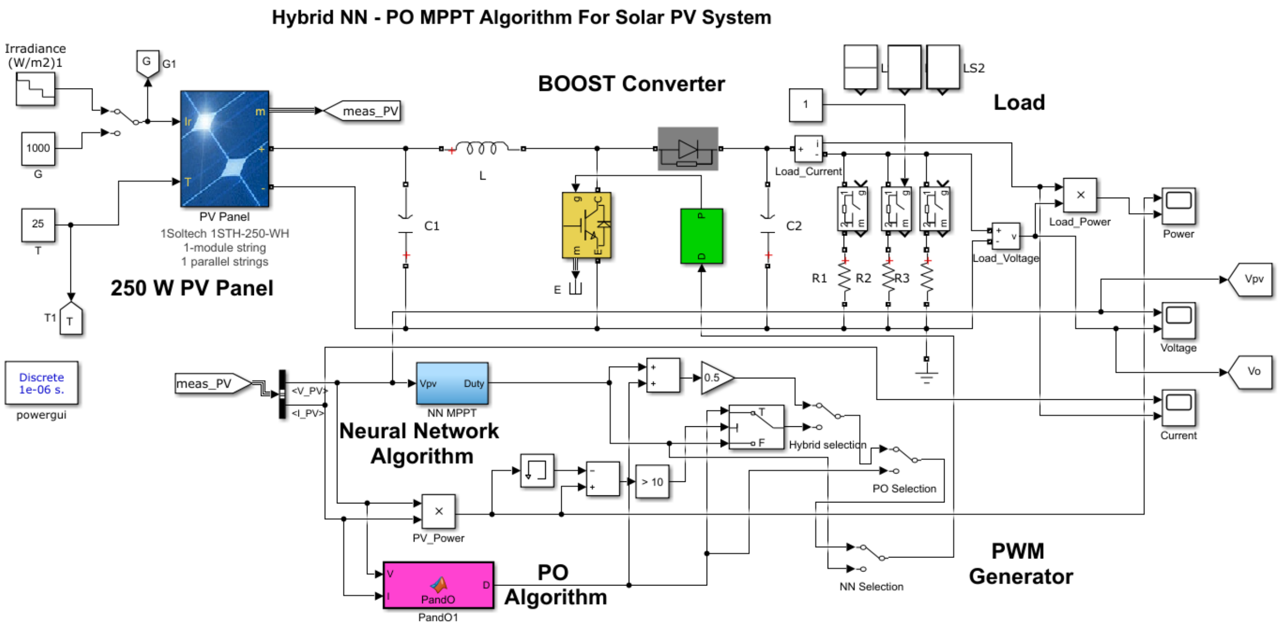


Fig 6. MATLAB/ Simulink Hybrid NN – P&O MPPT Algorithm for Solar PV System

To analyse the performance of the output voltages, the output currents and the output power are measured as shown. The PV parameters of the system are shown in Table I.

