Analyzing and contrasting approaches for maximum power point tracking in photovoltaic systems

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Abstract - This Solar photovoltaic (PV) systems have established themselves as a highly dependable means of harnessing solar energy. The output generated by a solar PV system hinges on two key variables: solar radiation and temperature, both of which experience fluctuations during the day Subsequently, the point on the PV yield qualities bend where greatest power can be separated (MPP) additionally fluctuates. To address this inconstancy, different Greatest Power Point Following (MPPT) techniques are utilized to guarantee the most extreme power is constantly gathered from PV frameworks. This research conducts a comprehensive simulation-based analysis to compare three well-established MPPT algorithms: perturb and observe (P&O), particle swarm optimization (PSO), and an artificial neural network (ANN)-based MPPT approach, which has been implemented using MATLAB Simulink. These MPPT algorithms are instrumental in regulating the duty cycle of a DC-to-DC Boost converter. In evaluating their performance, we assess tracking speed, accuracy, and overall efficiency. Significantly, under challenging conditions characterized by partial shading and rapidly fluctuating irradiance levels, the ANN-based MPPT algorithm exhibits a notably superior capacity for precise and efficient tracking compared to both the PSO and P&O algorithms.

Keywords - Maximum Power Point Tracking ; Photovoltaic ; Particle Swarm Optimization ; Perturb and Observe ; Artificial Neural Network.

I. INTRODUCTION

Is the first paragraph of a written research paper, and it should explain the nature of the previous work.

The world is witnessing Lately, sun oriented photovoltaic (PV) innovation has arisen as an exceptionally practical choice for power age. This rising reception of sun oriented photovoltaics (PV) is driven by the exhaustion of non-renewable energy source assets and the mounting ecological worries related with their use. Power produced by photovoltaic cells is portrayed by its quiet, clean, and low-upkeep activity. The exhibition of PV modules is affected by different elements, including temperature, sunlight based radiation, and concealing circumstances. These modules show nonlinear voltage-current (V-I) qualities, and the most extreme power (Pmax) they can create is addressed by a solitary point on the voltage-power (V-P) trademark bend. In any case, this greatest power point (MPP) is reliant upon the general climate, and befuddles between the source and the heap qualities can prompt diminished power yield. To resolve this issue, Greatest Power Point Following (MPPT) methods are utilized. MPPT advances the activity of PV modules by adjusting their qualities to the heap, in this way limiting power misfortunes [1,2]. The MPPT regulator assumes a pivotal part in this cycle, as it changes the obligation pattern of a DC converter, which goes about as a connection point between the PV modules and the heap. An assortment of MPPT systems can be found in the writing, each custom-made to boost power yield from PV modules across various applications. Normally utilized MPPT strategies incorporate Partial Short out Current (FSCC), Gradual Conductance (IC), and Bother and Notice (P&O). Also, high level delicate processing based MPPT systems have been grown, like Counterfeit Brain Organizations

(ANN), Fluffy Rationale approaches, and Molecule Multitude Improvement (PSO). In this review, we plan to examine three MPPT approaches: PSO, ANN, and P&O, under standard test conditions (STC) and and Under Fast Varying Solar Radiation (FVSR) as well as differing irradiance levels.

II. SYSTEM MODELLING AND SIMULATION

The essential part of a PV cell is a p-n intersection made inside a flimsy semiconductor wafer. Sun powered energy is speedily changed over into power through the photovoltaic impact. The electrical properties of a PV cell are nonlinear and intensely impacted by temperature and sun based light [4-3]. In this review, the single-diode model is chosen for its effortlessness and precision.

This model can be electrically addressed by a comparable to circuit, as displayed in “Fig. 1”, containing a photocurrent source associated in series with a diode, a shunt opposition (Rsh), and a series obstruction (Rs).

