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A COMBINATION OF PI & FUZZY LOGIC BASED IMPROVED P&O MPPT TECHNIQUE FOR PARTIAL SHADING CONDITIONS

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Abstract

A combined strategy for monitoring the maximum power point of photovoltaic (PV) energy generators in environments that have partial shading is the goal of this study (MPPT). The perturb and observe (P&O) algorithm is frequently used for MPPT; however, there is a possibility that it will not converge to the global maximum power point if the P-V curve has multiple peaks that are influenced by partial shading. This is because multiple peaks make it more difficult for the algorithm to find a single point that represents the maximum power output of the system. This is the case despite the fact that there is a chance that it will approach the global maximum power point. In this study, the effects of partial shading are analysed, and after that, the model's reaction to the findings is talked about.

It has been demonstrated, with the assistance of simulation, that the hybrid MPPT method that has been proposed effectively raises the efficiency of a photovoltaic system, while at the same time reducing the amount of time that is required to put the technique into practise.

Keywords: Maximum power point tracking (MPPT), partial shading, solar photovoltaic (PV), perturb and observe (P&O), photovoltaic (PV), Fuzzy-PI.

I. INTRODUCTION

In today's world, the demand for photovoltaic (PV) systems is expanding at a rapid rate. This is due to the environmentally friendly nature of the process of converting energy, as well as the characteristics of solar energy, which include an abundant supply, the absence of any costs associated with it, long-term viability, and widespread accessibility. In addition, the demand for photovoltaic (PV) systems is expanding at a rapid rate. This is one of the reasons why the market for photovoltaic (PV) systems around the world is expanding at such a rapid rate. It is anticipated that the amount of energy that is generated by photovoltaic cells will have reached 800GW by the year 2030 [1]. This target is set for the year 2030. The energy from the sun is converted into electrical energy through the use of a device known as a solar panel. A solar panel is essentially a collection of individual solar cells that are all interconnected with one another. The energy conversion efficiency of these solar cells is quite poor, and the initial investment that is required to purchase them is quite high; however, despite the many benefits they provide, it is quite expensive to acquire them.

In addition to this, there is a relationship between the output voltage and the output power that is being produced that is not linear. This is something that needs to be taken into consideration. As a direct result of this, these systems make use of techniques that, when grouped together, are referred to as maximum power point tracking (MPPT). These techniques are intended to wring the maximum amount of power possible from solar panels. Figure 1 presents a block diagram that shows a photovoltaic (PV) system that makes use of a maximum power point tracker (MPPT). In the past, many different MPPT strategies have been proposed for application in photovoltaic (PV) systems. These strategies have been widely varied. These methods include "Perturb and Observe," which can also be abbreviated as "P&O" [2], "Incremental conductance," also known as "INC," [3], "Hill climbing," [4], "Fractional Open

Circuit Voltage," also known as "FOCV," [5], and "Fractional Short-Circuit Current," also known as "FSCC," [6]. Even though these methods are capable of following the maximum power point (MPP) when the weather conditions are stable and change slowly, it is possible that they will not be able to converge on the global MPP when the weather conditions are variable and partial shading is present. This is because the global MPP is dependent on the local maximum power point (MPP). In a P-V curve, there will only be one MPP if the conditions are those of uniform irradiance; on the other hand, if the conditions are those of non-uniform irradiance (partial shading), then there will be multiple MPPs. The string current places restrictions on what can be done, which is reflected in the P-V curve, which shows multiple peaks in addition to the single peak. The authors presented an updated version of the P&O algorithm that they had suggested in their previous work [7], which can be found in this reference. In order to locate all of the potential maximum power points along the P-V curve, the developers of this algorithm varied the duty cycle of a DC-DC converter between the boundaries (the highest and the lowest). This was accomplished by shifting the boundaries in both directions. It is possible to successfully detect all peaks by utilising this method; however, the process itself takes a considerable amount of time. In spite of this, it is still doable.

