Review: Maximum Power Point Tracking of Solar PV System

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Abstract : The energy crisis is one of humanity's most pressing and severe issues, and it's happening at a time when fossil fuels are running out, therefore finding new sources of energy is one of modern man's greatest difficulties. Solar energy is a renewable, virtually everlasting source of energy that photovoltaic (PV) cells can convert directly to electrical energy. Although the usage of sunlight is free, PV cells are somewhat expensive, therefore it is important to get the most power out of them for economic reasons. There are numerous ways for achieving maximum power point, as well as many review publications, but only a few studies have compared these techniques from an economic and technical standpoint. This study provides an overview of MPPT approaches for various types of converter topologies, based on a thorough and relatively new categorization system, with a focus on method comparison.

***Index Terms* – Maximum Power Point Tracking, DC-DC Converter, Solar PV array system**

1. INTRODUCTION

The fast increase of population and industry, as well as technical advancements and improvements in living standards, have resulted in an ever-increasing human need for energy, resulting in a direct relationship between development and energy consumption. Nowadays, fossil fuels provide a large portion of energy, but concerns such as the political and economic crises, environmental degradation, and the scarcity of fossil resources, among others, have highlighted the need for alternative energy sources. One of the essential solutions for resolving these issues is solar energy.

Solar energy is extremely clean and does not emit any greenhouse gases, which means that the environmental and health costs of producing electricity will be reduced, and the global warming issue will be better addressed by utilizing renewable energy rather than fossil fuels. Another advantage of solar energy is that it is accessible all around the world, thus nearly any country may utilize it to generate electricity without relying on other countries. The greatest benefit of solar energy is that it is everlasting, ensuring that the source may be utilized for thousands of years and so can be considered a lifelong source.

In addition to the foregoing, solar energy is both free and entirely safe, with a tremendous amount of energy worth. The energy transferred from the sun to the earth's surface over a day is roughly a thousand times more than the energy released by fossil fuels [1]. PV cells are one of the most popular techniques to capture solar energy and convert it directly to electricity. PV cells are made up of two types of semiconductors: N type and P type semiconductors. The N-type is found in the portion of the cell that faces the sun, whereas the P-type is found towards the rear of the cell [2]. These cells also have nonlinear I-V and PV characteristics that are strongly influenced by irradiation, ambient temperature [3], and load impedance [4]. The nonlinearity of the I-V and P-V characteristics of PV cells, as well as the influence of ambient circumstances on them, are depicted in Figures 1 and 2. As demonstrated in the figures, increasing the temperature lowers the maximum power of the PV cell, while increasing the irradiance raises it.

The number of installed cells is quickly rising nowadays, and these cells are classified as stand-alone, grid-connected, or hybrid. In Germany, for example, over 1.5 million photovoltaic systems have been built [5], generating around 40,093 megawatts (MW) by the end of May 2016 [6]. Of course, there are two major roadblocks in the way of PV cells: their relatively high cost and low efficiency. Because of economic considerations and the rising demand for energy, it is very important to extract the most power from cells.

2. DIFFERENT CONVERTER TECHNOLOGY USING MPPT

Author was suggested [1], a maximum power point tracking DC-DC quadratic boost converter for high conversion ratio needed applications is proposed. The suggested system comprises of a quadratic boost converter with high step-up ratio and fuzzy logic based maximum power point tracking controller. The converter reference signal is generated using a fuzzy logic-based maximum power point tracking method, with the change in PV power and change in PV voltage selected as fuzzy variables. The output signal of the fuzzy logic controller is generated by determined membership functions and fuzzy rules that are designed to track the maximum power point of the PV system.

The quadratic boost converter provides a high step-up function with robustness and stability, as shown by MATLAB/ Simulink modeling and experimental results. In addition, as compared to typical boost converters, this technique is accomplished with a low duty cycle ratio. Furthermore, simulation and experimental findings have proven that the suggested system is responsive and adaptable to quickly changing atmospheric conditions. The suggested system has a steady-state maximum power point tracking efficiency of 99.10 percent. Furthermore, the converter's output power oscillation is minimized, which is a key issue with maximum power point trackers.