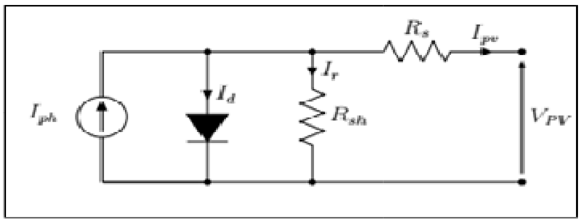

Fig. 1. Equivalent circuit of a PV cell

The relation of the equivalent circuit of the PV system is as follows

$$I_{pv} = I_{ph} - I_d - I_r = I_{ph} - I_0\left(e^{\frac{V_{pv}+R_sI_{pv}}{nV_t}} - 1\right) - \frac{V_{pv}+R_sI_{pv}}{R_{sh}} \quad (1)$$

- I_{pv} : is the cell output current.
- I_{ph} : represents the light-produced current in the cell.
- I_d : is modelled using Shockley formula.
- I_r : is derived current by the shunt resistance.
- I_0 : is reverse saturation current of the diode.
- V_{pv} : is cell output voltage.
- R_s : is cell series parasitic resistance.
- R_{sh} : is cell shunt parasitic resistance.
- V_t : is the thermal voltage.
- n : is diode ideality factor.
- K : is Boltzmann constant $1.3806503\text{x}10^{-23}$J/K
- q : is elementary charge 1.60217646x10-19C
- T : is cell temperature in Kelvin degree.

and

$$V_t = \frac{KT}{q} \quad (2)$$

Displaying photovoltaic cells includes a few key boundaries. These incorporate IpvIpv and IphIph, addressing the cell's result and light-created flows, separately. The Shockley recipe models Id, while Ir is gotten from shunt opposition. I0 implies the converse immersion current of the diode, and Vpv addresses cell yield voltage. Parasitic protections, Rs (series) and Rsh (shunt), influence electrical qualities. Moreover, Vt (warm voltage) and nn (diode ideality factor) assume parts, and actual constants, like the Boltzmann consistent K and rudimentary charge q, are utilized. Cell temperature T is communicated in Kelvin. These boundaries are fundamental for precise displaying and portrayal of photovoltaic cells.

III. MPPT CONTROL FOR PV SYSTEM

A MPPT unit, furnished with a fitting control calculation, is a power transformation framework that empowers the extraction of most extreme power from a PV exhibit. It accomplishes this by changing either the current drawn from the PV cluster or the voltage across it to work at or close to the Greatest Power Point (MPP), subsequently expanding the provided power “Fig. 2”. To upgrade the energy effectiveness of PV clusters, different MPPT calculations, each with various degrees of intricacy, exactness, proficiency, and execution challenges, have been created [5-6-14].

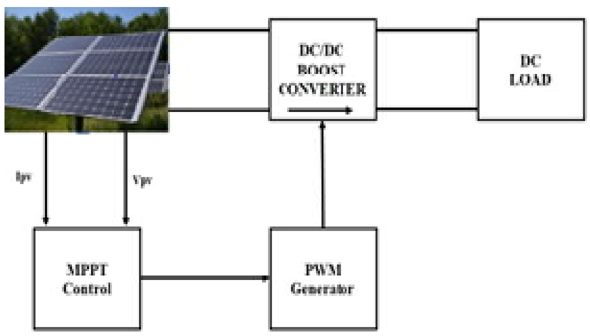

Fig. 2. MPPT Control for PV System.

IV. PERTURB AND OBSERVE ALGORITHM

The P&O-MPPT technique is ordinarily utilized because of its minimal expense, basic design, and negligible estimation necessities [7-8]. “Fig. 3” outlines the P&O technique utilizing a flowchart,

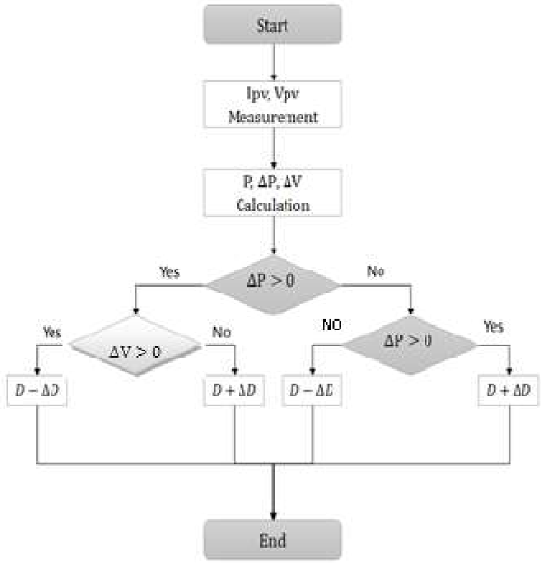

Fig. 1. Flowchart for P&O Algorithm.