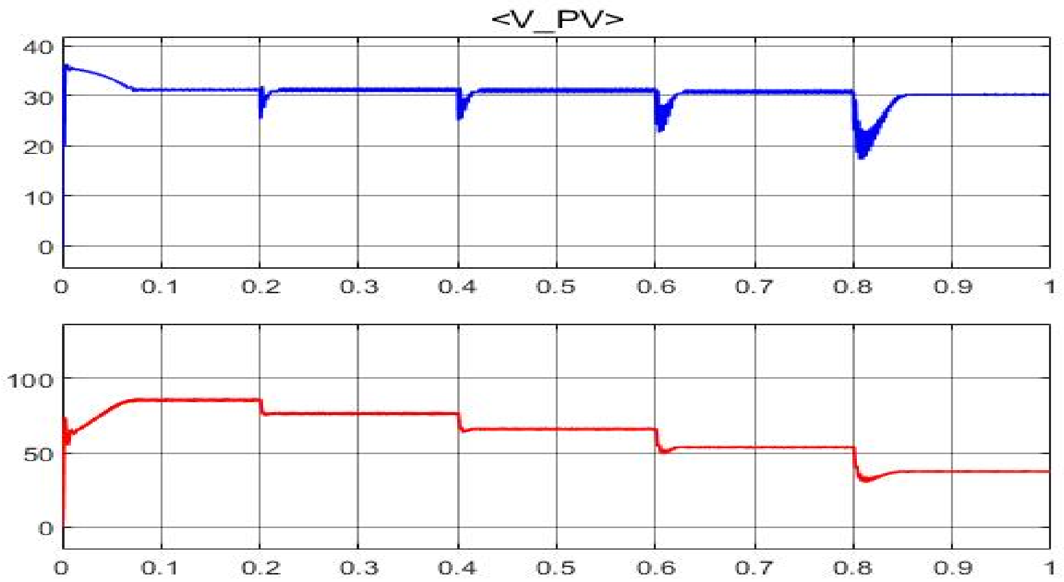
Table 1: PV PARAMETERS

Parameters	Specifications

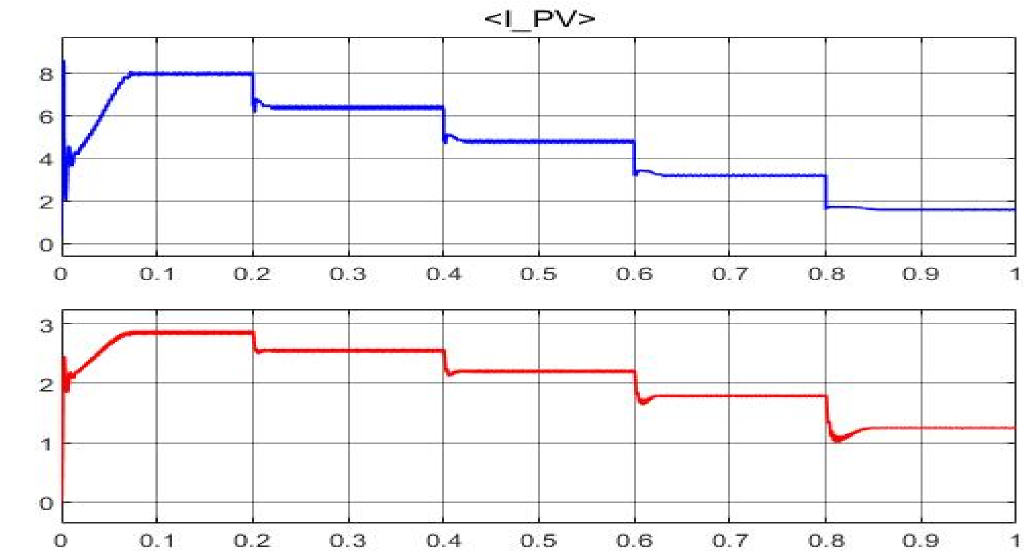
Maximum power, P_m	250 W
Series-connected modules per string	1 nos
Parallel strings	1 nos
Cells per module (Ncell)	60
Maximum power voltage, V_{pm}	30.7 V
Maximum power current, I_{pm}	8.15 A
Open circuit voltage, V_{oc}	37.3V
Short circuit current, I_{se}	8.66 A

A. Simulation Results with Different Algorithms

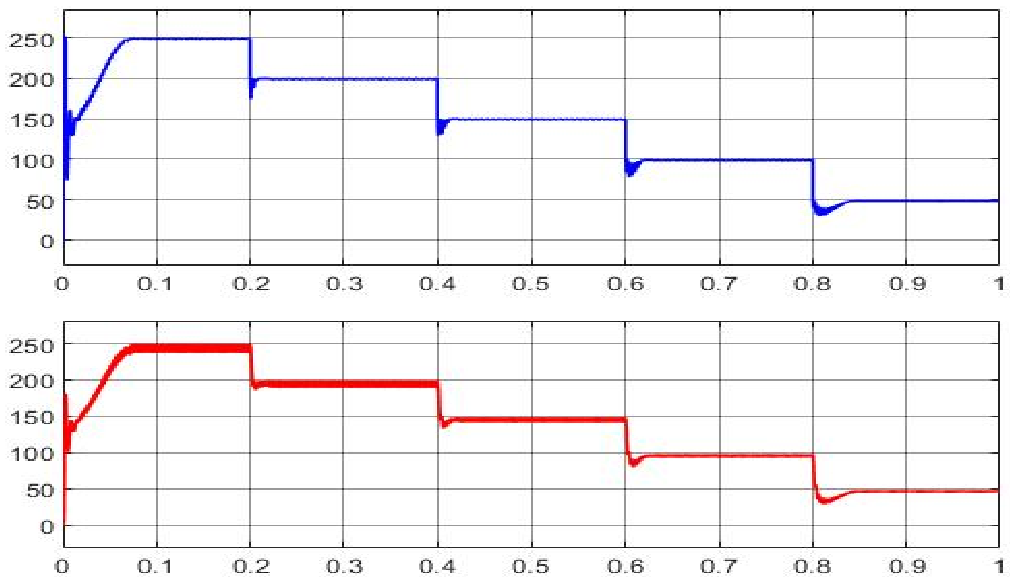
For comparative study with different algorithms, three algorithms are applied for MPP tracking in this research as (i) Perturb and Observe (P and O) method, (ii) ANN method And NN – P&O. The simulation results for different algorithms under standard condition, 1000 W/m2 irradiation and 25^{0}C temperature are shown in the following figures.



