Performance Evaluation of Hybrid NN-PO MPPT Technique For Solar PV Systems

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Abstract- - ***This paper presents a meticulous performance evaluation of a Hybrid Neural Network and Perturb and Observe (NN-PO) MPPT technique employed in solar PV systems. The study delves into the intricate synergy of neural network intelligence and perturb and observe methodology, aiming to optimize the power output under varying environmental conditions. Through a comprehensive analysis, including simulations and empirical assessments, the paper scrutinizes the effectiveness, adaptability, and efficiency of the hybrid approach. The findings contribute valuable insights to the realm of solar energy technology, offering guidance for practitioners, researchers, and engineers seeking to advance the performance and reliability of MPPT strategies in solar PV systems.***

Keywords: ***Photovoltaic Systems, Maximum Power Point Tracking (MPPT), Hybrid Techniques, Neural Network Perturb and Observe, Solar Energy, Power Optimization Performance Evaluation.***

I. INTRODUCTION

Power It has been evident over the past ten years that the world's fossil fuel supplies are starting to run out. Although estimates of energy resources differ, it is believed that coal reserves may only survive for another 200 years, and oil and gas reserves will run out in about 40 and 60 years, respectively. To meet the demands of the modern world, an urgent search for alternative energy sources is required due to the global depletion of fossil fuel supplies at an accelerated rate. As the evidence of the global warming phenomenon grows, so does the need to lessen our reliance on fossil fuels. Since the industrial revolution, we have significantly increased the amount of carbon dioxide released into the atmosphere by burning these fossil fuels. the environment. As carbon dioxide builds up in the atmosphere, it absorbs long-wave infrared light that the planet would otherwise release back into space. The earth's temperature has increased as a result of this radiation remaining in the atmosphere. If this global warming effect is not reduced as quickly as feasible, it will have far-reaching effects. Because of how sensitive the earth's natural balance is, even a 1°C or 2°C increase in temperature can cause the ice caps to melt and cause widespread flooding around the planet. Finding alternative energy sources is therefore essential to meeting the world's ever-growing energy needs while reducing our detrimental effects on the environment. Using alternative energy sources like biomass, solar, and wind Energy industries have been drawn to generate power on a massive scale using ocean, thermal, and tidal resources. Because of their accessibility and benefits for producing power locally, solar and wind energy systems are therefore seen as viable power generating options.It has been evident over the past ten years that the world's fossil fuel supplies are starting to run out. Although estimates of energy resources differ, it is believed that coal reserves may only survive for another 200 years, and oil and gas reserves will run out in about 40 and 60 years, respectively. To meet the demands of the modern world, an urgent search for alternative energy sources is required due to the global depletion of fossil fuel supplies at an accelerated rate.

Solar power-A way to power Generation

The sun is a source of practically unlimited energy, most of which is wasted but provides us grows all of our food and keeps us warm with millions of kilowatts of power. The sun provides Earth with energy several thousand times over each day. Last but not least, solar energy is the clean, safe energy that has supported life on Earth since its inception. Solar energy has existed for as long as humans have. We began harnessing the sun's energy directly to create electricity in the previous 200 years. French physicist Alexandre Edmond Becquerel discovered in 1839 that some materials, when exposed to light, generated minute amounts of electric current. The photovoltaic cells were not patented until 1946 by a person by the name of Sven Ason Berglund. The year 1954 was designated as the modern era of solar power technology. This occurred when Bell Laboratories realized how powerful silicon could be while doing experiments with semiconductors. It was a whole new development. In actuality, silicon that had been modified to work with specific impurities was incredibly light-sensitive. Certain solar energy gadgets are now up to 6% effective thanks to a 1954 Bell Laboratories invention, but the story doesn't end there. The amount of interest in solar energy and producing solar electricity from solar cells surged substantially after this amazing breakthrough. All of a sudden, there was strong financial support for and belief in the study and development of new, cutting-edge solar power devices. Solar photovoltaic (PV) cells were not at all economically viable in 1956. The cost per watt of solar energy was approximately $300. Energy had decreased as expected, but fossil fuel prices had also decreased, giving solar a declining competitive advantage. Nonetheless, the solar business has gained new life thanks to the massive growth of the PV markets in Germany and Japan during the 1990s. Japan put in 25,000 solar rooftops in 2002. Large PV orders like these are generating economies of scale, which are gradually bringing down prices. With the prospect of consistently falling costs, the PV market is already expanding at a scorching 30 percent annual rate.