Intelligent techniques such as fuzzy logic (FL) and neural networks are two examples of those that have been used during these abnormal conditions [8]. Despite the abnormal conditions that have been present, this has been done in order to improve performance as well as overall efficiency. The goal of this is to improve overall efficiency. In an algorithm that is based on FL, the input that is used is the slope of a PV curve, and the output that is used is variations in the duty ratio of a DC-DC converter. This algorithm also uses the slope of a PV curve to determine how to adjust the duty ratio. The algorithm is outlined in [9], which also provides a description of the algorithm. The structure of the system is comprised of a set of seven rules, and every one of the inputs and outputs possesses seven membership functions of their own, each in their own right. Through the utilisation of this method, the entirety of the search space has been analysed, and the global MPP on the PV curve has been preserved through the utilisation of the duty ratio that is associated with it. The authors of the paper [10] propose yet another FL for MPP tracking in their work. This particular FL takes into account both changes in error and errors in power, and it consists of seven membership functions and forty-nine rules. A P&O method that is assisted by FL is yet another method that has been proposed as a possible solution. Within the context of this method, the slope of the PV curve and the previous step size (perturbation voltage) are both regarded as inputs, whereas the change in step size is regarded as an output. The membership functions of each input are as follows: three, and those of each output are as follows: five. In addition, there is a predetermined set of nine guidelines that govern the system. These FL-based MPP trackers provide better performance than more conventional methods; however, because the search space is so extensive, it takes them longer to scan. This piece of research presents an original method for monitoring the global MPP that is ready to be put into action right away. In this particular instance, FL is utilised to ascertain the location of the global MPP region, and a tweaked variant of the P&O algorithm is utilised in order to locate the global MPP within the scope of the determined search region. Both of these processes are carried out in order to ensure that the global MPP can be located.

II. LITERATURE SURVEY

B. Subudhi and R. Pradhan [1], "A Comparative Study on Maximum Power Point Tracking Techniques for Photovoltaic Power Systems,". This paper provides a comprehensive review of the maximum power point tracking (MPPT) techniques applied to photovoltaic (PV) power system available until January, 2012. A good number of publications report on different MPPT techniques for a PV system together with implementation. But, confusion lies while selecting a MPPT as every technique has its own merits and demerits. Hence, a proper review of these techniques is essential. Unfortunately, very few attempts have been made in this regard, excepting two latest reviews on MPPT [Salas, 2006], [Esram and Chapman, 2007]. Since, MPPT is an essential part of a PV system, extensive research has been revealed in recent years in this field and many new techniques have been reported

to the list since then. In this paper, a detailed description and then classification of the MPPT techniques have made based on features, such as number of control variables involved, types of control strategies employed, types of circuitry used suitably for PV system and practical/commercial applications. This paper is intended to serve as a convenient reference for future MPPT users in PV systems.

M. I. Bahari, P. Tarassodi, Y. M. Naeini, A. K. Khalilabad and P. Shirazi [2], "Modeling and simulation of hill climbing MPPT algorithm for photovoltaic application,". This paper is focused on robust H_∞ fuzzy Maximum Power Point Tracking (MPPT) of photovoltaic (PV) system under actuator asymmetric saturation and different climate conditions. To adjust the output PV voltage, a DC-DC boost converter is used. This last is controlled by duty ratio that is remains practically saturated between 0 and 1. In order to consider of input limited, firstly, a polytopic model is investigated in fuzzy integral state feedback controller. Secondly, H_∞ stabilization conditions are derived in linear matrix inequalities (LMI) terms based on Takagi-Sugeno (T-S) fuzzy model and Lyapunov approach. Finally, the proposed control is applied to a PV system and our simulation results show the effectiveness of the proposed approaches.

M. A. Elgendy, B. Zahawi and D. J. Atkinson [3], "Assessment of Perturb and Observe MPPT Algorithm Implementation Techniques for PV Pumping Applications,". The energy utilization efficiency of commercial photovoltaic (PV) pumping systems can be significantly improved by employing simple perturb and observe (P&O) maximum power point tracking algorithms. Two such P&O implementation techniques, reference voltage perturbation and direct duty ratio perturbation, are commonly utilized in the literature but no clear criteria for the suitable choice of method or algorithm parameters have been presented. This paper presents a detailed theoretical and experimental comparison of the two P&O implementation techniques on the basis of system stability, performance characteristics, and energy utilization for standalone PV pumping systems. The influence of algorithm parameters on system behavior is investigated and the various advantages and drawbacks of each technique are identified for different weather conditions. Practical results obtained using a 1080-Wp PV array connected to a 1-kW permanent magnet dc motor-centrifugal pump set show very good agreement with the theoretical analysis and numerical simulations.

F. Liu, S. Duan, F. Liu, B. Liu and Y. Kang [4], "A Variable Step Size INC MPPT Method for PV Systems,". Solar energy is a fast growing energy resource among the renewable energy resources in the market and potential for solar power is huge to contribute towards the power demand almost in all the countries. To capture the maximum power from the sun light in order to generate maximum power from the inverter, control system must be an equally efficient with the well designed power electronic circuits. Maximum power point tracking (MPPT) control system in general is taking care of extraction of maximum power from the sun light whereas current controller is mainly designed to optimize the inverter power to feed to power grid. In this paper, a novel MPPT algorithm using neuro fuzzy system is presented to ensure the maximum MPPT efficiency in order to ensure the maximum power across the inverter terminals. Simulation and experimental results for residential solar system with power electronic converters and analysis have been presented in this paper in order to prove the proposed algorithm.