(a). Voltage



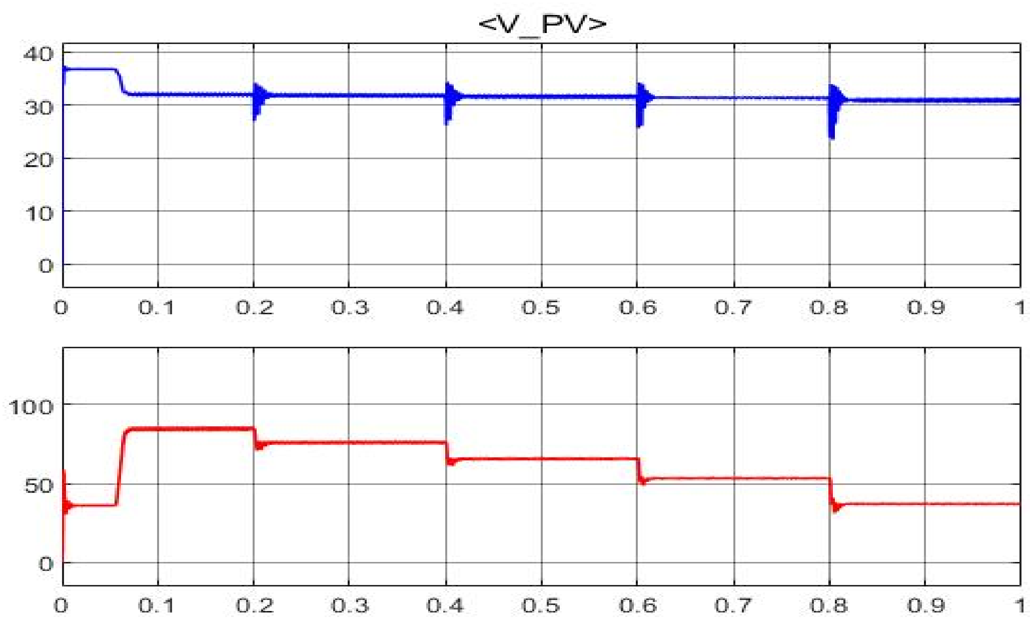
(b). Current



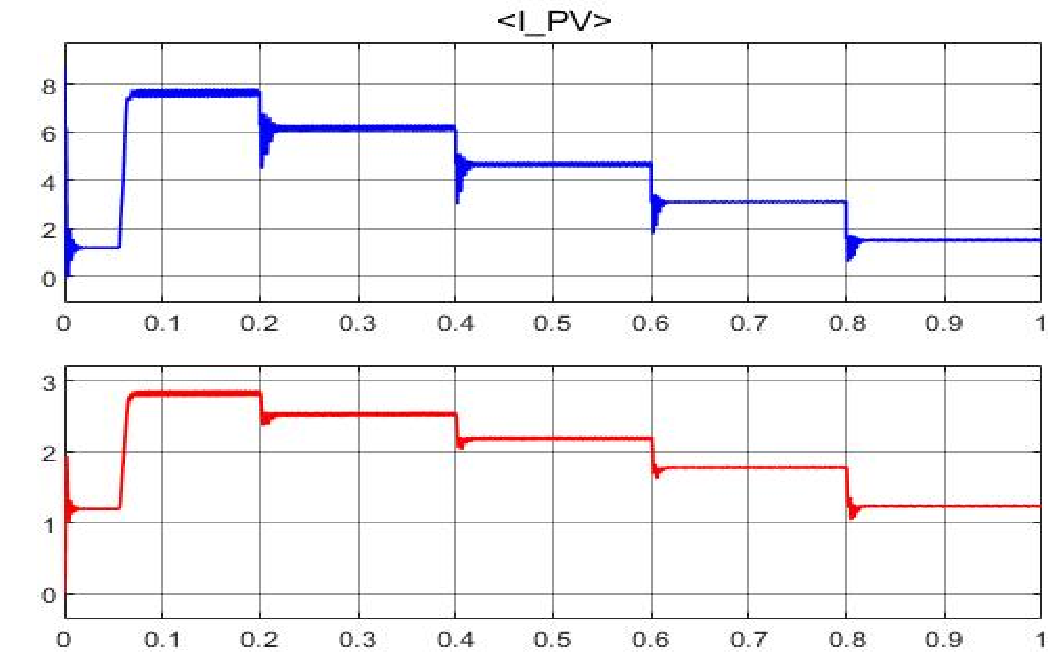
(c). Power

(d). Duty Cycle

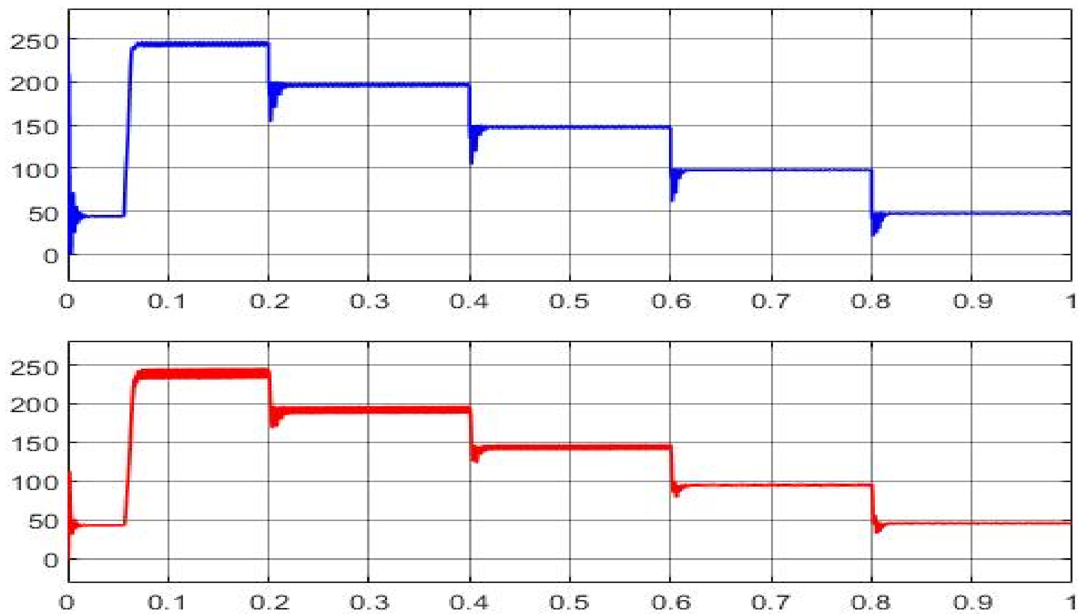
Fig 7. PV Output (a) Voltage, (b) Current, (c) Power & (d) Duty Cycle with P&O Method.