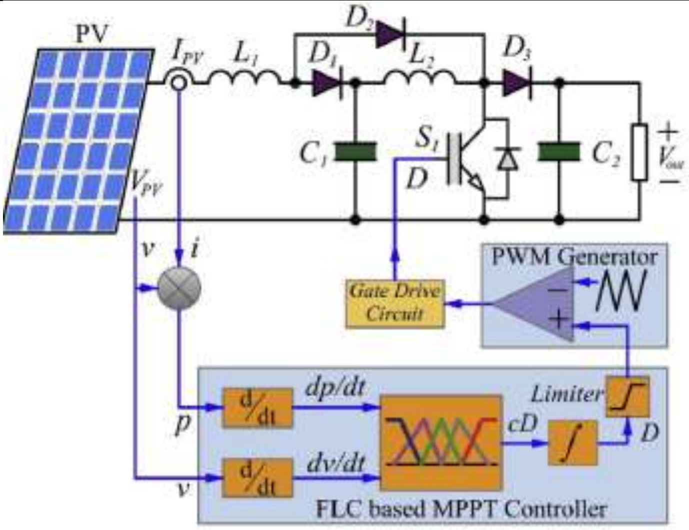

Fig.1. MPPT converter topology using Fuzzy logic controller [1]

The QBC has a greater voltage conversion ratio and a lower duty cycle than traditional boost converters, resulting in lower voltage stress and improved efficiency. Because the second active switch is omitted, the QBC is likewise more simple, reliable, and efficient than cascaded converters. A FLC-based MPPT controller is also included in the proposed system. There are two inputs and one output in the proposed FLC. The PV panel's output power and output voltage are chosen as input variables, and the change in duty cycle is computed as the FLC's output variable.

The QBC's duty cycle is calculated by integrating the FLC output. The QBC guarantees robust and steady operation with low duty cycle, even when significant step-up is required, according to results derived from MATLAB/Simulink simulations and experimental investigations. For steady state operation, the MPPT efficiency was found to be 99.10 percent. The proposed FLC-based MPPT quadratic boost converter has a quick transient response and reaches MPP in around 180 milliseconds. Furthermore, the FLC-based MPPT algorithm decreased converter output power oscillation at the MPP.

The great efficacy of the Fuzzy Logic Controlling FLC method is demonstrated and proven in the literature, validating FLC priority in the Maximum Power Point Tracking MPPT application. Based on this, the author was proposed, and [2] focuses on the study and examines the effect of changing the membership of input and output variables on the quality of FLC performance. Other relevant factors such as fuzzy inference rules, x-axis divisions, and membership restrictions are also maintained constant to illustrate this impact. To do the simulation and regulate the duty cycle D, as well as the pulse width modulation gate drive pulses width of the Buck-Boost DC-DC converter, MATLAB/Simulink software is used. The supplied load powers are different between the two examples of various membership shapes, confirming and indicating the beneficial effect of the proposed adjustments in the second membership shape, according to the gathered data.