V. NEURAL NETWORK-BASED MPPT TECHNIQUE

The ANN-MPPT technique is prepared utilizing MATLAB and the Levenberg-Marquardt strategy. The Levenberg-Marquardt approach empowers the fast and exact goal of nonlinear least squares issues.

We picked the Levenberg-Marquardt strategy for preparing the brain network in light of the exceptionally nonlinear nature of temperature and irradiance impacts on yield power and voltage “Fig. 4”. The development of the brain network-based MPPT for a PV cluster follows the stages illustrated in the accompanying segments [9-10-15] “Fig. 5”.

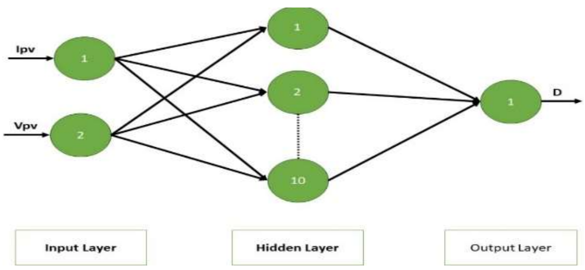

Fig. 4. Neural Network Architecture.

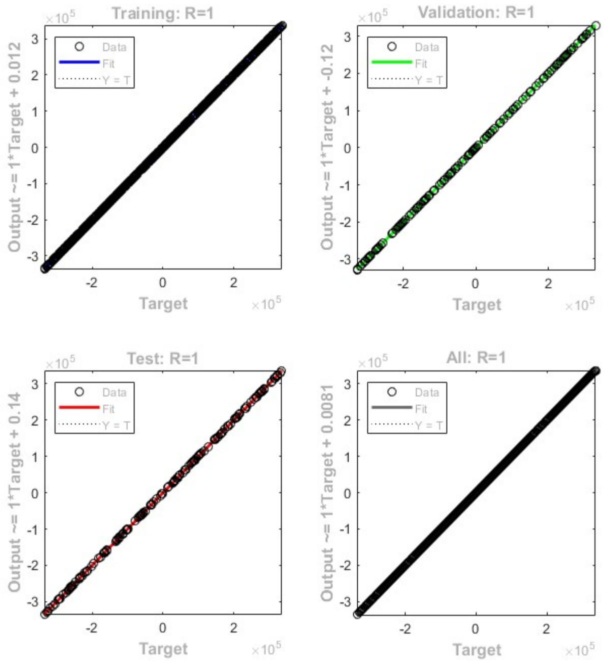

Fig. 5. Neural Network Regression.

VI. PARTICLE SWARM OPTIMIZATION (PSO)

The PSO-MPPT strategy depends on the way of behaving of groups of birds and includes a multi-layered multitude of particles, where every molecule addresses an answer. These particles constantly change their situations to find the ideal area in view of their previous encounters and communications with adjoining particles. The place of every molecule is impacted by both the best-performing molecule in its area (Pbest_i) and the best arrangement tracked down by the whole populace of particles (Gbest) [12].

To accomplish this, every molecule's development is constrained by changing its speed, which is expanded or diminished in view of the correlation between its ongoing position esteem and the best worth. Assuming that the ongoing position is sub-par compared to the best worth, the speed increments, as well as the other way around.

The molecule's situation (xi) is altered by the accompanying condition [13],

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (3)$$

Where (vi) represents the velocity and is obtained as follows,

$$v_i^{k+1} = wv_i^k + c_1 r_1\{P_{best\,i} - x_i^k\} + c_2 r_2\{G_{best} - x_i^k\} \quad (4)$$

With c_1 and c_2 are acceleration coefficients, w denotes the inertia weight, and r_1, r_2 are random values drawn from the uniform distribution U. "Fig. 6" illustrates the PSO flowch.