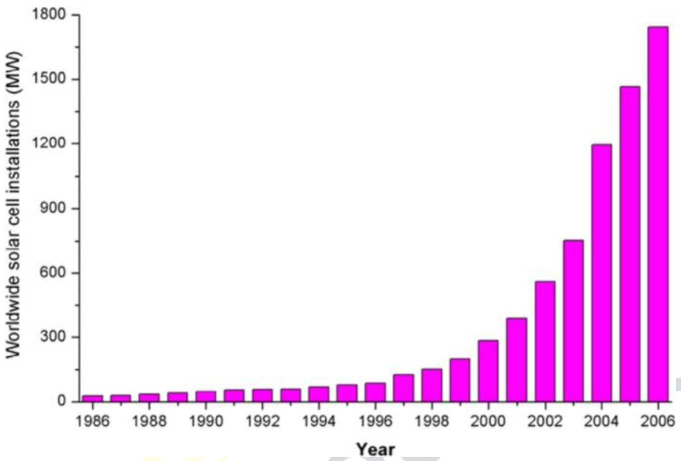


Fig1 : Worldwide annual solar cell installations from 1986 to 2006

The annual fluctuations in solar cell or photovoltaic (PV) installations globally from 1986 to 2006 are depicted in Fig. 1. The yearly installation of solar cells increased by more than 19 times in the ten years between 1996 and 2006, as the figure illustrates (from 88.6 MW in 1996 to 1,744 MW in 2006). By the end of 2006, there were more than 7,400 MW of installed solar cells. Beginning in 1996, the growth rate sharply increased. In the near future, new technologies such as thin-film technology and new concentrator method, among others, contribute to high production yields at lower prices and with less material usage. One of the most promising renewable energy sources in the world right now is photovoltaic solar energy. In contrast to fossil fuels like coal, the benefits of gas, oil, and nuclear power are obvious: it produces no pollution, has no moving parts that need to break down, and requires no maintenance. Unlike conventional power generation stations, photovoltaic power generation does not require a large-scale installation in order to function, which is a significant feature. Distributed power generators can be mounted on any home, company, or educational institution, utilizing already-developed space and enabling private users to quietly and safely produce their own electricity.

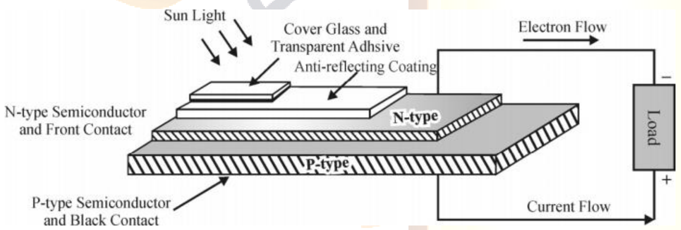


Fig. 2: Schematic Block Diagram of PV Cell

Small Photovoltaic systems are available in three different configurations: stationary, portable, and permanently mounted. Getting the most power possible out of the panel at the lowest possible cost is the goal, regardless of the installation. Similar to wind turbine power systems, solar systems use various MPPT techniques based on the circumstances. In one specific setup, the MPPT controller determines the ideal power levels by using an unloaded reference solar cell. With the help of this extra cell, it is possible to pinpoint the exact maximum power point that is immune to electrical noise. Nevertheless, the additional cell needs a bigger surface area and can be expensive. Therefore, this MPPT method ought to be limited to stationary installations that use ten or more separate panels for energy collection. Any intermittent energy source, including solar panels, must have its power output carefully considered in relation to the required demand when placed. They are frequently added to the electricity grid to supplement it, or they are enhanced by generators or backup batteries. Photovoltaic panels, a rechargeable battery, and a non-rechargeable backup battery are used in another arrangement.

Wind Power-Approach to power Generation

Wind One of the first methods of utilizing mechanized energy is power, which has been utilized extensively throughout human civilization's history. Wind energy is a cheap, sustainable, safe, and widely used clean energy source that is abundant in most parts of the world. The first known windmills appeared in Europe in the eleventh century, and wind power generation is believed to have started in China. Ever since, windmills have become a ubiquitous sight in landscapes, particularly in Europe. In the final years of the 1800s (1887 - Charles F. Brush is recognized for having invented and constructed the first wind turbine that could generate energy in 1888. The two and three did not come together until the Second World War.