(a). Voltage



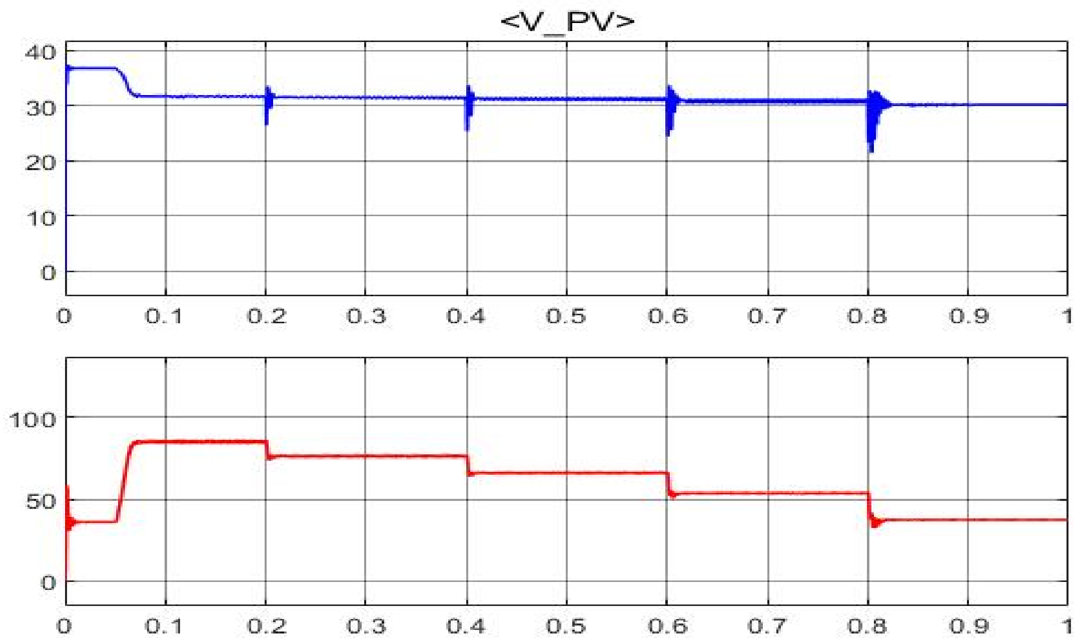
(b). Current



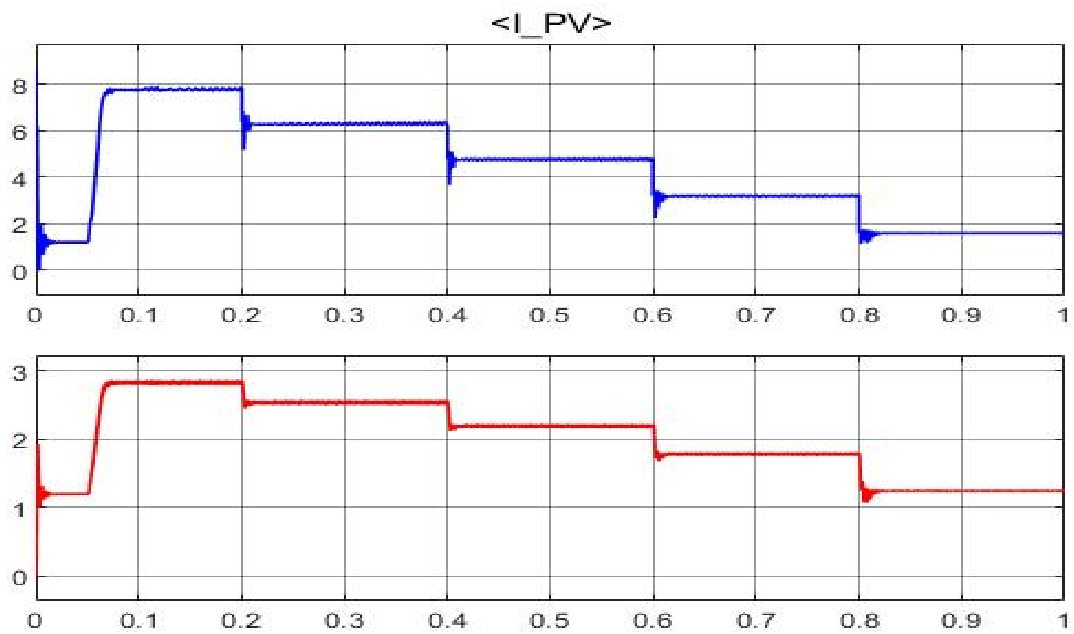
(c). Power

(d). Duty Cycle

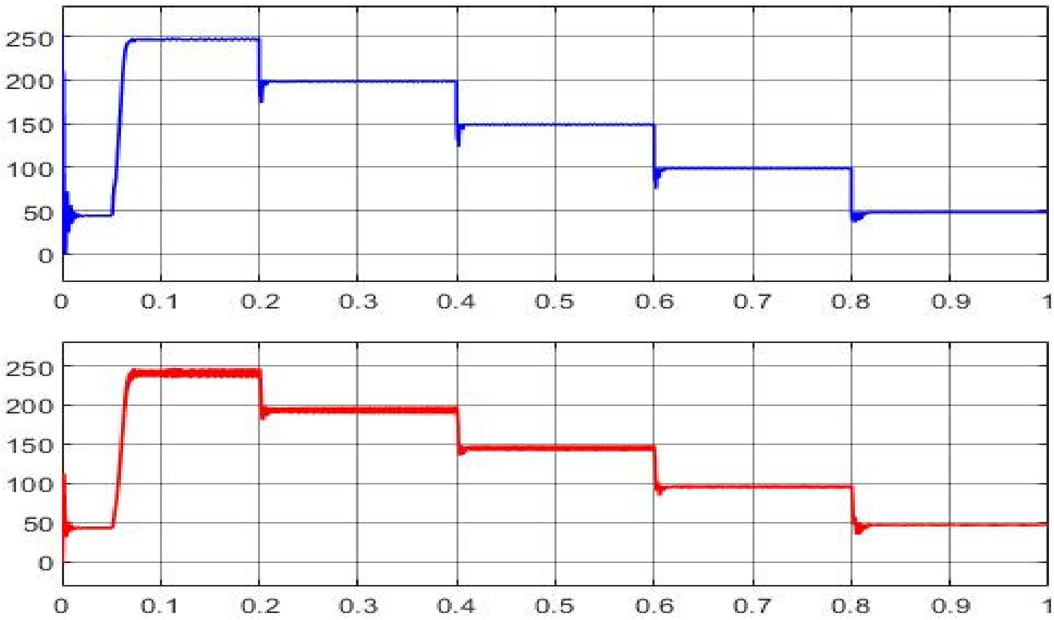
Fig 8. PV Output (a) Voltage, (b) Current, (c) Power & (d) Duty Cycle with ANN Method.



(a). Voltage



(b). Current



(c). Power

(d). Duty Cycle

Fig 9. PV Output (a) Voltage, (b) Current, (c) Power & (d) Duty Cycle with NN – P&O Method.