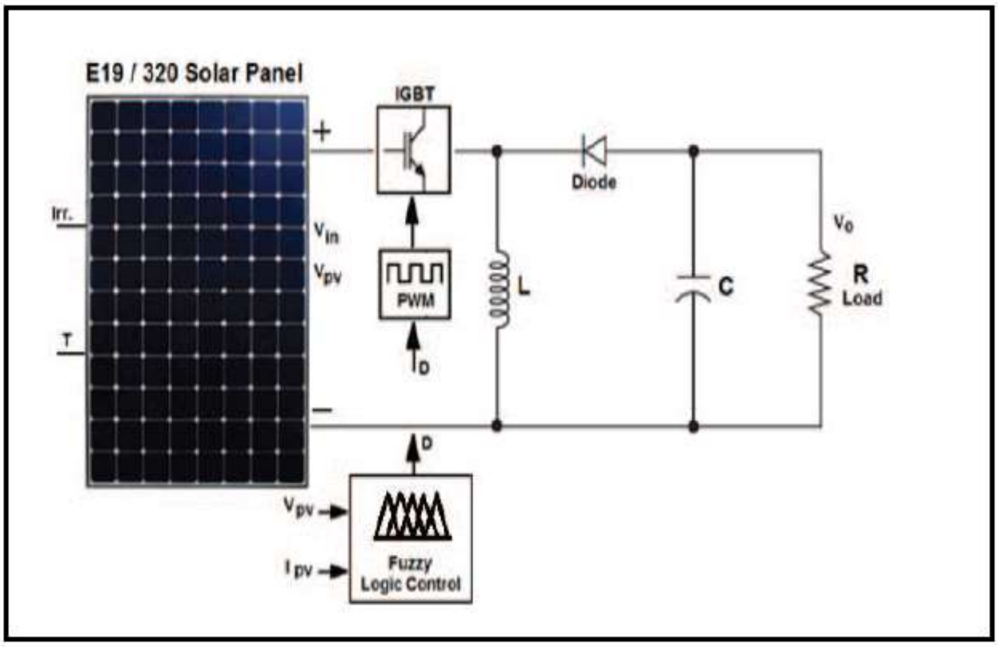

Fig.2. MPPT Tracking using fuzzy logic controller [2]

The other parameters in the FLC process are maintained constant in this research [2] to clearly illustrate the effect of the suggested adjustment. After running a MATLAB/Simulink simulation with FLC and the proposed changes to input and output variable memberships, it was discovered that focusing around the zero error location results in higher load power, i.e. highly effective FLC performance when proposing a narrow membership shape around zero location, as shown in the collected simulation results.

Under uniform irradiation circumstances, the traditional methods for maximum power point tracking assure correct performance. When a photovoltaic (PV) array is exposed to partial shadowing circumstances (PSC), multiple local maxima emerge on the PV array's P-V characteristics curve, which are caused by the usage of bypass diodes to avoid hot spots. The appearance of multiple peaks on the characteristics of the PV array makes tracking more difficult under these conditions, necessitating the integration of a more efficient power control system capable of discriminating between local and global maxima in order to harvest the maximum amount of energy and thus increase the overall system's efficiency. The mismatch losses associated with the shading effect can be further minimised by employing various PV array designs such as Total-Cross-Tied (TCT), Bridge Linked (BL), and Honey-Comb, in addition to applying global maximum power point tracking techniques (HC).

Author designed [3] an intelligent MPPT controller for this aim, which allows predicting and extracting the global maximum power point (GMPP) from a PV array under partial shade circumstances (PSC), regardless of the utilised configuration or size. The adaptive neuro-fuzzy inference mechanism underpins this clever MPPT controller (ANFIS). The ANFIS network that has been adopted has two inputs and one output. The suggested ANFIS has two inputs: voltage and current, and the output is the output power of each configuration. The ANFIS network is trained using data from performance analyses of various PV array designs. The ANFIS network also employs a hybrid learning approach that incorporates both the least squares estimator and the gradient method.

In this work, the Bishop model of a PV module, which best represents solar cell behavior at negative voltages, is used to simulate PV arrays, and it is implemented with Simulink and SimPower software. For TCT configuration under partial shading conditions, the efficacy of the suggested approach is examined for various shading scenarios and abrupt irradiance changes.

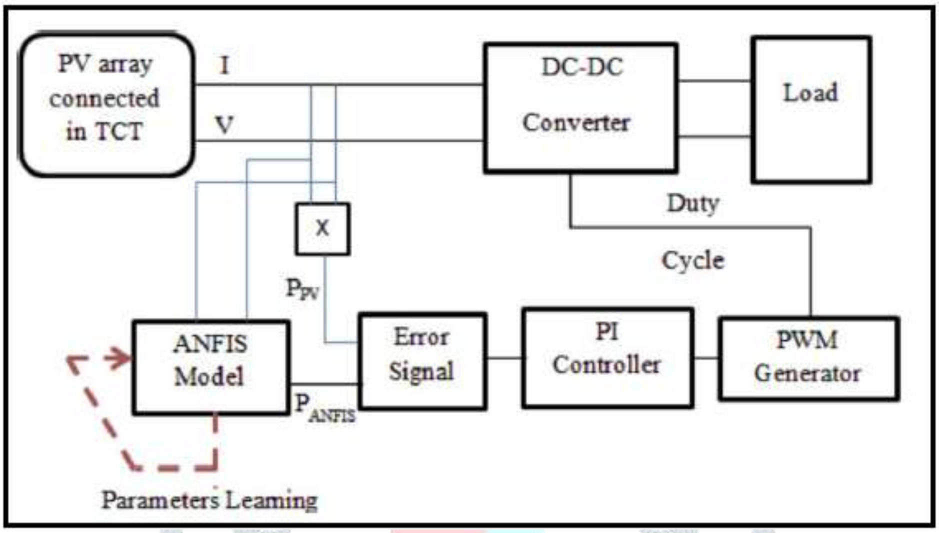

Fig.3. Block diagram of ANFIS controller for MPPT tracking [3]