III. METHODOLOGY

- The proposed strategy integrates PI and Fuzzy logic controllers into a single framework.
- With both controllers in series, we get increased peak power and decreased settling time.

Partial shading condition:

To generate a higher voltage, several PV modules can be connected in series and in parallel to satisfy the voltage or current ratings of the load. In case of PSCs, if there is at least one PV module which is less illuminated, it will produce lesser current. In this situation, the shaded module will work as a load and consume some power generated by other PV modules. Here the string current is limited by the current of the less illuminated modules. This problem can be avoided by connecting a parallel diode

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with the PV module which is also known as bypass diode. This bypass diode permits the string current to circulate in the right path even there is one or more than one module are partially or completely shaded. Because of bypass diodes, there are more than one peaks occurs in P-V curve, known as local and global maxima points occur in the P–V characteristics curve. Four PV arrays configuration having 3 modules in series (3S configuration) with different shading patterns are shown in Fig 1(a, b, c, d). P-V curves of these patterns are shown in Fig 1. Here IR1, IR2 and IR3 are in 2 *w* / *m*.

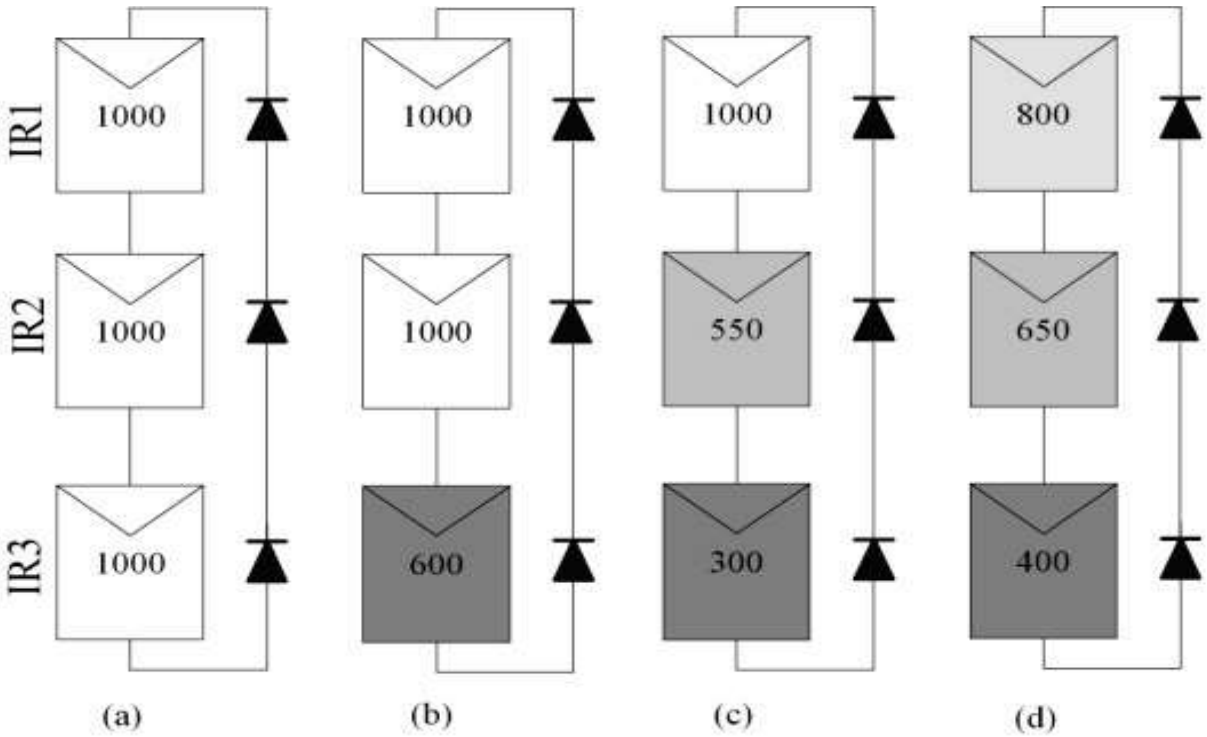

Figure. 1: PV arrays configuration with different PSC's

In PV array configuration 'a', there is no shaded module, and it has only one peak, while in configuration 'b', there is one shaded module i.e., two different irradiance levels (600 and 1000 *w* / *m* 2) exist in the array, and it is having two peaks. In case of configuration 'c' and 'd', each module has different shading intensity i.e., three different irradiance level and these configurations have three peaks. So, the number peaks in P-V curve is same as the number of different irradiance level in PV string. Fig 2 shows PV curve pattern in different shading conditions.