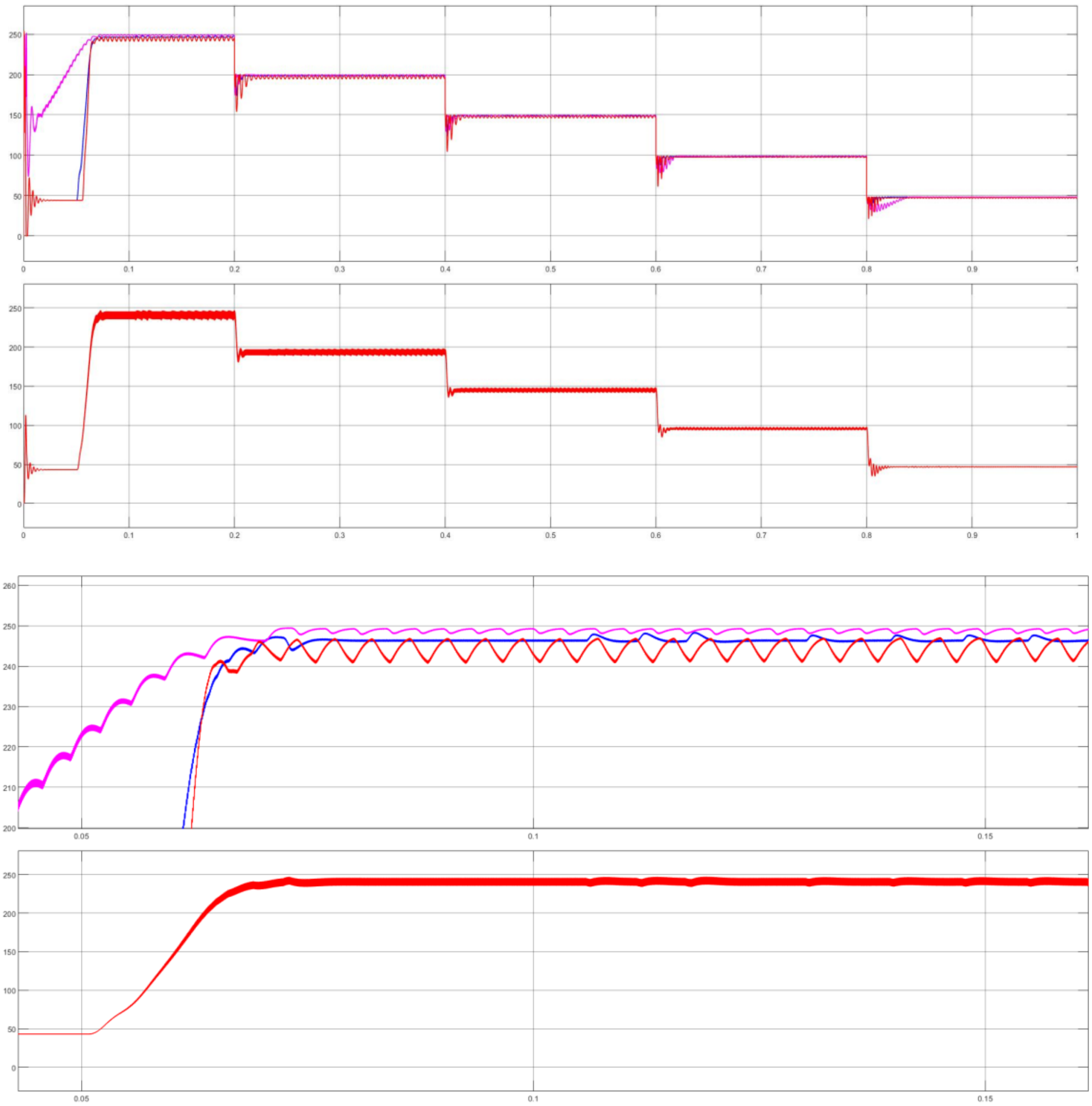


Fig 10. Comparison Between all three techniques

Fig. 10 shows comparison for power output variation under the $\mathbf{25^0}$ temperature at constant irradiation 1000 W/m2. According to this fig. 10, the power provided and the transient performance by Hybrid NN – P&O is better compared to P and O method and ANN Method.

B. Simulation Result Comparisons of MPPT Techniques

The simulation results of output voltage, output current, and output power for temperature of 25ºC and the irradiation 1000 Wm-2 are shown in Table II. According to the simulation results, in comparison of the three output powers, the power provided by NN – P&O technique is larger in **1000** $\mathbf{W}\boldsymbol{M}^{\mathbf{2}}$ irradiation case.

Table 2: Comparison Of Simulation Results For 25ºc Temperature And 1000 $\mathbf{W}\boldsymbol{M}^{\mathbf{2}}$ **Irradiation**

Irradiation (W/m^2)	Parameter	Algorithm		
		ANN	P and O	Hybrid NN – P&O
1000	Vo (V)	29.8	28.9	30.5
	Io (A)	8.0438	8.0096	8.0596
	Po (W)	249.1	248.9	249.8

The simulation results of output voltage, output current and output power for temperature of 25ºC and the irradiation of 1000 Wm-2 are shown in Table III.

Table 3: Comparison Of Simulation Results For 1000 Wm-2 Irradiations And 25^0 Temperature

Temperature (ºC)	Parameter	Algorithm		
		ANN	P and O	Hybrid NN – P&O
25	Vo (V)	29.8	28.9	30.5
	Io (A)	8.0438	8.0096	8.0596
	Po (W)	249.1	248.9	249.8

According to the simulation results. In comparison of the other two output powers, the power provided by NN – P&O technique is larger in the 25^0 temperature case.

CONCLUSION