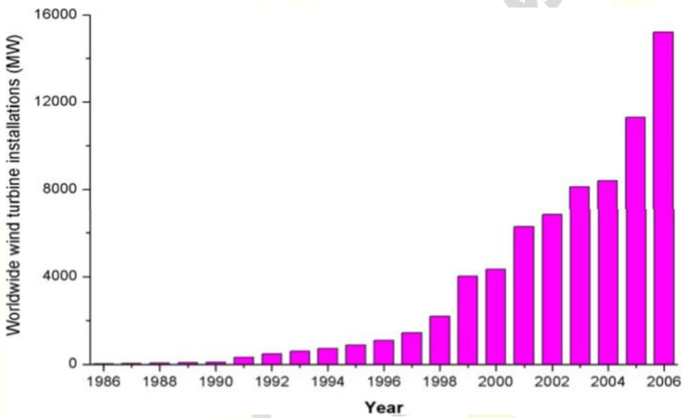


Fig. 3 : Worldwide annual wind turbine installations from 1986 to 2006

Wind Energy Conversion System (WECS)

Wind A turbine is a crucial component of an electrical generation wind power system. It is divided into various sizes based on the quantity of power produced. Electricity produced by a large wind turbine can reach megawatts (MW). A backup source of less than 100kW of electricity can be provided by a tiny wind turbine. A little wind turbine typically produces 20 to 500 watts of electricity, which is used to charge batteries. The wind turbine uses a rotor with two or more blades that are mechanically connected to an electrical generator to absorb the kinetic energy of the wind. To maximize energy capture, the rotor is situated atop a tall tower. There are now two wind turbine configuration types.

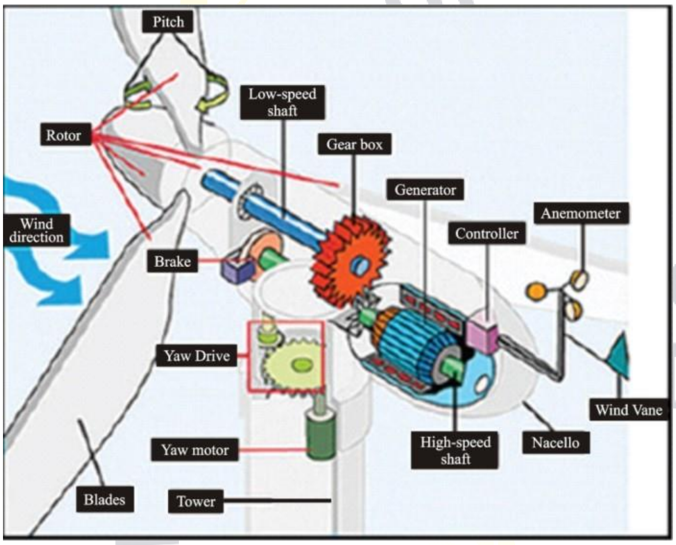
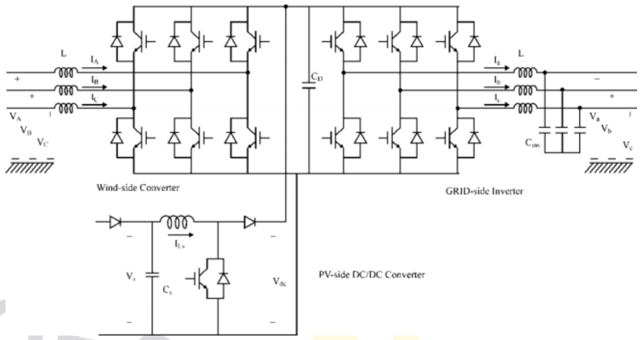


Fig 4 : Components of a horizontal-axis wind turbine

The There are numerous components involved in the process of turning wind energy into electricity. The hub and blades are the parts that are most visible. They function in a horizontal axis turbine in a manner similar to an airplane or helicopter propeller, but in reverse. Because of how inefficiently they use land, vertical axis turbines are used less frequently in commercial applications. Nevertheless, they are more frequently utilized in low-lying locations and in residential settings because they don't need strong winds to start generating electricity. Either a generator or a gearbox shaft can have the hub of either turbine orientation fastened to it. Input torque and angular velocity are adjusted by the gearbox to values that are better suited for the generator.

