iJournals: International Journal of Software & Hardware Research in Engineering
ISSN:2347-4890, ijournals.in/ijshre
Volume 12 Issue 3, March 2024

Comparative Study of Conventional P&O And Intelligent ANFIS Based MPPT For Grid-Connected PV System

Authors: Anjali Yadav[1]; Imran Khan[2]; Malik Rafi[3]

Department of Electrical Engineering, Azad Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India[1,2]; RR Institute of Modern Technology, Lucknow[3]

Email: njaliyadav199511@gmail.com[1]; pe.imran@gmail.com[2]; malik_rafi@rediffmail.com[3]

***Abstract*- In the last decade, artificial intelligence (AI) based techniques have been extensively used to track maximum power point (MPP) in solar as well as in other power systems too. This is so because conventional MPPT techniques are incapable of tracking global maximum power point. MPPT algorithms are necessary because PV arrays have a non-linear voltage-current characteristics with a unique point where power produced is at its maximum. AI based MPPT technique exhibits fast convergence speed, less steady-state oscillation and high efficiency when compared with the conventional MPPT techniques. MATLAB/Simulink model for PV system is used to simulate the Perturb and Observe (P&O) and ANFIS MPPT methods. The result shows that the AI based MPPT accurately tracks the maximum power point.**

***Keywords*- Maximum Power Point Tracking (MPPT), Artificial Intelligence (AI), Perturb and Observe (P&O)**

I. INTRODUCTION

We are living in the era of high-tech civilization, and every civilization needs energy for its development, so effective utilization of our resources is essential. Global energy consumption is burgeoning global energy production due to increased industrialization, population growth and advanced lifestyle. According to the International Energy Agency (IEA), there will be an increase in global energy consumption by 44% till the year 2030. The global energy crunch has provided a renewed impetus to the growth and development of Clean and Renewable Energy sources. There are lots of non-conventional energy sources like solar energy, ocean energy, biomass, wind energy etc. Our primary focus is on solar energy.

Research during the last decade has focused primarily on developing clean and sustainable energy sources such as solar, wind, hydro, biomass…etc. Photovoltaic (PV) system is the most promising energy generation system because it is clean, pollution free and freely available to everyone also because of its low operational and maintenance cost, and high availability [1]. Moreover, it converts the sunlight directly into electricity through the photovoltaic effect without creating any noise or environmental harm [2].

PV applications can be divided into two combinations: stand-alone and grid-connected energy systems. Stand-alone energy systems require a battery bank to store the PV energy; this is felicitous for low power applications. Moreover, grid-connected PV energy systems do not require battery banks; they are restored usually in high-power applications

Despite the advantage of abundance, the output active power P from solar power system varies according to the solar irradiance E_E and temperature T due to non-linear characteristics of PV cell. To overcome the aforementioned limitation, maximum power point tracking (MPPT) becomes the research focus to improve the η of the solar power system and ensure that the operation point is always at maximum power point (MPP).

The existing AI-based MPPT technique utilize the sensory information including solar irradiance E_E, input voltage of solar power system $V_{I,PV}$, and input current $I_{I,PV}$ measurements to prognosticate the GMPP throughout the non-linear P-V curve. The amalgamation of AI in MPPT accelerates the convergence speed and transient response because of their complex, robust, self-learning and digitalized system.

The primary function of MPPT is to obtain the highest possible output power from the PV module under varying radiation and temperature conditions. MPPT that is based on AI is known as computational intelligence (CI) based MPPT, soft-computing MPPT, modern MPPT or bio-inspired MPPT. It mainly consists of fuzzy logic control (FLC), artificial neural network (ANN), fuzzy inference system (ANFIS), genetic algorithm (GA) and hybrid algorithms. Conventional MPPT techniques consist of Perturb and Observe (P&O), Incremental Conductance(IC), Hill Climb (HC), Fibonacci searching, GMPPT segmental searching and extremum seeking control.

In this paper a comparative study has been carried out between AI based ANFIS MPPT and conventional P&O MPPT.