An adaptive neuro-fuzzy inference system-based maximum power point tracking controller for PV systems operating in partially shaded situations is suggested in this technique [3]. Several simulations were run to test the proposed controller's performance under various shading conditions and for SP, BL, HC, and TCT setups. For every kind or size of PV array arrangement, the suggested technique may properly track the maximum power available. Under partial shade conditions and for any PV array layout, simulation results showed that the proposed approach can swiftly monitor the real maximum power point with high efficiency and low oscillations around the GMPP. Furthermore, the suggested approach demonstrated resilience in the face of abrupt irradiance level changes during partial shade. In summary, the suggested methodology has several benefits over previous artificial intelligence techniques, including greater efficiency under partial shade situations, quicker tracking speed, higher output stability, resilience, and ease of hardware implementation.

A significant number of MPC-based MPPT techniques have recently been proposed in the literature with highly promising performance; nevertheless, these methods have not yet been thoroughly investigated and compared. As a result, one of the authors [4] set out to conduct a thorough investigation and assessment of MPC-based MPPT techniques applied to a variety of typical power converter topologies. The performance of an MPC-based MPPT is strongly related to the converter topology, and it is also influenced by the accuracy with which the converter parameters are determined. The sensitivity to converter parameter alterations is also examined.

The trackers' static and dynamic performance is evaluated using comprehensive simulation models and confirmed by laboratory tests, in accordance with the EN 50530 standard. The goal of this study is to provide practical advice for professional engineers and academic researchers when choosing the MPP tracker for their project.

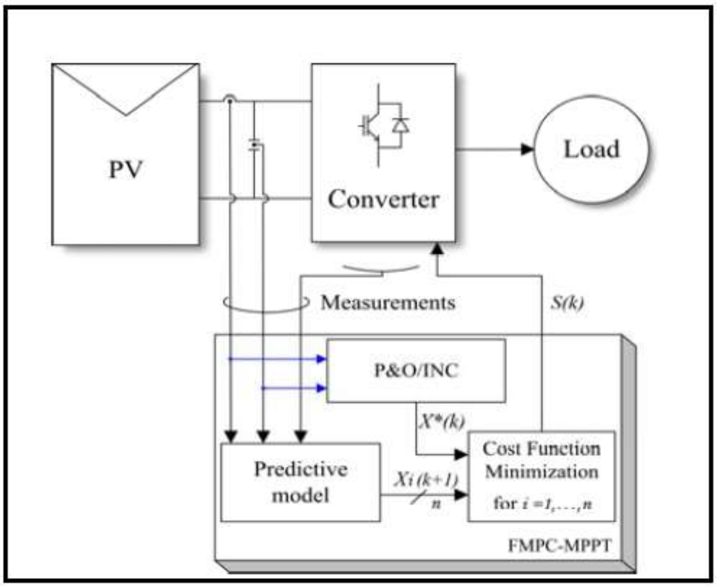

Fig.4. FMPC based MPPT tracking approach block diagram [4]