Hybrid System

In many small-scale systems, the DC system consists of a load, a controller that prevents the batteries from overcharging, and a bank of batteries that store energy. The DC system is set at a constant DC voltage. The load could consist of an inverter to an ac system or it could be dc. Due to the poor impedance matching between the wind generator and the constant DC voltage (battery), connecting a wind generator to this type of voltage may cause serious issues and restrict the amount of power that can be transferred to the DC system. Researchers have looked into adding a dc-dc converter to the dc link as a solution to these issues. The hybrid system's whole power



control is managed via the power conditioning system. The suggested power electronic based interface is shown in Fig. 5.

Fig. 5 : Power electronic interface of the hybrid system.

II. LITEATURE REVIEW

Mohamed In an effort to increase MPPT accuracy and efficiency, a number of studies have looked into integrating neural networks with traditional MPPT algorithms like Perturb and Observe (P&O). These methods seek to take advantage of neural networks' capacity for learning in order to adaptively modify the perturbation step size in P&O algorithms in response to external factors. Some research include experimental validation on real-world solar PV systems to complement modeling results. In experimental settings, MPPT controllers are installed in field- or lab-scale photovoltaic installations in order to evaluate their performance in real-world situations.

Aman Sharma et. Al [1] most industries, namely in the areas of fuzzy logic algorithms, incremental conductance (IncCond), and perturbation and observation (P&O), used MPPT techniques. In MATLAB/Simulink, the three control methods are examined under various irradiance scenarios, and their tracking efficacy is subsequently assessed. A charge controller is used for the backup system, which means that a reference current for battery charging is provided based on the battery's current voltage and Status of Charge (SOC). In the end, comparison findings were obtained, and algorithms were contrasted according to a number of criteria, including efficiency, ease of implementation, and dynamic response.

Julio et.al. [2] studies Seeking the best possible electrical energy quality for network connectivity leads to a number of phenomena that degrade energy quality; these phenomena are produced by the inverter and converter, which are identified as the relevant equipment. In order to avoid power quality issues, it is crucial to ascertain the ideal penetration level for solar panels. The total harmonic distortion's reliance on the current, solar irradiation, inverter output current, RMS voltage at the grid connection point, and active and non-active power registers forms the basis of the methodology. With the aid of ETAP 16.0.0 software, these parameters were computed using a programming and loop reference frame.

Bhagyashree et. al. [3] The utility load now faces new demands in terms of power quality, voltage stabilization, and effective energy use due to the widespread use of distributed energy sources in the electrical grid. The most reliable renewable energy sources are thought to be solar and wind power. Unfortunately, because of the unpredictability of solar and wind irradiance, photovoltaic and wind energy systems do not provide a very consistent source of electricity production when operating independently. A combination of solar and wind power producing structures can therefore create a very promising and dependable source of electricity. A hybrid wind and photovoltaic system model has been presented in this paper. For those who are stationed remotely, this type of technology is quite advantageous and helpful.

Nirav et. al. [4] The extensive use of distributed energy sources in the electrical grid has resulted in increased demands on the utility load in terms of power quality, voltage stabilization, and efficient energy use. It is generally agreed that wind and solar energy are the most dependable renewable energy sources. Unfortunately, when used independently, photovoltaic and wind energy systems do not offer a highly reliable source of electricity production due to the unpredictable nature of solar and wind irradiance. Therefore, a very promising and dependable source of electricity can be created by combining solar and wind power producing structures. This study presents a hybrid wind and photovoltaic system model. This kind of technology is quite beneficial and useful for people who are stationed away.

Tripurari et.al. [5] This paper proposes a self-tuning filter-frequency locked loop (STF-FLL) based control algorithm for improving power quality in a single phase utility grid integrated to a solar photovoltaic (PV) array with a wind energy generation system (WEGS) based on permanent magnet synchronous generators (PMSG). The primary purpose of the STF-FLL control is to efficiently extract the essential components of the load current. A high level of insensitivity and immunity to power disruptions is provided by the suggested technique. The system's primary goal is to provide active power to a single phase grid that is coupled at the point of common coupling (PCC) and the load. Additionally, it offers load reactive power correction and reduces power quality problems such distortion from grid current harmonics.