II. PV MODELLING

Solar cells are made up of semiconductor element. Various photovoltaic cells are combined together to form a PV array through series and parallel connections. In order to increase voltage, series connections are responsible, while parallel connections are responsible for increasing current. The ability of PV system to produce power is contingent on solar temperature and irradiation intensity. When the radiation from the sun penetrates the surface of the PV cells, a direct current flows through the photovoltaic panels. The equivalent circuit is shown in Figure 1.It consists of a current source in parallel to a diode, series resistance which describes the losses related to the contact resistance and a shunt resistance which represents the losses due to the leakage current to the ground.

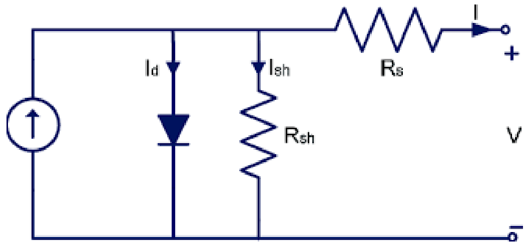

Fig. 1. Electrical model of PV cell

The output current of the PV could be gotten from Kirchhoff's law as presented in [5]

$$I = I_{ph} - I_d - I_{sh}$$

Where I represents the cell current, I_{ph} is the photocurrent, I_d is the diode current, I_{sh} is the parallel current.

Therefore, the relationship between I_{PV} and V_{PV} can be written as,

$$I = I_{ph} - I_0.\left(e^{\frac{q(V_{PV}+R_S I_{PV})}{nKT}} - 1\right) - \frac{V_{PV} + R_s I_{PV}}{R_{sh}}$$

Where I_0 is the reverse current of saturation (A), I_{ph} is the photocurrent of the module, I_{PV} is the current of the module, V_{PV} is the voltage of the module, K is the Boltzmann's constant($1.38 \times 10^{-23} J/K$,q is the elementary charge of electron($1.6 \times 10^{-19} C$), n is ideality factor of p-n junction and T is the temperature of PV cell (K), R_s is the series resistance of the cell (Ω) and R_{sh} is the shunt resistance of the cell(Ω).

However, the power at maximum power point (Pmax) is given by:

$$P_{max} = V_m I_m$$

$$P_{max} = V_m \left(I_{ph} - I_0.\left(e^{\frac{q(V_{PV}+R_S I_{PV})}{nKT}} - 1\right) - \frac{V_{PV} + R_s I_{PV}}{R_{sh}}\right)$$

Efficiency of the system can be given as:

$$\eta = \frac{P_o}{P_{in}} = \frac{V_m I_m}{L.A} = \frac{V_m I_m}{L_i \cos\theta . A}$$

III. MAXIMUM POWER POINT TRACKING (MPPT)

As presented in figures 2 and 3, there is only a single point on the P-V characteristic of the PV module where the power is at its maximum value, which is known as maximum power point (MPP). The meteorological conditions influence the position of this point: power increases as irradiation increases. The MPPT techniques are highly important to guarantee the functions of PV module at the MPP in various weather conditions. In the following subsections, ANFIS and P&O techniques are detailed as these are the purpose of this study.