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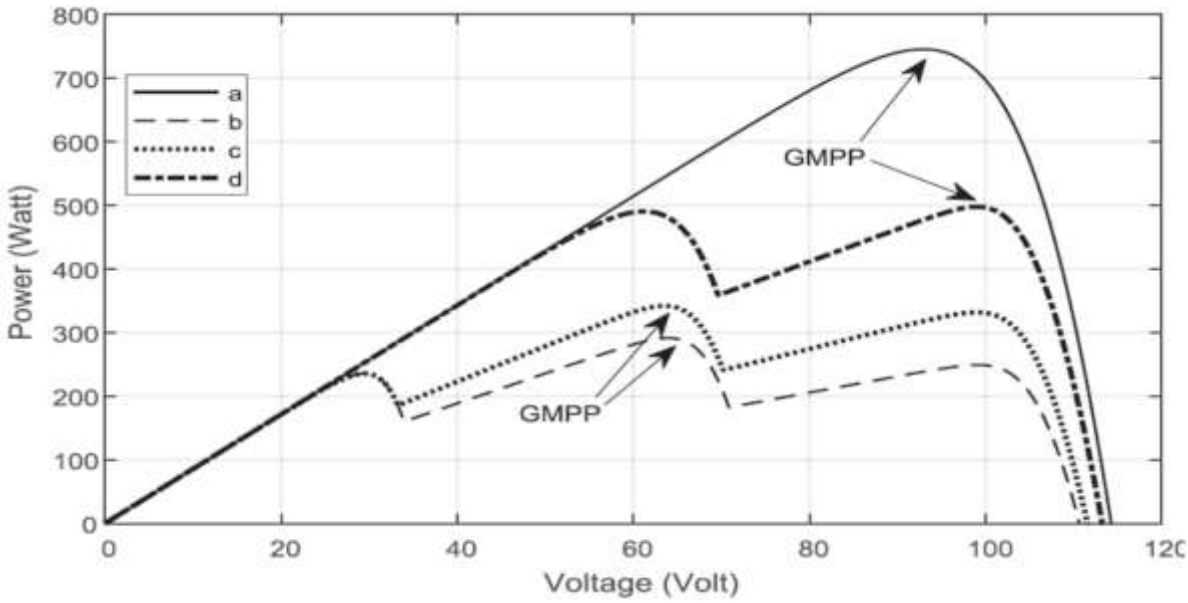

Figure. 2. P-V Curves under different partial condition's

Study of Characteristic Curves Under PSC's

A PV array having 3S configuration shown in Fig.3, has been considered for the analysis. Here IR1, IR2 and IR3 are the irradiance values on respective modules. There are three patterns of irradiance level shown in the table II. The P-V curves of these configurations have been shown in the Fig 4. Here the entire search space has been divided into three search regions (SR1, SR2 and SR3) on the basis of open circuit voltage (Voc) of PV module. So, the search regions have been defined as SR1 (0V to 38.1V), SR2 (38.2V to 76.2V) and SR3 (76.3V to 114.3V).