Varsha et.al. [6] Researches The quality of electrical power is impacted when renewable energy (RE) sources like solar and wind energy are integrated into the utility grid. For utility companies to draw in new customers or keep their current ones, they must guarantee a high-quality power supply and services. This work can be accomplished with the aid of an efficient power quality (PQ) monitoring and improvement system. The utility grid's distribution static compensator (DSTATCOM) can be used to increase PQ. In order to give the DSTATCOM effective control for PQ improvement in the utility grid in the presence of solar PV energy, this research work presents a control scheme based on the synchronous reference frame (SRF) theory. The DC bus in the design is made up of a capacitor and a bank of batteries.

Ravi et. al. [7] Examine Higher invention and more loads result in higher power usage. The majority of loads are nonlinear, which contributes to the system's harmonic currents. In turn, these harmonic currents lead to voltage magnitude variations, capacitor overloading, system resonance, and efficiency declines. Customers and utilities are becoming more concerned about power quality. High-quality power transmission is required in a distribution line. Voltage sag is one of the main problems with power quality in the distribution system that dynamic voltage restorers can help to mitigate. In order to satisfy the required power and for electricity, this study focuses on the new integration of solar PV-Battery based Dynamic Voltage Restorer is integrating in the distribution system.

Priyank Shah et. al. [8] This work provides an adaptive line enhancer control strategy for three phase grid interfaced solar photovoltaic (PV) systems using sign least mean kurtosis (SLMK). Numerous goals are served by the SLMK-based control scheme, including load balancing, enhanced solar power penetration into the distributed network, and power factor correction. The fundamental load current weights for each phase are extracted using the SLMK technique. According to test results, the suggested system performs satisfactorily in both steady state and dynamic scenarios, such as load unbalancing and fluctuating solar insolation. Grid voltages and currents' total harmonic distortions (THDs) are found to be within IEEE-519 and 929 standard bounds.

Jayasankar et.al. [9] Researches Demand for energy is rising quickly, and using renewable energy sources is crucial to reducing the gap between supply and demand. Increased use of power-hungry electronics and non-linear loads contaminates the grid and degrades power quality. Using the grid-interfacing inverter of renewable sources as a shunt active filter can tackle the problems of power quality and energy scarcity at the same time. To give grid-interfacing inverters the ability to increase power quality, an appropriate control technique must be implemented. A fuzzy controller can be used in place of a conventional PI controller to provide greater control and enhance system performance. This work uses a PI controller to simulate a grid-connected wind-solar hybrid system with features for improving power quality.

Rajan Kumar et. al. [10] The creation of a dependable water pumping system powered by solar photovoltaic (PV) is the subject of this research. The PV generation unit installed for the water pumping is powered by a continuous power grid support, guaranteeing an uninterrupted and complete volume of water delivery and, consequently, reliability. The water pump is powered by a high-efficiency, decreased sensor-based brushless DC (BLDC) motor drive. A power factor corrected (PFC) buck-boost converter is controlled in order to permit power transmission from the utility grid to the common DC bus. The converter is operated in discontinuous conduction mode (DCM), which requires a single voltage sensing and provides an inherent power quality enhancement, in order to simplify and reduce the cost of control.

III. PROPOSED METHODOLOGY

Model In the era of electric power, clean and sustainable power sources such as photovoltaic (PV) control have become essential because to the natural decline and scarcity of conventional power sources. The sun-based photovoltaic modules convert the energy from the sunshine directly into electrical energy. The yield power of photovoltaic sources is mostly dependent on the ecological conditions and type of related burden due to their nonlinear I-V and PV features. As a result, these factors will affect the PV frameworks' overall productivity [1]. However, the solar PV module's productivity is modest. Given the exorbitant cost of solar cells, a most extreme power point tracker is anticipated to operate the PV cluster at its maximum power point.

Effect of Variation of Solar Irradiation

The solar irradiation values have a significant impact on the P-V and I-V curves of a solar cell. Because of environmental changes, solar irradiation varies constantly; nevertheless, control mechanisms are available to monitor this variation and modify the solar cell's operation to match the necessary load needs. Greater sun irradiation results in higher solar input to the solar cell, which increases power magnitude at the same voltage. The open circuit voltage rises as solar radiation increases. This is because more sunlight shining on the solar cell provides the electrons with a higher excitation energy, which increases the electron mobility and generates more power [10].