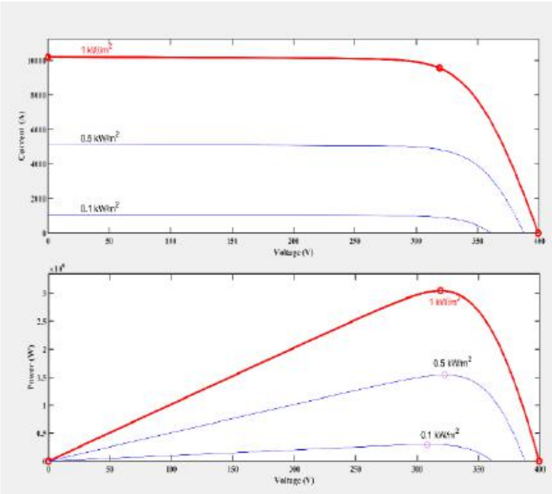

Fig. 2. The PV array at 25 °C and the specified irradiance

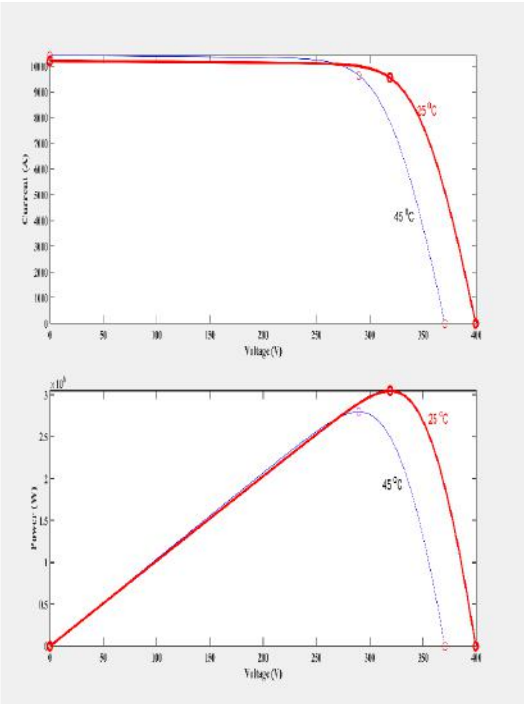

Fig. 3. The PV array at 1000 w/m² and the specified temperature

3.1 Perturb and Observe (P&O) technique

P&O technique is the most widely used technique because of its simplicity and effectiveness. The flowchart of P&O technique is shown in figure 4. The basic principle of this method is perturbing (incrementing or decrementing) the array terminal voltage during every iteration and visually examine the effect of this perturbation on the PV output power then compares it with the previously iterated value.If the power increases, the perturbation will keep in the same direction, otherwise the perturbation is reversed. When the maximum power point (MPP) is achieved, the operating point starts to oscillate around the MPP.

However, P&O method has few drawbacks such as:

- The increase of the power losses as a result of the oscillation around the MPP in the steady state condition.
- During a step change condition in the irradiation level, the P&O algorithm is underrated and slow.
- Besides the high number of iterations, this method requires to measure the current and the voltage in each stage, this strongly affects the efficiency of (P&O) algorithm and leads to more losses in power.

The P&O method is based on the modification of the trip ratio or duty cycle (D) of the boost converter that modifies the value of the current supplied by the photovoltaic panel. A positive gradient (dP/dV) means the actual point is located on the left of the MPP. A negative gradient means the point is on the right side of the power curve. This tracking is repeated several times until the point where dP/dV is zero, which is the tracked MPP for the PV module

