An Overview of MPPT for Photovoltaic Panels Using Various Artificial Intelligence Techniques

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Abstract- *One of the most crucial demands for those in the display are power. Solar energy conversion not only promotes the electric age but also lessens pollution from fossil fuels. The generation of PV control has proven to have a crucial potential for supplying the energy need. The PV module's efficiency and lifespan are increased by the MPPT. This document provides a thorough discussion of the PV system as well as several intelligence techniques. There is also a summary of how artificial intelligence methods and PV systems are combined and applied in a much more effective way.*

Key words: Artificial neural network, fuzzy logic, Genetic calculations Maximum power point tracking, Photovoltaic

1. INTRODUCTION

Power is one of the most important needs for people in the display. The conversion of solar energy into power not only advances the power era, but it also reduces pollution caused by fossil fuels. [1] The continuous rise in the level of nursery gas outflows and fuel costs is the most compelling reason for the Endeavour to use various sources of renewable vitality. Among various sustainable energy sources, solar energy may be an appropriate one because it is clean, free of emanation, and simple to convert specifically to power using a photovoltaic (PV) framework. The generation of PV control has demonstrated a critical potential in meeting the demand for energy. [2] However, widespread use of a PV framework is uncommon because of its high initial cost. Again, there is no proof that the vitality conveyed by PV exhibits consistent yield because it is entirely dependent on the sun's irradiance and the surrounding temperature of the PV modules, cell locale, and stack. An appropriate instrument is required for achieving maximum control from the PV cell under favorable climatic conditions, which is referred to as maximum control point tracking (MPPT) in the writing. The MPPT improves the efficiency and lifespan of the PV module. Sun-oriented irradiance, temperature, and stack impedance all affect how much a sun-based board will yield. In order to advance the operation of the sun-based board, a dc-dc converter is used because the stack impedance varies on the application. The temperature and irradiance dependent on the sun are dynamic. [1] Since each existing MPPT approach has distinct key focuses and downsides, choosing a specific MPPT system from among them might be a confusing task.[2]

The mechanical following device can be used with MPPT, however the control system modifies the electrical working point of the PV modules to provide optimal efficiency and, consequently, optimal yield. MPPT calculations are used to infer the whole control from the sun-based cluster based on contrasts in temperature and illumination. The voltage at which a PV module can produce the best control is its highest control point. The charge controller was used to accommodate the changing voltage and current. The charge controller continues because it is continually modifying the stack when it isn't, removing control from the PV module. The MPPT calculates the best operating point for supplying the most extreme sum of control to the stack and regulates the yield voltage and current of the solar-powered panel. The efficiency of the sun-oriented cell will increase if the MPPT adaptation can precisely regulate the continuously changing operating point where the greatest amount of control is available.

2. PHOTOVOLTAIC

It was suggested that a typical grid-connected PV framework consist essentially of the boost converter, inverter, and PV module Figure 1 depicts the configuration of the PV framework with a lattice-related boost converter, a DC-AC inverter, and a network interface for the PV board. In such a framework, the voltage and current from the sun-oriented board are sent into the boost converter and MPPT controller; the main goal is to force the PV board to get a desired voltage that ensures the largest control yield, known as MPP voltage. According to the electrical diagram, the DC-DC converter and PV board can be viewed as a single unit that needs to be managed to eliminate unpleasant factors like stack and irradiance. Over time, the control is reduced, with lower temperatures offering the most control. Furthermore, it should be noted that when a PV module is explicitly linked to a stack, the stack impedance determines the PV module's operational state and, in an ideal stack, enables the PV module to obtain the most control. [3]

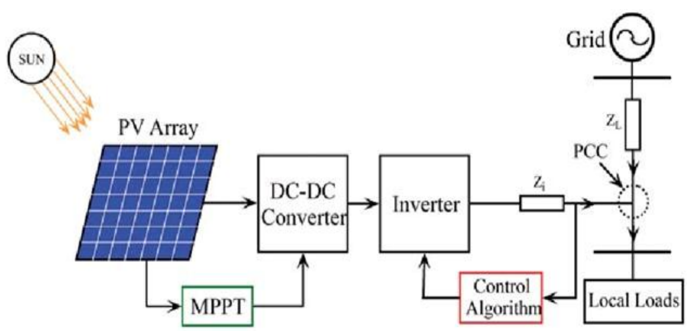

Figure-1-Block diagram of photovoltaic

2.1 System Configuration

2.1.1 PV panel

The corresponding solar cell circuit is shown in Figure-2 with the intrinsic shunt and series resistances represented by Rsh and Rs, respectively, and the output current and voltage of the solar array, Ipv and Vpv, respectively. By using Rsh and Rs, which are very huge and very little, the electrical model is made simpler.