Only the behavior of the converter based on its mathematical model is taken into account in FMPC-MPPT when making predictions. The oscillation in the output PV power under steady meteorological circumstances will be inherited from P&O/INC since the reference tracked by FMPC is created using the P&O/INC algorithm. The dynamic performance of FMPC-MPPT will also be inherited from P&O under changing atmospheric conditions. As a result, applying FMPC to MPPTs does not solve the difficulties that conventional MPPTs have. Indeed, the usage of FMPC on MPPT overcomes the limitations of the PI controller utilized in the MPPT's voltage control loop (in case of voltage control). When compared to FMPCMPPT, DMPC-MPPT is less susceptible to model parameter mismatch and has superior dynamics during rapid environmental condition changes.
However, certain noise measurement may result in an extrapolation with a slope sign opposite to the PV curve's slope sign under low solar irradiance levels (when the PV curve's knee is flatter) and in real-world applications. As a result, the forecast will turn out to be incorrect. When multiple loops are run under these conditions, a rather high power oscillation is created at the PV array's terminals.
The mathematical modeling of the photovoltaic module was provided to the author [5]. The connection between current and power and voltage characteristics reveals that it is not linear. It works with Buck-Boost and Zeta converters to account for temperature and irradiance changes in the environment. The incremental conductance technique is a common approach for determining maximum power point because it can follow quickly changing maximum power points. The output voltage quality is determined by the type of converter utilized. When compared to the Buck-boost converter, the output voltage ripples of the Zeta converter are much less.
PV output power fluctuates with temperature and irradiation levels, and Buck-Boost and Zeta converters are integrated with PV modules. Buck-Boost benefits from the dynamic behaviour. For a Zeta converter, the output voltage ripple is very low and positive, but for a Buck - Boost converter, it is negative. The incremental conductance chart is used to calculate the maximum power point, which oscillates the operational power point around MPP. As a result, the Zeta converter is appropriate for higher power quality.
A maximum power point tracking (MPPT) technique based on the perturb and observe (P&O) method with sliding mode control was presented by the author [6]. (SMC). A precise and efficient model of the PV system is necessary for effective PV system control. The nonlinear nature of the I-V characteristic curve in PV systems has caused a serious concern. Variable irradiance and temperature cause this nonlinear behaviour. The SMC-based P&O MPPT approach is used to track the maximum power for the PV system in this article. It is planned to include a two-step sliding mode control. The first step is to create a sliding surface, and the second is to create a discontinues control law. With SMC, the P&O algorithm is a simple, straightforward, and less complicated technique. At various irradiances, the smooth maximum power point is achieved in less time. PV panel, SMC, MPPT P&O technique, and dc/dc boost converter are all part of the system. Simulation can be used to assess the efficacy of the suggested approach. In the presence of a load, the results were tested at various temperatures and irradiances.

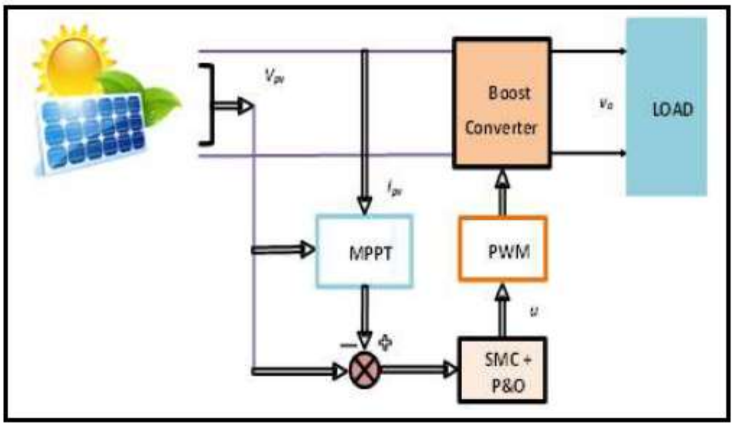

Fig.5. Block diagram of P & O MPPT appraoch [6]

An SMC-based P&O method is used in this approach [6] to obtain the highest power point for a solar photovoltaic system. The attainment of MPP is divided into two parts. The sliding surface is designed in the first step, and the discontinues law is designed in the second phase. Chattering has been reduced in the SMC-based P&O approach, maximum power has been achieved, overshoot in output power has been controlled, and the output is also extremely smooth at various irradiances. The findings are compared to the INC approach based on SMC. When compared to the SMC-based INC technique, the SMC-based P&O method offers a superior output responsiveness.

By increasing the amount of power generated by the PV modules, maximum power point tracking (MPPT) techniques are used to increase the efficiency of photovoltaic (PV) systems. Under non-constant irradiance and temperature circumstances, the tracking approach becomes increasingly difficult. One of the most commonly used tracking strategies is the Perturb and Observe (P&O) algorithm.

The P&O tracking algorithm, on the other hand, has several flaws, such as prolonged oscillation about the MPP. This approach introduces a novel way for tracking the MPP under varying irradiation and temperature circumstances. The P&O approach is combined with the Owl Search Algorithm in the suggested methodology (OSA). The Matlab/Simulink environment is used to simulate the suggested MPPT method. Three case studies are studied, including start-up and step variations in irradiation and temperature. The suggested method is compared to the P&O method.