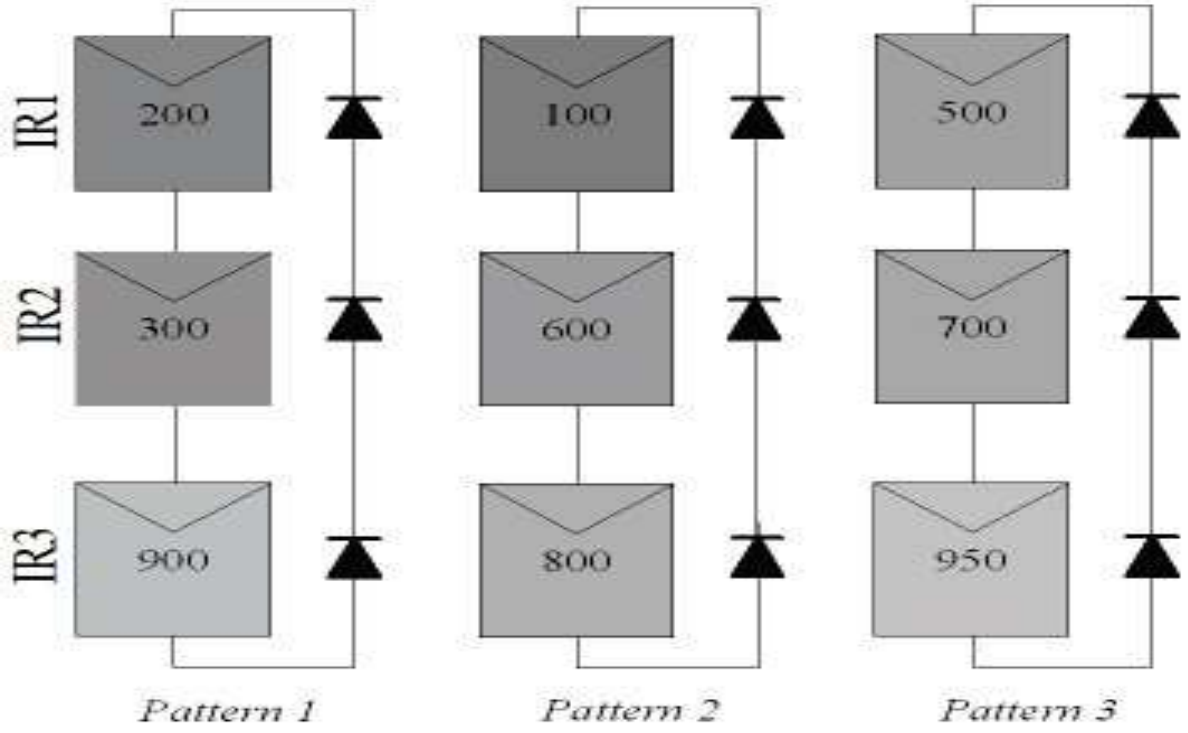

Figure. 3: Irradiance pattern on modules

TABLE I: PATTERN CONSIDERED FOR ANALYSIS

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Pattern/Irradiance	IR1	IR2	IR3
Pattern 1	200	300	900
Pattern 2	100	600	800
Pattern 3	500	700	950

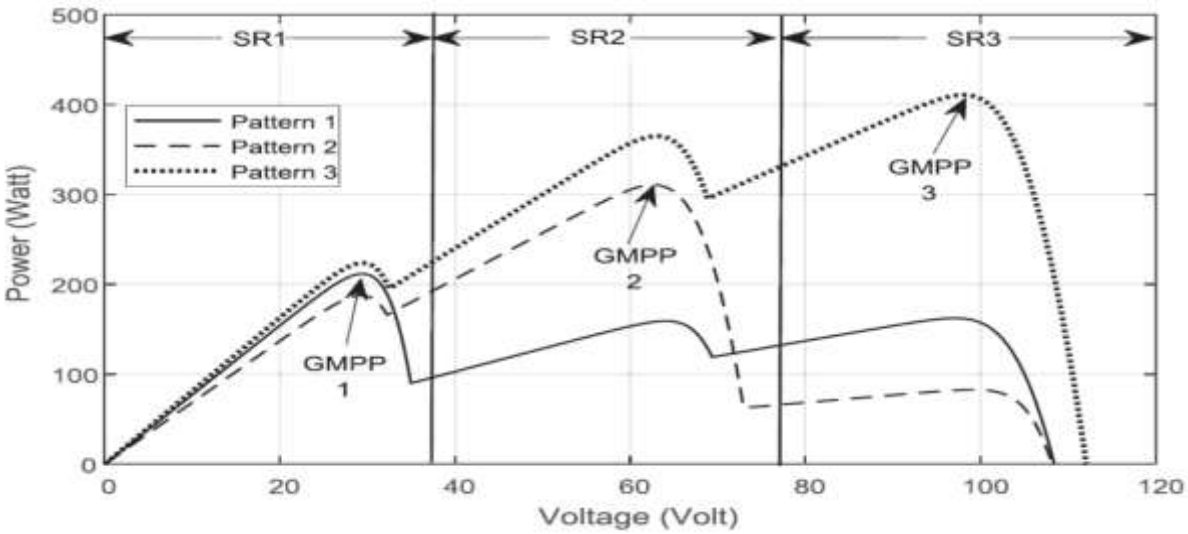

Fig. 4: P-V curve for different patterns

Proposed Controller: (Fuzzy+PI)

Fuzzy Logic System:

First-generation simple fuzzy logic controllers can generally be depicted by a block diagram. The knowledge-based module contains knowledge about all the input and output fuzzy partitions. It will include the term set and the corresponding membership functions defining the input variables to the fuzzy rule-base system and the output variables, or control actions, to the plant under control.