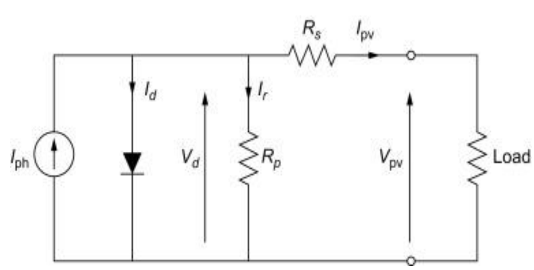

Figure-2 Simplified equivalent circuit of PV cell

The output current □□□ is

$$□□□ = □□h − □□ [\exp (\frac{qVpv}{kbT\ A}) − 1] \qquad (1)$$

The photo-current can be expressed by

$$□□h = (\frac{G}{Gn}) [□□□□ + (□ − □□)] \qquad (2)$$

The expression of the saturation current is given by

$$□□ = □□□ [\frac{T}{Tr}]^3 \exp [\frac{q}{kbT\ A} (\frac{1}{Tr} − \frac{1}{T})] \qquad (3)$$

Where

I_d: saturation current (A)

T: cell temperature (K)

T_r: reference temperature (K)

□$_{rr}$: saturation current at □□

G: solar irradiance (W/□2)

G_n: reference irradiation (W/□2)

□□□□: short-circuit current at reference condition

k_i : short-circuit temperature coefficient

k_b: □□□□□□□□′ □ constant

q: electron’s charge

A: ideality factor

2.1.2 DC-DC converter

As a DC-DC power converter, we use a boost converter. In Fig. 3, its circuit topology is displayed. where i_L is the inductor current, V_{pv} is the input voltage, and V_s is the output voltage We assume that the PV current and inductor current are equivalent. Convertor load, inductor, input capacitor, and output capacitor, respectively, are the passive components R, L.

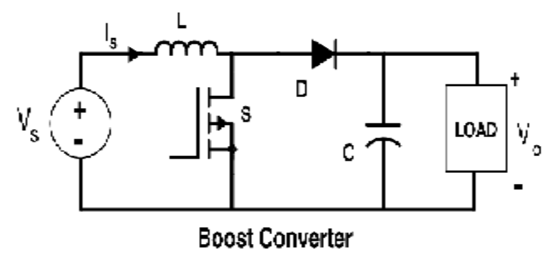

Figure 3-Boost converter

3. MPPT CONTROL TECHNIQUES

The power output's characteristic of the PV system is nonlinear and crucially influenced by solar irradiation and temperature. Therefore, the PV systems operating point must change so that the produced energy is maximized.

3.1Fractional Open-Circuit Voltage (FOCV)

This algorithm is based on the relation between the maximum power point voltage □□□□ and the open circuit voltage □□□. The maximum power point voltage □□□□ is always a constant fraction of the open circuit voltage □□□ as it is given by Eq.4.

□□□□ = □□.□□□ (4)

The constant fraction □□ is between 0.7 and 0.8. □□□ is measured and used as in input to the controller. FOCV needs measurements of □□□. So, it is necessary to introduce a static switch into the PV array. The switch must be connected in series to open the circuit. In this method, □□□ is needed for the PI regulator

3.2 Fractional Short-Circuit Current (FSCC)

The Fractional Short-Circuit Current (FSCC) method is based on the proportionality between the optimum operating current □□□□ and the short circuit current □□□. Eq.(5) shows that □□□□ can be determined instantaneously by detecting

□□□. □□□□ = □□.□□□ (5)

where □□ is the constant factor.

This technique requires measurements of the short circuit current □□□. It is essential to introduce a static switch in parallel with the PV array to get this measurement so that the shortcircuit's condition is generated. When □□□ = 0, there is no supplied power by the PV system. As a result, no energy is generated. As mentioned in the previous technique, the PV voltage measurement's is required for the PI regulator.