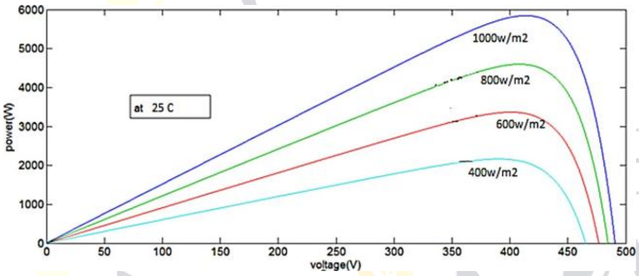


Figure 6 : Variation of P-V curve with solar irradiation

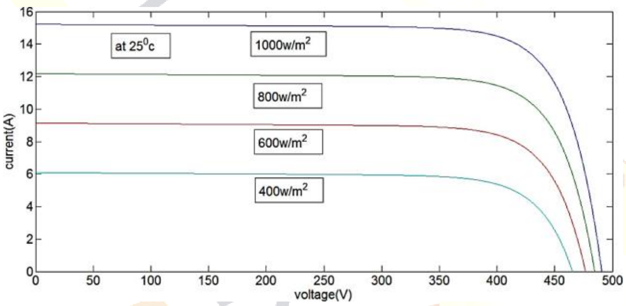


Figure 7 : Variation of I-V curve with solar irradiation.

Effect of Variation of Temperature

On the other hand, the ability of the solar cell to generate power is negatively impacted by an increase in temperature around it. A drop in the open circuit voltage value corresponds with an increase in temperature. An increase in temperature results in an expansion of the material's band gap, necessitating a greater amount of energy to break through this barrier. As a result, the solar cell's efficiency drops [7] and [10].

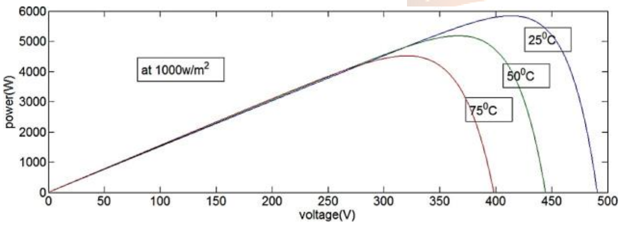


Figure 8: Variation of P-V curve with temperature

Modes of Operation

A boost converter has two modes of operation. They depend on the switch being opened and closed. The charging mode of operation is the initial mode, which is activated when the switch is closed. The second mode of operation is the discharging mode, which occurs while the switch is open.

Charging Mode

In In this mode of operation, the inductor is charged by the source through the switch while the switch is closed. Although the charging current is exponential in nature, it is supposed to change linearly for simplicity's sake [11]. The diode limits the amount of current that may go from the source to the load, and the capacitor discharges to satisfy the load's demand.

Discharging Mode

In In this state of operation, the diode is forward biased and the switch is open [11]. At this point, the inductor discharges, charging the capacitor and satisfying the load demands with the help of the source. The load current fluctuates extremely little and is frequently taken for granted to remain constant during the operation.

IV. RESULT ANALYSIS

Simulation and Results

After modeling the Stand-Alone PV System, the comparative analysis of Maximum Power Point Tracking Algorithms is analyzed. The simulation models for Maximum Power Point Tracking Algorithms are executed with MATLAB/Simulink version R2021A. The simulation results of Maximum Power Point Tracking Algorithms for all the schemes are shown in the following sections.

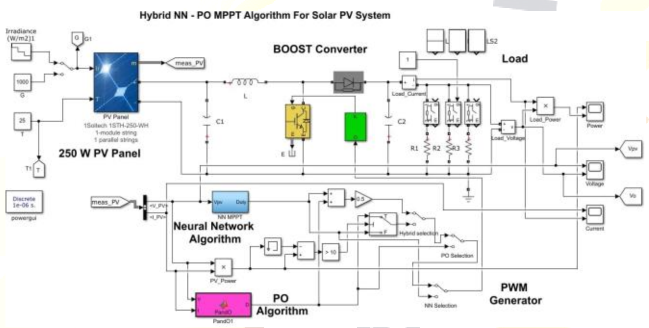
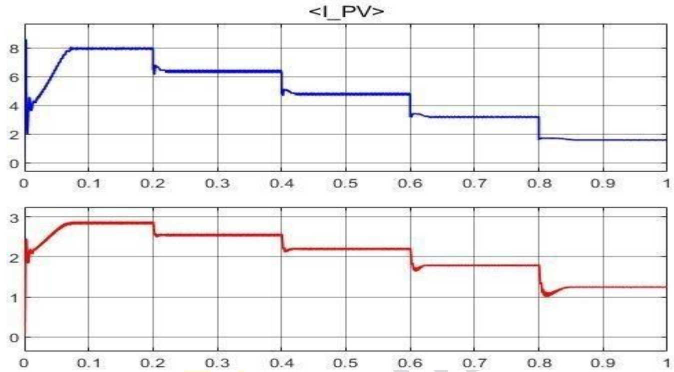