The performance of a 50 kWp PV system with a P&O based MPPT algorithm is simulated using Matlab/Simulink in this technique [7]. The algorithm's oscillating behaviour was seen during steady-state conditions or after a sudden shift in temperature or irradiation. Combining the owl search algorithm with the traditional P&O approach substantially enhanced the efficiency of the perturb and observe process. The OSA was utilised to generate a near-optimal duty cycle value, which was then input into the P&O algorithm, which tracked the MPP steadily and rapidly without oscillations. The simulation results demonstrate that the proposed P&O-OSA combined algorithm converges quickly and successfully drives the PV system to generate maximum power during startup and step changes in irradiance and temperature. Furthermore, the suggested technique is straightforward to construct and does not incur any additional costs above the existing perturb & observe MPPT algorithm.

PV systems are now plagued by two major issues: high production costs and low efficiency, particularly in the face of changing weather conditions. PV systems are therefore coupled with different optimization controllers, such as maximum power point tracking, to reduce such issues. An artificial neural network maximum power point technique has been created to be linked between a PV system and a DC-DC buck converter, and each element of the system has been clearly discussed by the author [8].

The entire system was modeled in the MATLAB/Simulink environment, and simulation results showed that the proposed technique was effective. The suggested technique has been tested to track the maximum power point under various weather circumstances, and the results demonstrate that the maximum power point (MPP) of a PV system can be tracked quickly and accurately. The entire system, which includes PV arrays, a Buck converter, an ANN tracker, and a load, was modeled in the MATLAB/Simulink environment. This Simulink model has been tested at various temperatures and degrees of irradiation, and the output results of both P-V and I-V characteristics, output power, and system efficiency clearly show that the modeled system is legitimate. This demonstration was carried out by comparing the results of the experimental platform with the results of the simulated model, demonstrating that ANN is highly recommended for usage in the field of PV system maximum power point tracking.

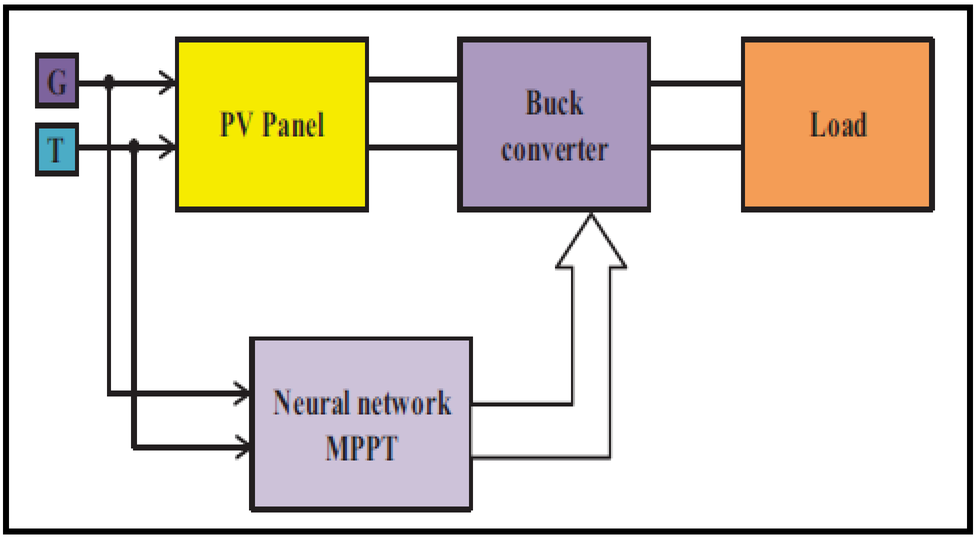

Fig.6. Schematic arrangement for the complete proposed system [8]

Based on the experimental platform, a photovoltaic system model was created and designed. The PV control system should optimize photovoltaic system output power by operating the PV as close to the maximum power point (MPP) as feasible; the MPP is dependent on temperature and sun irradiation. To track the MPP of the PV array, a DC-DC buck converter is employed. The MPPT approach aims to harvest the maximum amount of electricity from the PV array. The ANN method is used to anticipate MPP conditions while taking sun irradiance and cell temperature into account. The simulation results for the ANN approach presented in this study demonstrate that the ANN method is highly quick and accurate in discovering and monitoring the MPP whether both cell temperature and solar irradiation change rapidly or slowly. The findings of the comparison between real values and neural network values show that the use of MPPT trackers in PV systems has boosted the efficiency and output power of solar PV systems.