3.3 Perturb and Observe (P&O)

The application of Perturb and Observe (P&O) algorithm has been widely used since it is an easy one to be implemented. This algorithm perturbs the operating voltage to ensure maximum power. The basic flow chart of P&O algorithm is shown in Fig.4.

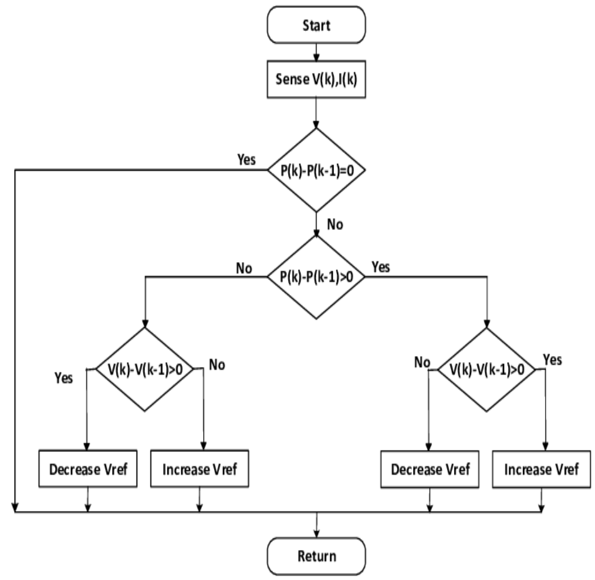

Figure. 4. Basic Perturb and Observe Algorithm

The P&O technique compares the power of the previous step and the new step so that it increases or decreases the voltage or current. Operating on the left of the MPP, it is noticeable that incrementing (decrementing) the voltage allows to increase (decrease) the power and decrease (increase) the power when on the right of the MPP. The perturbation is kept the same to reach the MPP when there is an increase in power and vice-versa. P&O has a good behavior when the irradiance does not change quickly with time. However, the power oscillates around the MPP in steady state operation and it fails with variations of temperature and irradiance.

3.4. Incremental Conductance method (IC)

The Incremental Conductance (IC) algorithm, explained by the flow chart given by Fig.5, compares the incremental and instantaneous array conductance ($\frac{dI}{dV}$ and $\frac{I}{V}$ respectively) in a PV system. Depending on the result, it increases or decreases the voltage until MPP is reached.

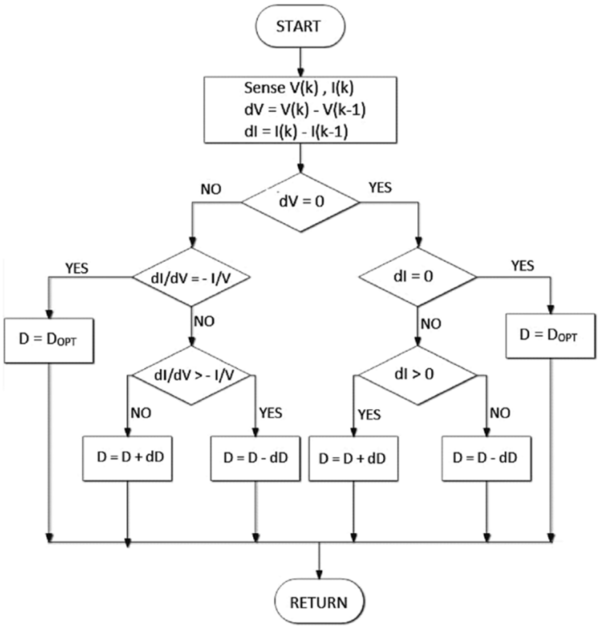

Figure 5-Basic Incremental Conductance Algorithm

- when $\frac{\partial P}{\partial V} < 0$ $(\frac{\partial I}{\partial V} < \frac{I}{V})$, decreasing the reference voltage forces ∂� ∂� to approach zero;
- when $\frac{\partial P}{\partial V} > 0$ $(\frac{\partial I}{\partial V} > \frac{I}{V})$, increasing the reference voltage forces ∂� ∂� to approach zero;
- when $\frac{\partial P}{\partial V} = 0$ $(\frac{\partial I}{\partial V} = \frac{I}{V})$, reference voltage does not need any change.

Contrary to P&O, the PV voltage remains constant once the MPP is reached. This technique decreases the oscillations problem and it is easy to be implemented.