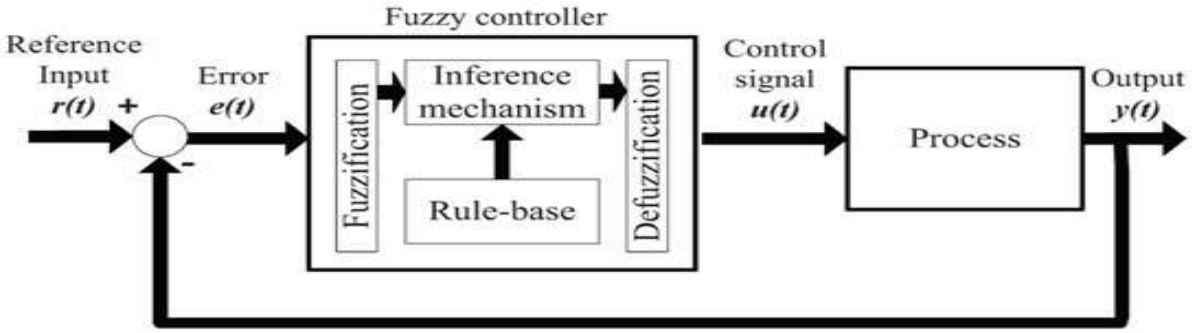

Figure.5: Simple Fuzzy Logic System

The fuzzy logic control system consists of two inputs error and change in error, error is obtained by comparing the reference input signal with output signal. This error is checked with respect to time that is called change in error and these are the basically two input of fuzzy logic controller. The fuzzy logic

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controller consists of three components fuzzification, inference mechanism and DE fuzzification which are explained in detail in below paragraph. When these inputs are given to fuzzy logic controller then fuzzy logic controller decided what would be the output of this controller using fuzzy rules which are settled by fuzzy controller designer. Similarly, the fuzzy logic controller output is given to output motor or machine after processing mechanism.

Fuzzy Logic Control System:

Fuzzy logic is a many valued logics in which truth values of variables may be any real number between 0 and 1. This logic is employed for obtaining the partial truth between true and false values. If we compare it with Boolean logic, then in Boolean logic there are only two integer values 0 and 1 but in fuzzy logic system linguistic variables are used means non-numeric values such as age temperature etc. with their relative degrees and these degrees are managed by membership function. Which are shown in figure 2