$$P(k) = V(k) \times I(k)$$

$$\Delta P = P(k) - P(k-1)$$

$$\Delta V = V(k) - V(k-1)$$

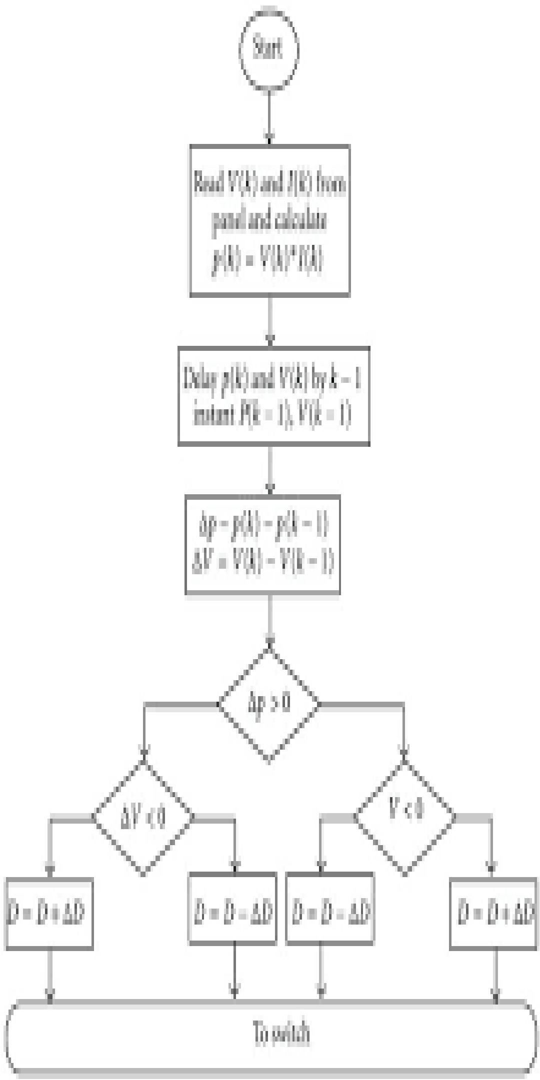

Figure.4. Flowchart of P&O MPPT

3.2 ADAPTIVE NETWORK FUZZY INFERENCE SYSTEM(ANFIS) BASED MPPT

The adaptive network-based fuzzy inference system (ANFIS) is a block that groups the neural network and fuzzy logic. The ANN is used to reduce the tracking error and parameter optimization, while the FLC is used to control nonlinear inputs without necessarily needing any prior knowledge of the system from the input data the fuzzy rules are formed, and the first fuzzy model is established, then the neural network is used to refine the rules of the fuzzy first model that has been designed.ANN helps to easily tune the membership function and rule table [c, d]

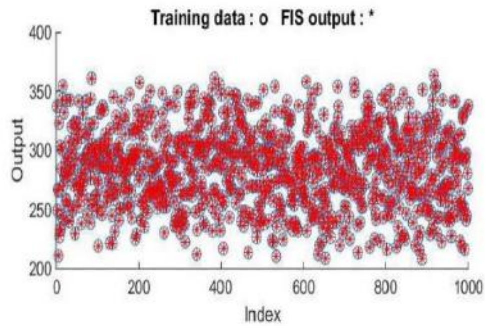

Figure.5. ANFIS trained data

A. ANFIS architecture

The ANFIS architecture is illustrated in fig,6.

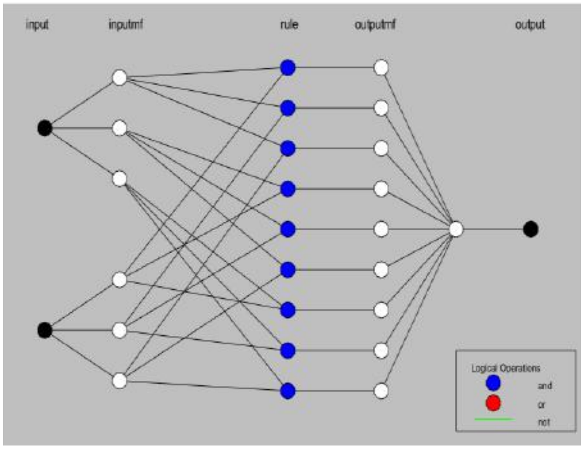

Figure.6. ANFIS Architecture

The ANFIS block has two inputs and an output. The rules are formed based on if-then model Takagi and Sugeno's [3]. For a first order two rule sugeno fuzzy inference system, the two rules may be stated as:

Rule 1: If x is A_1 and y is b_1, then $f_1 = p_1x + q_1y + r_1$.

Rule 2: If x is A_2 and y is B_22, then $f_2 = p_2x + q_2y + r_2$.

The description of ANFIS layers is given below,

Layer 1: Each node of this layer is adaptive the output is given by:

$$\theta_i^1 = \mu_{Ai}(x) \qquad (1)$$

Where, the input of node I is X, the associated linguistic variable is Ai and μ_{Ai} is the membership function of Ai, $\mu_{Ai}(x)$ is given below:

$$\mu_{Ai}(x) = \exp\left\{-\left(\frac{x-c_i}{a_i}\right)^2\right\} \qquad (2)$$

Layer 2: The nodes are fixed nodes denoted as II. The outputs of this layer can be symbolized as.

$$\theta_i^2 = \omega_i = \mu_{Ai}(x) * \mu_{Bi}(y),\ i=1,2$$

Layer 3: The nodes are too fixed nodes. They are categorized with N, indicating that they play a normalization role to the firing strengths from the preceding layer. The output from the ith node is the normalized firing strength given by:

$$\theta_i^3 = \overline{\omega_i} = \frac{\omega_i}{\omega_1 + \omega_2} \qquad (4)$$