3.4. Sliding Mode Control (SMC)

Sliding mode control (SMC) is known as a robust control technique and it is appropriate for controlling switched systems. For PV system, the switching surface is chosen as [4]

$$(�,�)=\frac{\partial Ipv}{\partial Vpv}+\frac{Ipv}{Vpv} \quad (6)$$

4. DIFFERENT ARTIFICIAL INTELLIGENCE TECHNIQUE

4.1 Artificial neural network

The science behind brain organization, which plays a crucial role in the human body, is essentially where the idea of an artificial neural network (ANN) is given. The neural network of the human body is used to carry out work. A neural network is essentially a web of millions of neurons that are connected to one another. With the help of these connected neurons, all parallel processing wears out the human body, making it the best example of parallel processing. A neuron is a rare organic cell that transmits information from one neuron to another with the help of some electrical and chemical changes. It consists of a cell body, or soma, and the axon and dendrites, two different types of outgrowths that resemble tree branches. The cell body is made up of a core that carries information about innate traits and plasma that houses the atomic materials or building blocks needed by the neurons. A neuron receives signals from other neuron through dendrites, which is one method in which the entire process of accepting and delivering signals is organized. The axon is a long, slender structure that the neuron uses to transfer electrical messages through neural connections to other neurons when it makes electrical spikes. [5]

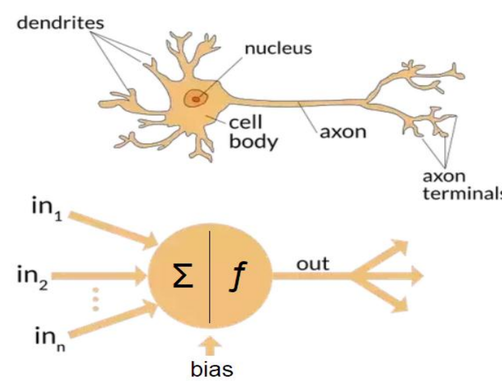

Figure 6- Biological structure of ANN

4.2 Genetic algorithm

Genetic Algorithm (GA), first proposed by J. Holland in the 1970s and driven by the organic evolution of living things, are search calculations based on the standards of common preference and hereditary traits. Hereditary calculations isolate the problem domain as a population of individuals and make an iterative attempt to investigate the fittest individual. GA transforms a group of low quality people into a group of high quality people, where each person speaks to a different aspect of the problem to be resolved. A wellness work serves as a quantitative representation of each rule's adaptation to a certain environment and is used to assess the quality of each run of the performance. The tactic starts with a starting populace of randomly generated individuals. Three key hereditary administrators—determination, hybrid, and transformation—are successively connected to each person with varying probabilities during each era. The GAs is computer software that replicates the evolution and heredity of live organisms. Given that GAs are multi-point look strategies, an optimum arrangement is definitely possible for multi-modular objective capabilities using GAs. GAs is also relevant to problems with discrete look space. In this way, GA is not only incredibly easy to use but also a very effective optimization tool. In GA, the look space is made up of strings known as chromosomes that individually speak to a potential solution to the problem. Each chromosome's wellness value is its objective work worth. A population may be a collection of chromosomes along with their associated health. Populations are produced in eras with an emphasis on the GA [6].

4.3 Fuzzy logic

A way of thinking that is based on how people think is called fuzzy logic (FL). With all switching actions restricted to better YES and NO attributes, the FL methodology mirrors the human dynamics approach.

A typical logic block that a computer can comprehend will use the correct data and perform work that is obviously TRUE or FALSE, similar to a human YES or NO.

The inventor of fuzzy logic Lotfi Zadeh found that, in contrast to computers, human dynamics incorporate a number of potential outcomes between YES and NO, for example:

Absolutely, yes

Maybe

I'm not sure

may not

Definitely not

Fuzzy logic is concerned with potential productivity gain levels.[7]

4.4 Particle Swarm Optimization

PSO is a Mehta heuristic algorithm that Kennedy and Eberhart first devised. The programme mimics how a flock of birds would migrate and separate themselves from one another as they searched for an ideal location in a multidimensional world. PSO is a genetic algorithm-like evolutionary computing technique (GA). Particles are swarms that start off randomly and update generations to find the best solution. PSO has two methodologies: the cognitive methodology and the social methodology. The algorithm moves toward the global optimum like a particle travelling through the search space. When defining a particle in PSO, D stands for dimensions and R stands for real numbers . Every particle has a unique beginning velocity and position that are chosen at random. Each particle must retain its pbest, also known as the local best position, and the Gbest, also known as the overall best position. The following equations are used to update the particle's position and speed. Where, are two random values ranges [0, 1] and & are the leaning factors, is the velocity, is the location, is the personal best position of the particle, and is the global best position for the PSO. [8]