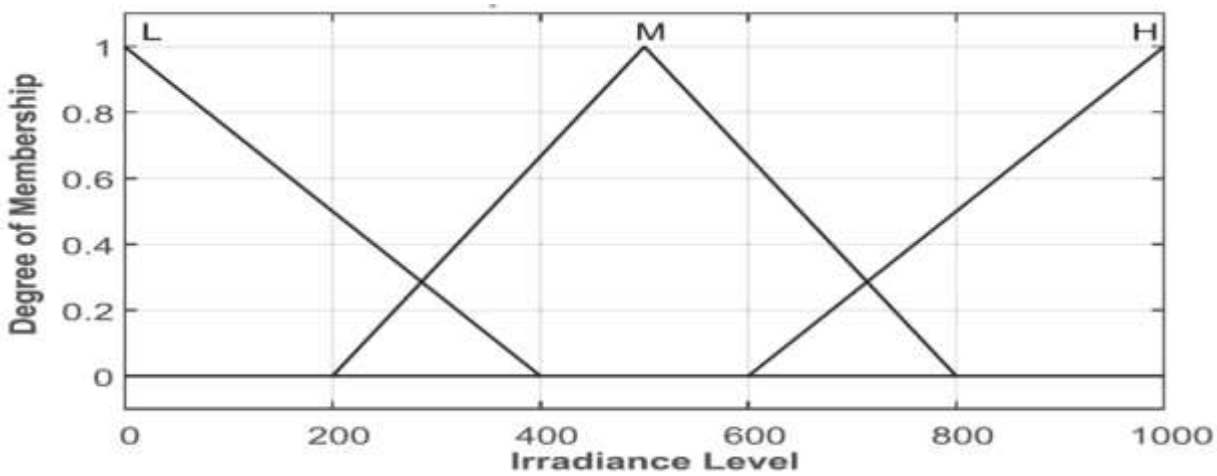

Figure.6: Fuzzy Logic Membership Functions of IR1, IR2 and IR3

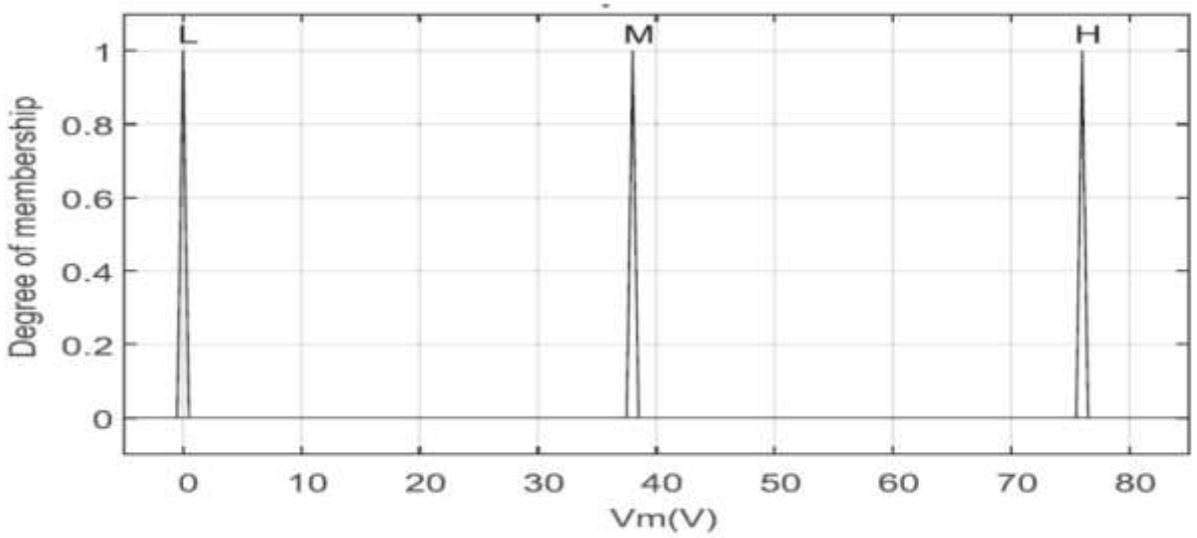

Figure. 7: Membership function of *Vref*

In inference step, a set of fuzzy rules are defined according to our prior knowledge of output pattern. In this step, Mamdani fuzzy inference method has been used. Table- III shows the 27 rules defined for the proposed fuzzy logic controller. In the last step, MOM (mean of maxima) method has been used for the defuzzification. Table-III shows the defuzzification outline for the proposed algorithm.

TABLE II: RULE BASE FOR FUZZY CONTROLLER

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Rule Number	Linguistic Inputs			Linguistic Output
	IR1	IR2	IR3	^{V}ref
1	HL	HL	HL	H
2	HL	HL	ML	H
3	HL	HL	LL	M
4	HL	ML	HL	H
5	HL	ML	ML	M
6	HL	ML	LL	M
7	HL	LL	HL	M
8	HL	LL	ML	M
9	HL	LL	LL	L
10	ML	HL	HL	H
11	ML	HL	ML	M
12	ML	HL	LL	M
13	ML	ML	HL	M
14	ML	ML	ML	H
15	ML	ML	LL	M
16	ML	LL	HL	M
17	ML	LL	ML	M
18	ML	LL	LL	L
19	LL	HL	HL	M
20	LL	HL	ML	M
21	LL	HL	LL	L
22	LL	ML	HL	M
23	LL	ML	ML	M
24	LL	ML	LL	H
25	LL	LL	HL	L
26	LL	LL	ML	L
27	LL	LL	LL	H

TABLE III: Defuzzification

Linguistic Variable (*Vref*)	Crisp Value (*Vref*)	Search Region (SR)
L	0	SR1
M	38.2	SR2
H	76.3	SR3

P & O Technique

Perturb and observe algorithm is the most suitable algorithm to track the MPPT in the non-linear PV curve. Once the search region is selected, the P & O algorithm is called to track the GMPP. In this method, perturbation is done in PV array voltage and array power is observed. If the power is increased by perturbation, then the perturbation is performed in the same direction [5]. Once the MPP is reached, the power at the next instant is decreased and then the direction of perturbation is reverse. At the steady state, this method oscillates around the MPP. To overcome this problem, perturbation size is kept very small.