The output p-v characteristic of a solar array exhibits multi-peak characteristics when partial shadowing condition (PSC) occurs. The conventional Maximum Power Point Tracking (MPPT) approach is prone to get stuck at a local maximum power point, and it is unable to monitor the global maximum power point rapidly and correctly. As a result, author [9] offers an efficient MPPT controller based on modified artificial bee colony (MABC) algorithm to monitor the maximum power point of the solar system rapidly and accurately under partial shade circumstances (PSCs). To prove its efficacy and superiority, the suggested control method is compared to the perturbation and observation (P&O) algorithm, particle swarm algorithm (PSO), and standard artificial bee colony (ABC) algorithm.

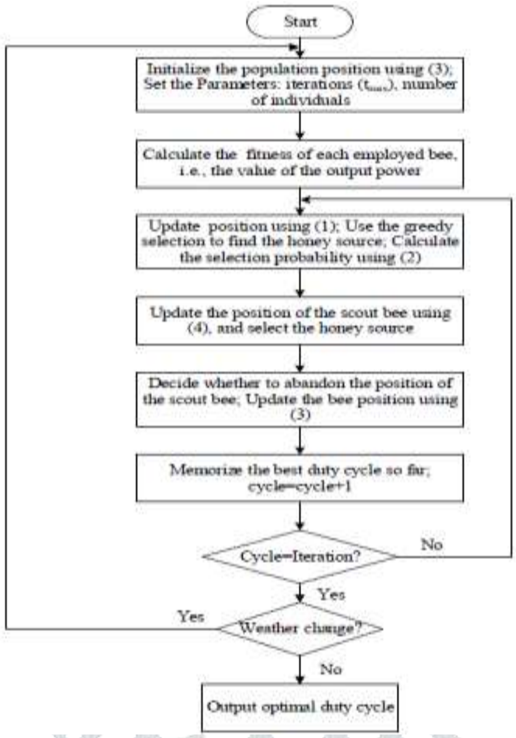

Fig.7. MABC MPPT algorithm block diagram

Under dynamic partial shading conditions, this article presents an MABC MPPT algorithm and compares it to traditional P&O, PSO, and standard ABC MPPT methods. In terms of tracking speed and accuracy, the suggested MABC MPPT algorithm beats the other three methods. The simulation results show that the suggested MPPT control approach is successful.
The CUCKOO SEARCH-based implementation of maximum power point tracking (MPPT) under partial shade conditions was suggested in the publication [10]. Solar irradiation is critical to the PV system's performance, and any variations in incoming solar irradiation would have a significant influence. Partially shading a PV system reduces power production and complicates MPP tracking since the system displays several maximum power points based on P-V characteristics. The focus of this study is on 64 TCT PV array configuration to maximize energy output under any environmental situation. In this case, the Cuckoo search algorithm is used in conjunction with a shadowing situation.
Cuckoo search based MPPT was used on a 6x4 PV array of 3.96 KW linked in TCT configuration under nominal irradiation conditions in this technique [10]. The system's performance has been investigated for various shading scenarios. The 6 by 4 PV array was split into three 2 by 4 sections to accommodate the three distinct shading scenarios, P1, P2, and P3. Cuckoo Search was found to track the GMPP with 99.72 percent accuracy under varied shading circumstances, as well as with reduced transient and tracking time.

3. CONCLUSION

More than forty-one MPPT techniques have been described, along with their benefits and disadvantages. Even if there are still some, There are additional ways that have not been included in this study, but they exist. The most often used techniques have been. Some ideas can be found here about how each approach is used Curve fitting and search up are examples of methods.For modest amounts of data, the table, FSCC, FOCV, CV, and load base methods may be appropriate cost is more essential than efficiency in large-scale applications Solar chargers for home use are accurate. Based on a differential techniques, numerical methods, perturbation-based methods, and conductance-based methods are all examples of methods based approaches are appropriate for commercial and everyday use. State space and intelligent techniques are used in high-sensitivity situations where efficiency, precision, and speed are critical, such as in space applications. It should be emphasized that while these suggestions are broad, it is vital to research, evaluate, and balance crucial variables before deciding on a technique.

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