The simulation findings reported in this thesis for the ANN, P&O, and Hybrid NN-P&O approaches demonstrate that the Hybrid ANN-P&O controller tracks the Maximum Power Point (MPP) faster than the individual P&O and ANN controllers. In the situation of rapidly changing solar irradiation, the NN-P&O approach is particularly quick and accurate in locating and tracking the MPP. Furthermore, under slowly changing solar irradiation, this approach can stably extract the maximum power point, and efficiency is increased when combined with the improved P&O-ANN method. The ANN approach, on the other hand, may keep its output voltage near to its maximum power voltage (Vmp) and hence supply more power than the P and O methods. Again, the ANN approach has a better transient response and achieves steady-state conditions faster. On the other hand, when irradiation changes rapidly in a short period of time, the P & O approach fails to follow the MPP. Furthermore, with gradually changing solar irradiation, this approach exhibits considerable oscillation around MPP, resulting in substantial power loss over time.

FUTURE SCOPE

The ability to combine two or more renewable energy sources depending on the users' natural local potential.
Combinations of algorithms and controllers, such as PSO, GA, Fuzzy Logic, and ANFIS, may be utilised to improve the efficiency of PV systems.
Environmental protection, particularly in terms of lowering carbon dioxide emissions.
Low-cost wind and solar energy may compete with nuclear, coal, and gas energy, particularly when future cost projections for fossil and nuclear energy are included. Supply diversity and security Quick deployment: modular and simple to set up.

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