Layer 4: The nodes are adaptive nodes. The output of each node in this layer is simply the product of the normalized firing strength and a first order polynomial. Thus, the outputs of this layer are given by:

$$\theta_i^4 = \overline{\omega_i}\, f_i = \overline{\omega_i}(p_i\, x + q_i\, y + r_i) \qquad (5)$$

Layer 5: There is only solitary fixed node characterized with $\sum$. This node performs the summation of all entering signals. Henceforth, the general output of the model is given by:

$$\theta_i^5 = overall - output = \sum_i \overline{\omega_i}\, f_i = \frac{\sum_i \overline{\omega_i}\, f_i}{\sum_i \overline{\omega_i}}$$

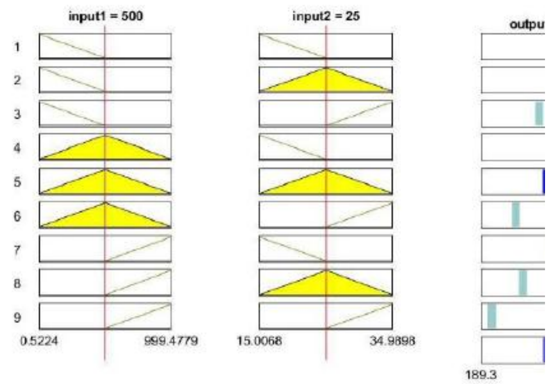

Figure.7. Rule base of ANFIS

(V) Results and Parameters

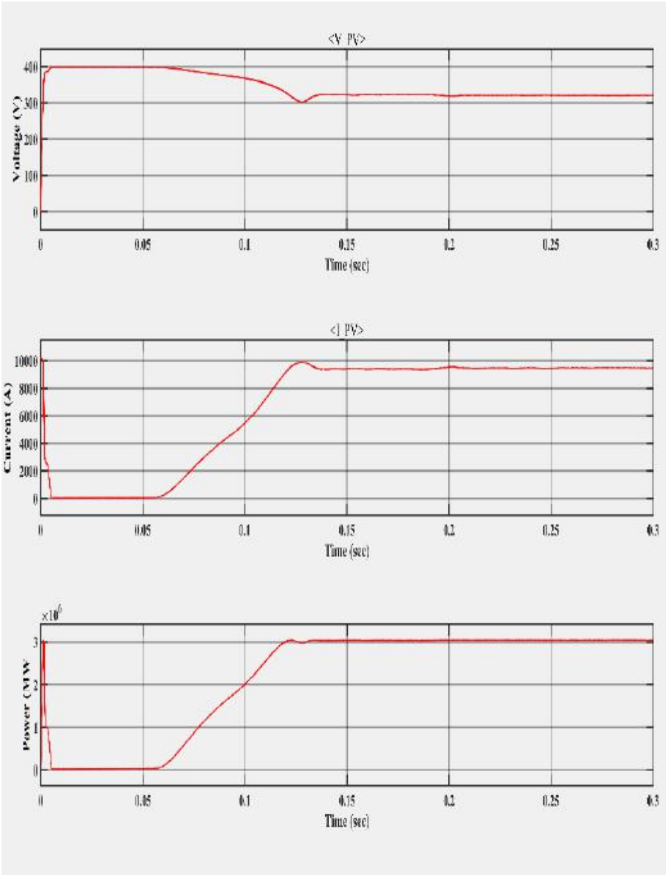

Figure 8. Voltage, Current and Power variation of the PV system using P&O MPPT

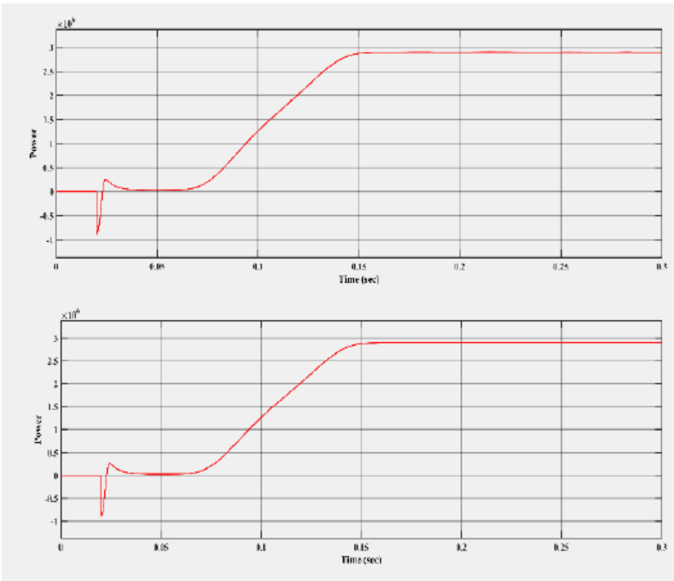