Fig 9: MATLAB/ Simulink Hybrid NN – P&O MPPT Algorithm for Solar PV System

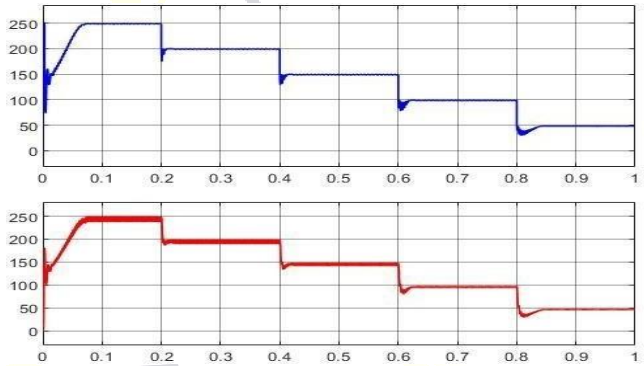
Simulation Results with Different Algorithms

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 (III) NN – P&O. The simulation results for different algorithms under standard condition, 1000 $W/m2$ irradiation and 25ºC temperature are shown in the following figures.

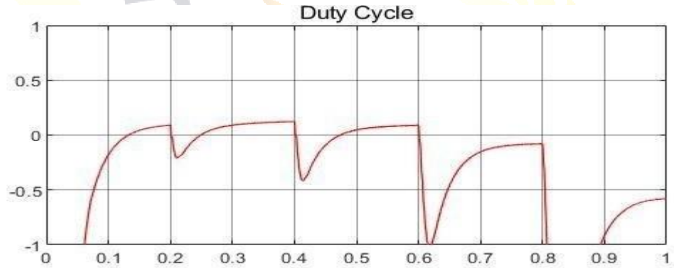
(a).Voltage



(b).Current



(c). Power

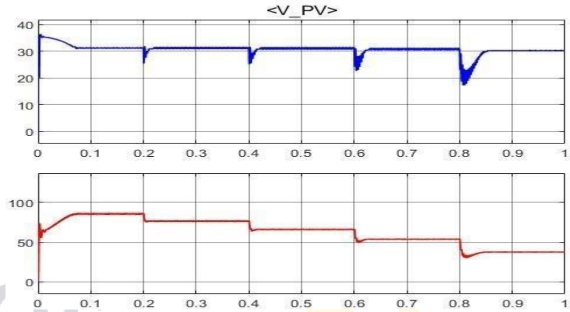


(d). Duty Cycle

Fig 10: PV Output (a) Voltage, (b) Current, (c) Power & (d) Duty Cycle with P&O Method.

V. CONCLUSION

Simulation results for ANN, P&O, and Hybrid NN–P&O methods presented in this thesis show that the Hybrid ANN-P&O controller tracks the Maximum Power Point (MPP) quickly compared to the individual P&O controller and ANN controller. The NN–P&O method is very fast and precise in finding and tracking the MPP in the case of rapidly changing solar irradiation. Furthermore, this method can stably extract the maximum power point under slowly changing solar irradiation, and efficiency is better with the combination of the improved P&O-ANN method. On the other hand, the ANN method can maintain its output voltage close to its maximum power voltage (Vmp) and thus can provide more power than the P and O methods. Again, the ANN technique exhibits better transient response and reaches steady state conditions more



quickly. On the contrary, when irradiation changes fast in a short time, the P & O method fails to track the MPP. Also, this method has high oscillation around MPP under slow changing solar irradiation, which leads to high power loss in the long term.

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