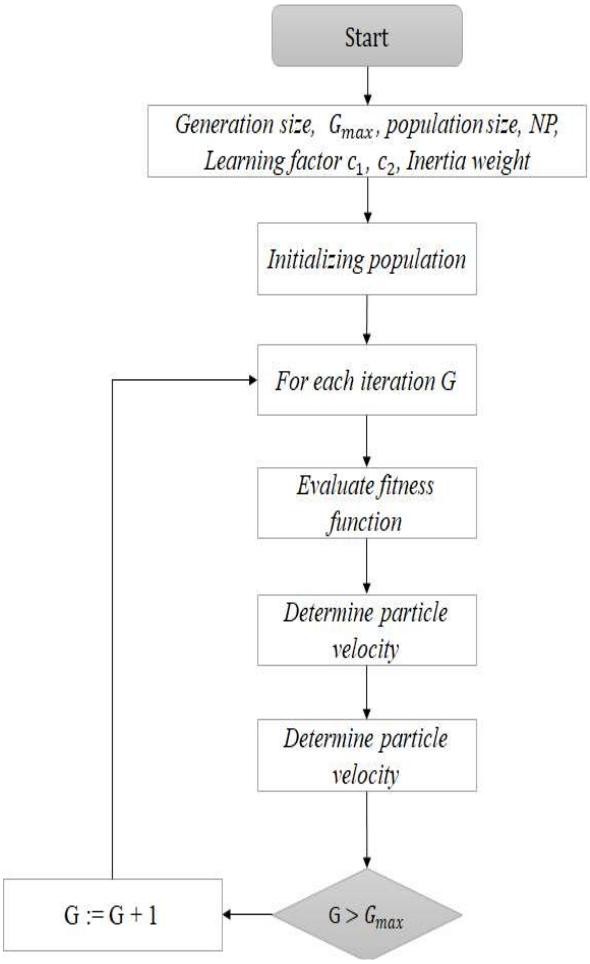

Fig. 6. Flowchart for PSO Algorithm.

VII. SIMULATION RESULTS

The simulation results demonstrate the effectiveness of the three MPPT algorithms in tracking the MPP of the PV system under various operating conditions. The P&O algorithm, while simple to implement, exhibits a relatively slow tracking speed and can suffer from oscillations near the MPP. The PSO algorithm, on the other hand, offers faster convergence and better accuracy but requires more computational resources. The ANN-based MPPT algorithm, trained on a dataset of PV system behavior under different irradiance and temperature conditions, consistently outperforms both the P&O and PSO algorithms in terms of tracking speed, accuracy, and efficiency. It is particularly effective in handling dynamic changes in irradiance, such as those caused by partial shading or rapid fluctuations. The ANN-based MPPT algorithm is therefore a promising candidate for maximizing power extraction from PV systems, especially in challenging environments.

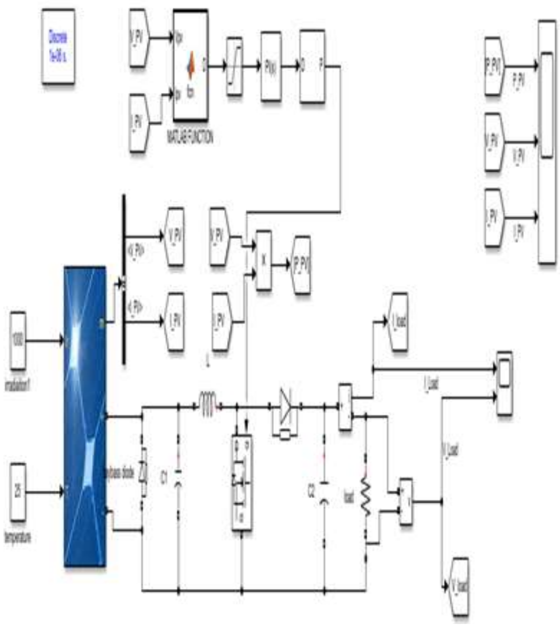

Fig. 7. Model of PV array with boost converter in Simulink.