Figure 9. Grid and Inverter Power using P&O MPPT

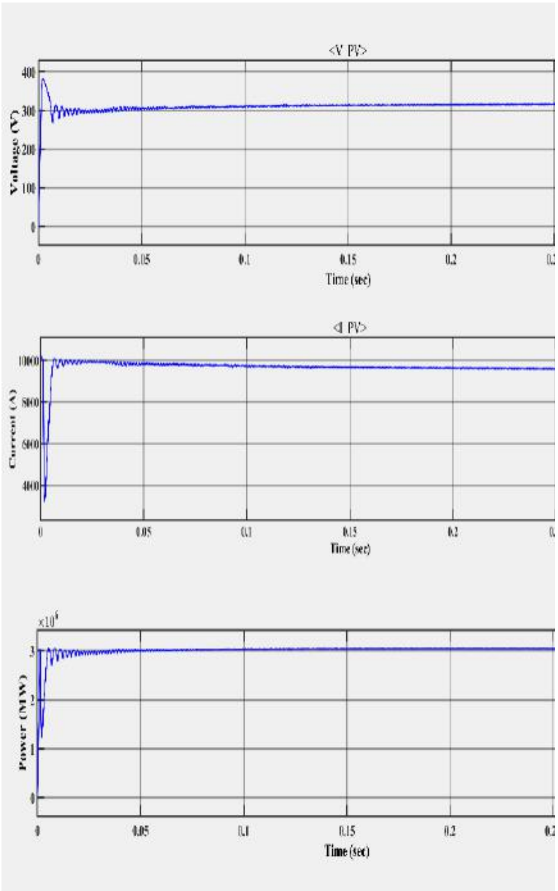

Figure 10. Voltage, Current and Power variation of the PV system using ANFIS MPPT

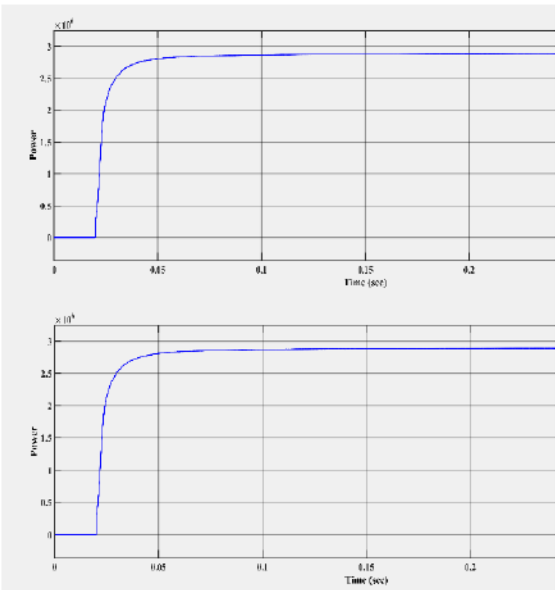

Figure 11. Grid and Inverter Power using P&O MPPT

Conclusion

This paper presents a grid-connected PV system. Also, the MPPT techniques are implemented using Adaptive neuro-fuzzy inference system (ANFIS) and perturb and observe (P&O) with boost converter topology. Simulation results with MATLAB/Simulink program show the power generated by P&O and ANFIS MPPT. ANFIS algorithm tracks rapidly changing irradiation conditions more accurately than P&O method. In P&O method, the voltage never actually reaches an exact value but perturbs around the MPP. So, the ANFIS method reaches the MPP faster and better than P&O because of not have drifting problem and it was the most efficient, at rapidly changing conditions.