In unstable environmental conditions of sun-oriented illumination and temperature, maximum power point tracking (MPPT) may be a widely used method to construct an effective solar system. Here, the challenge is to improve a solar generator's performance using an artificial neural network-based MPPT plot. The majority of the time, PV modules exhibit nonlinear I–V characteristics with different MPPs based on the temperature and sun-powered light. It must run at its MPP in order to enable the largest control exchange to the load from the GPV. This is frequently achieved by balancing the duty cycle of a DC-DC boost converter, whose obligation cycle is balanced by artificial neural networks, between the PV board and the stack. According to the obtained recreation results, the investigated ANN-based technique is more productive and motions around the MPP are substantially decreased as compared to the well-known perturb and observe MPPT. Following execution, both methods seem wonderful when using Matlab/Simulink. On the other side, the ANN-MPPT approach produces negligible motions around the MPP, which boosts productivity. [9]

In this paper, a sun-oriented PV framework with an artificial neural network-based MPPT controller has been proposed. The controller consists of two components, one of which uses MPPT calculations without neural organisation and the other of which uses MPPT calculations with neural organisation. For analysing the relative execution for following MPPT, two distinct parts are used. According to the results of recreation, the MPPT calculation using ANN forecasts temperature and irradiance variations with greater accuracy than the MPPT calculation without ANN. The differences between yield voltage and yield control can be seen in the direct relationship between the two. Even though the bend has a few nonlinear parcels, the control changes directly with the yield voltage. [10]

We provide an MPPT computation in this paper that is based on the single-layer neural network display of the photovoltaic board. It appears that the neural network can be used to correctly illustrate how the photovoltaic board's current, voltage, solar-based irradiance, and temperature relate to one another. Contrary to the similar circuit demonstration, the neural arrangement demonstration can be used to determine the slope of the P-V bend, enabling the design of the fundamental MPPT technique, which relies on the steepest ascending approach. The focus of long-term effort will be on developing an irradiance estimator plan and a crossover calculation plan that is robust to errors in irradiance estimation Additionally, the proposed method will be validated using accurate photovoltaic estimates. [11]

The most effective control point of solar-powered cells is when artificial neural systems are put into action. The execution was successfully completed, and the outcomes approved the accuracy with which the MPP was followed in varying weather circumstances. The low photovoltaic voltage was increased by the DC-DC boost converter to a higher level, and the H-bridge inverter was used to convert the DC voltage to AC. Using a neural network architecture, the circuit's mutilations caused by various components are corrected. After reversal, the AC voltage can be stepped up and transferred to the network for household uses. The ANN-based MPPT strategy reveals that it is the swiftest and most tenacious method of implementing MPP, and it allows us to transfer control to the lattice using transformer[12]

This research examines the use of artificial neural networks (ANN) for tracking the biggest control point. A mistake back engendering approach is used to prepare the neural network. The focus of neural organisation is on properly and quickly following the most extreme control point. In this technique, a neural network is used to show the reference voltage of the most extreme control point under various climatic circumstances. The most severe control point can be followed by properly controlling the dc-dc boost converter. Utilizing MATLAB/SIMULINK, reenactment results are obtained to confirm the results of the hypothesis inquiry. [13]

When the boards are connected to the boost converter under various changeable stack situations, BPNN-DL in this paper obtains the best control point and amplifies the yield control from the sun based networks. By enabling the forecast of reference voltage under various climatic conditions, BPNN-DL enables the separation of various yield controls and ensures the best yield control with constant yield voltage. In contrast to current techniques, the proposed BPNN-DL appears to be capable of achieving the largest yield control (98% exactness) from each board under specific conditions. In the future, receiving the machine learning modules could be the focal point of a reduction in execution costs.[14]