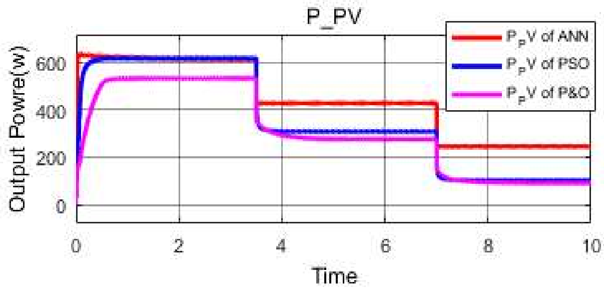

Fig. 8. Comparison of P_PV from PSO, ANN and P&O.

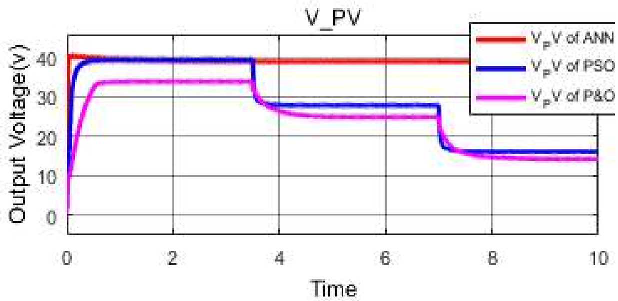

Fig. 9. Comparison of V_PV from PSO, ANN and P&O.

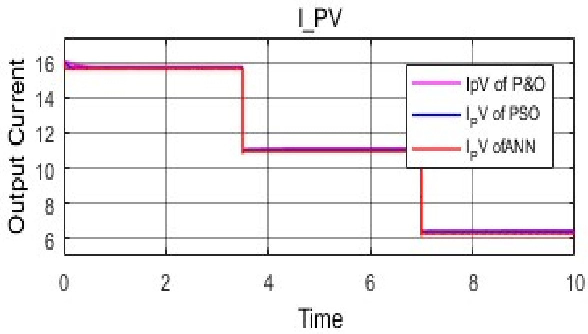

Fig. 10. Comparison of I_PV from PSO, ANN and P&O.

VIII. DISCUSSION AND RESULTS

Under the two accompanying scenarios, a comparison of the three MPPT (P&O, PSO, and ANN) techniques has been conducted. (i) Standard Test Conditions (ii) Radiation based on sunlight that changes quickly. “Fig. 7” shows the MATLAB Simulink model for the intended framework. They consider the MPPT computations depending on the velocity that follows

A) Standard Test Condition (STC)

At STC, the cluster yield power is estimated to be 600 W. The surrounding temperature is 25 oC and the radiation level is 1000 W/m2. “Fig. 8” illustrates the power yield correlation of the three MPPT techniques at STC. It can be observed that P&O, PSO, and ANN MPPT computations follow the MPP in around 0.5 s, 0.2 s, and 0.035 s, respectively.

In this scenario, the ANN's time reaction outperforms the subsequent two techniques. The PSO approach allows for a margin of error for MPP to be followed with comparable efficacy to the other two procedures.

B) Fast Varying Solar Radiation (FVSR)

PV clusters receive fast changing radiation as a stage signal. In this case, the temperature was set at 25 0C, but the radiation on the four series-related PV modules is distinct, measuring 1000, 700, and 400 W/m2. “Fig. 8” presents the response of the three MPPT calculations in terms of power result to this rapidly varying radiation.

It is discovered that the P&O computation monitors the MPP the quickest (0.5s) from 0 to 3s of reproduction. Here the MPP is tracked by the PSO in 0.2s and the ANN in 0.035s. When the sun's irradiance unexpectedly changes (at 3 s), the P&O records the new MPP in 0.05 s.PSO and ANN require 0.11 seconds to follow the MPP, and“Fig. 9” and “Fig. 10” represents respectively output PV voltage and current of ANN, PSO and P&O MPPT computations.

IX. CONCLUSION

In conclusion, this paper has introduced and compared two distinct Maximum Power Point Tracking (MPPT) techniques, namely an ANN-based approach and a PSO-based method, both aimed at optimizing the power output of photovoltaic energy conversion systems under varying atmospheric conditions.

These techniques have been rigorously evaluated and compared against the traditional Bother and Notice (P&O) strategy.

Using the ANN algorithm, we achieved faster convergence to the maximum point compared to the PSO and P&O methods. Furthermore, the ANN algorithm demonstrated minimal fluctuation at steady state, resulting in significant power savings.

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