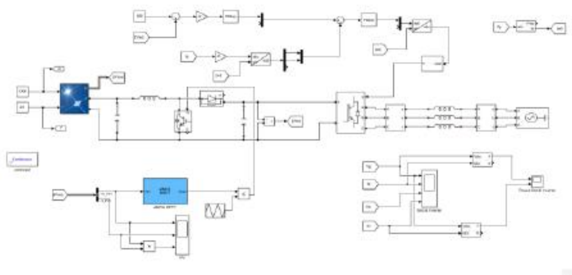

Figure 12. PV system using ANFIS MPPT

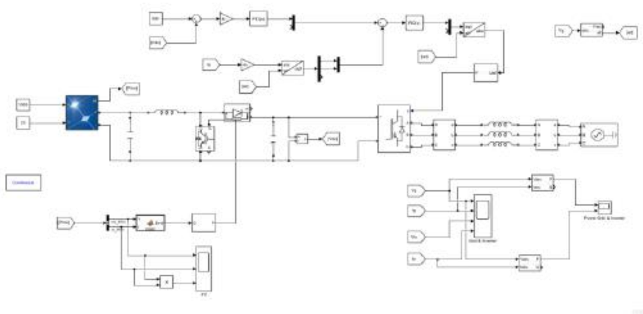

Figure 12. PV system using P&O MPPT

References

[1] D. Mills, “Advances in solar thermal electricity technology,” Sol. energy, vol. 76, no. 1-3, pp. 19-31, 2004, Doi: 10.1016/S0038-092X(03)00102-6.

[2] A. M. Noman, K. E. Addoweesh, and A. I. Alolah, “Simulation and practical implementation of ANFIS-based MPPT method for PV applications using isolated Ćuk converter,” International Journal of

Photoenergy, vol. 2017, Article ID 3106734, 15 pages, 2017

[3] R. K. Kharb, M. F. Ansari, and S. L. Shimi, "Design and implementation of ANFIS based MPPT scheme with open loop boost converter for solar PV module," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 3, no. 1, pp. 6517–6524, 2014.

[4] J. L. Agorreta, M. Borrega, J. López, and L. Marroyo, "Modeling and control of $ N $-paralleled grid-connected inverters with LCL filter coupled due to grid impedance in PV plants," IEEE Transactions on Power Electronics, vol. 26, no. 3, pp. 770-785, 2010, Doi: 10.1109/TPEL.2010.2095429.

[5] T. T. Marnoto, K. K. Sopian, W. R. Wan Daud, A. M. Algoul, and A. A. Zaharim, "Mathematical model for determining the performance characteristics of multi-crystalline photovoltaic modules," Proceedings of the 9th WSEAS international conference on Mathematical and computational methods in science and engineering, 2007, pp. 79-84.

[6]S. R. Revathy,1 V. Kirubakaran ,1 M. Rajeshwaran,2 T. Balasundaram,3 V. S. Chandra Sekar,4 Saad Alghamdi, 5 Bodour S. Rajab,5 Ahmad O. Babalghith,6 and Endalkachew MergiaAnbese, "Design and Analysis of ANFIS – Based MPPT Method for Solar Photovoltaic Applications," Hindawi International Journal of Photoenergy Volume 2022, Article ID 9625564, 9 pages, doi:10.1155/2022/9625564

[7] A. S. Mahdi, A. K. Mahamad, S. Saon, T. Tuwoso · Hakkun Elmunsyah, S. W. Mudjanarko, "Maximum power point tracking using perturb and observe, fuzzy logic and ANFIS," SN Applied Sciences (2020) Doi/10.1007/s42452-019-1886-1