The non-direct feature of sun-based PV systems necessitates an expert Greatest Control Point Following (MPPT) computation to control the yield control, which has a significant impact on the efficiency of the sun-based PV systems in order to extract the maximum amount of energy. The suggested computation is based on the obligation proportion that Neural Organize anticipates (NN). After the plan was developed using 625 tests and was approved, it ensures quick yield management, no overshoot, no excessive wobbling, and greater stability compared to traditional algorithms. By closely observing the Most Extreme Control Point, the recreation is able to confirm the acceptability of the NN computation under completely diverse environmental conditions (MPP). Additionally, the minor Cruel Squared Error (MSE) obtained from the NN validates the precision and stability of the obligation cycle. Also, the accuracy and stability of the duty cycle are justified by the low Mean Squared Error (MSE) acquired from the NN [15]

This research highlights the design of the neural arrange controller for the single stage acceptance engine (1 HP) speed control, controlled by the sun directed vitality framework. Using the incremental conductance technique, the crest control from the solar-powered board is freed. The single stage inverter that supports the solar-powered board yield voltage and current is supported by the SEPIC converter, which powers the acceptance engine. In order to increase the voltage obtained from the solar-powered board, the beats from the specific controller and Incremental Conductance computation based MPPT Controller are combined and then delivered to the SEPIC converter. The controller receives criticism for the acceptance engine's speed. The neural organise controller recreation has been completed. The recreation for the neural organize controller has been carried out. Recreation comes about gotten appears that Neural Organize controller performs superior for speed control of acceptance engine.[16]

This study compares four MPPT programmes built on FLC. Based on the examination of the plan handle and subsequent impacts, it can be stated that the determination of input components determines the difficulty of the ultimate control impacts. Recreational results and try evaluations show that the hypothetical investigation is correct. In any event, the MPPT advancements, which integrate FLC with other advancements, are not detailed in this work.[17]

Because it expands the yield control that the solar-powered PV module conveys, the MPPT controller concept is seen as being crucial. Based on the type of calculation used, the 50 techniques that were studied in this survey work are divided into eight categories. The MPPT strategies are discussed in this essay together with their advantages and disadvantages, indicating that the choice of the MPPT approach should be based on the utility's individual application and requirement. At the conclusion of each category, an unthinkable comparison is also provided. This comparison can be a powerful tool for selecting the most effective MPPT to meet the needs of both administrators and clients. This information may discover an charming source to assist the engineers in setting with the overwhelming mechanical situation.[2]

Integration of renewable energy with the control system is becoming more and more necessary. For battery charging, applications that are connected to a framework, etc., solar-powered PV technology is essential. It is essential to determine the most conceivable energy gather from photovoltaic board in order to improve yield control of a solar-powered photovoltaic method. The most stringent Control Point Following (MPPT) controller for a solar-based photovoltaic system is developed in this research by employing a synthetic neural network (ANN). A comparison is also made between the operation of an ANN-based MPPT controller and conventional MPPT techniques. In particular, incremental conductance, fragmented open circuit voltage, and slope increasing (annoy and watch). By using MATLAB/SIMULINK to examine outcomes, recreations are carried out.[18]

When using an ANN-based MPPT controller, the yield voltage is smoother and has less movements. The controller is more physically powerful and rapid. Although 16 information sets were used in this paper, a larger number of information sets may be used to prepare the structure, which would allow for the creation of an even more powerful and precise controller.[19]

In order to obtain the most extreme control possible from the sun-oriented cell of a photovoltaic (PV) module, the electrical working point is shifted using the commonly used control approach known as Maximum Power Point Tracking (MPPT) computation. Incredibly unfortunate control events also occur as a result of source and stack errors. Therefore, an MPPT must be designed in order to extract the maximum amount of control from a solar-powered panel. The goal of the paper is to present a novel, feasible, and efficient microcontroller-based MPPT framework for solar-oriented photovoltaic systems in order to ensure quick greatest control point operation under all rapidly changing environmental conditions. The suggested controller system employs PWM techniques to direct boost converter output control at its maximum practicable value while concurrently managing the battery charging system. Using a MATLAB/Simulink demonstration, parameter extraction, demonstrative evaluation, and boost converter inquiry are demonstrated. [20]

5. RESULT

Power is one of the most important requirements for those in the display. The use of solar energy not only advances the electronic era but also reduces the pollution caused by fossil fuels. The MPPT extends the life and efficiency of the PV module. The PV system and other intelligence methods are covered in-depth in this document. There is also an overview of how PV systems and artificial intelligence techniques can be deployed together much more successfully.

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