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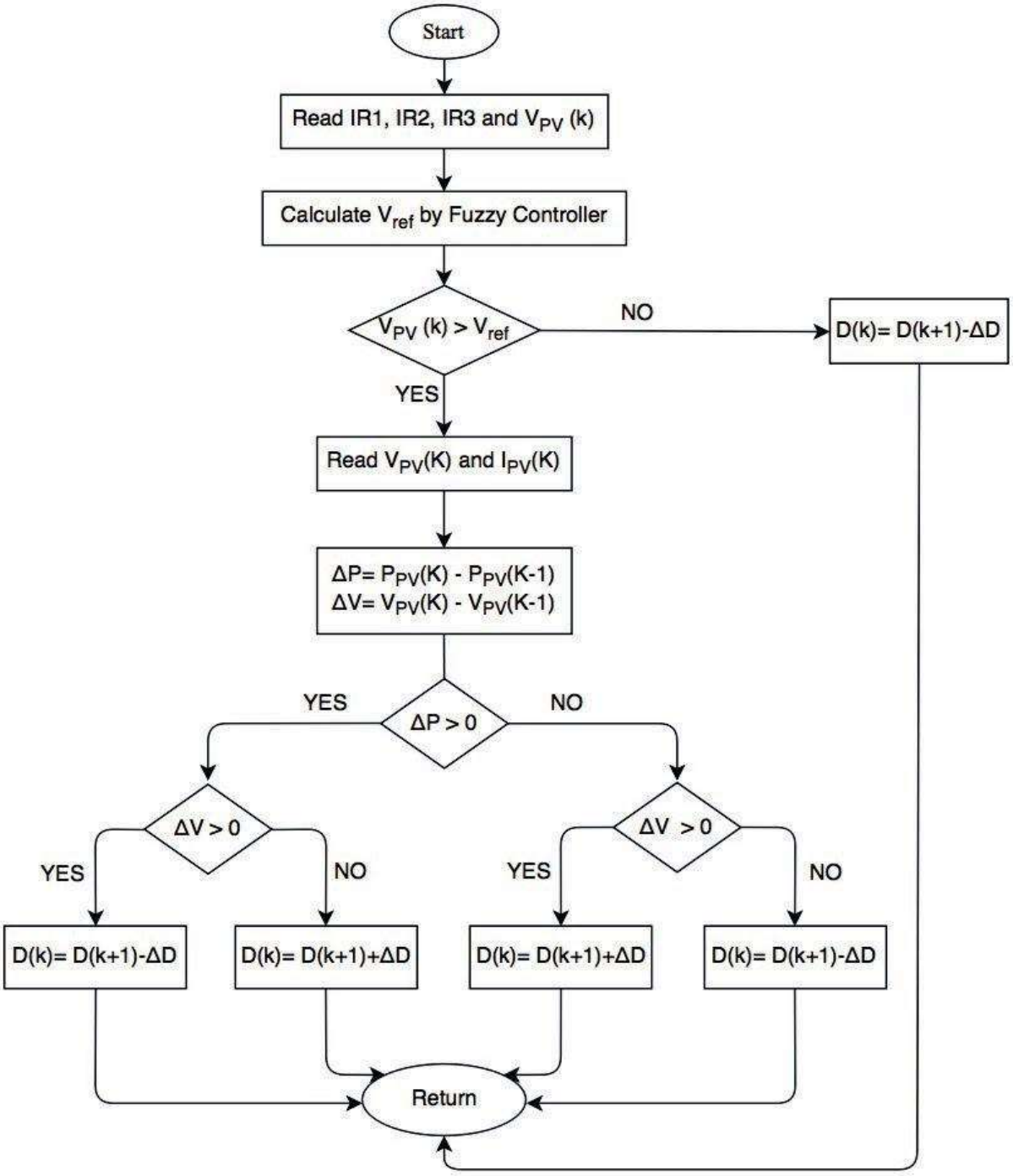

Figure. 8: Flowchart of proposed technique

Proportional Integral (PI) Controller

Proportional Integral controller sometimes also known as proportional plus integral (PI) controllers. It is a type of controller formed by combining proportional and integral control action. Thus, it is named as PI controller. In the proportional-integral controller, the control action of both proportional, as well as the integral controller, is utilized. This combination of two different controllers produces a more efficient controller which eliminates the disadvantages associated with each one of them. In this case, the control signal shows proportionality with both the error signal as well as with integral of the error signal. Mathematical representation of proportional plus integral controller is given as:

$$m(t) = K_p\, e(t) + K_i \int e(t) \qquad (1)$$

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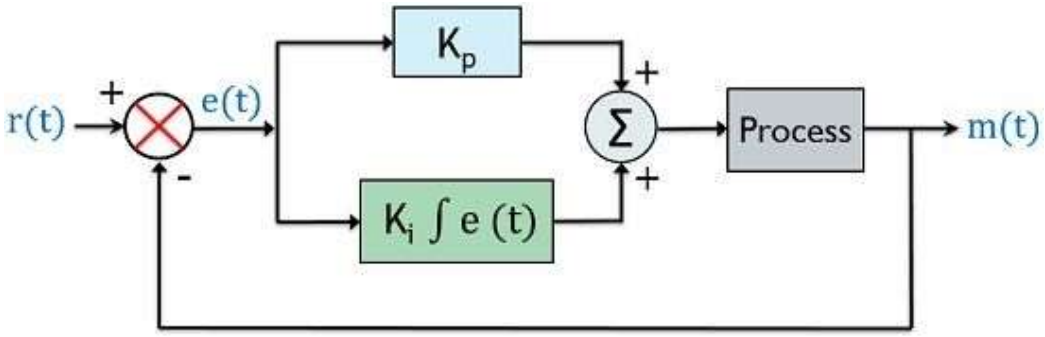

Figure 9: Control System with PI controller

IV. RESULTS & DISCUSSION

- To improve the maximum power using MPPT techniques under partial shading conditions.
- To reduce the settling time of MPPT technique under different irradiance values.
- To improve the overall efficiency of solar energy under partial shading conditions.

Simulation Results:

In this document, we analyse the results of a simulation run and talk about the effects of partial shading. Using the proposed hybrid MPPT method, the efficiency of a photovoltaic system can be improved in partially shaded environments.

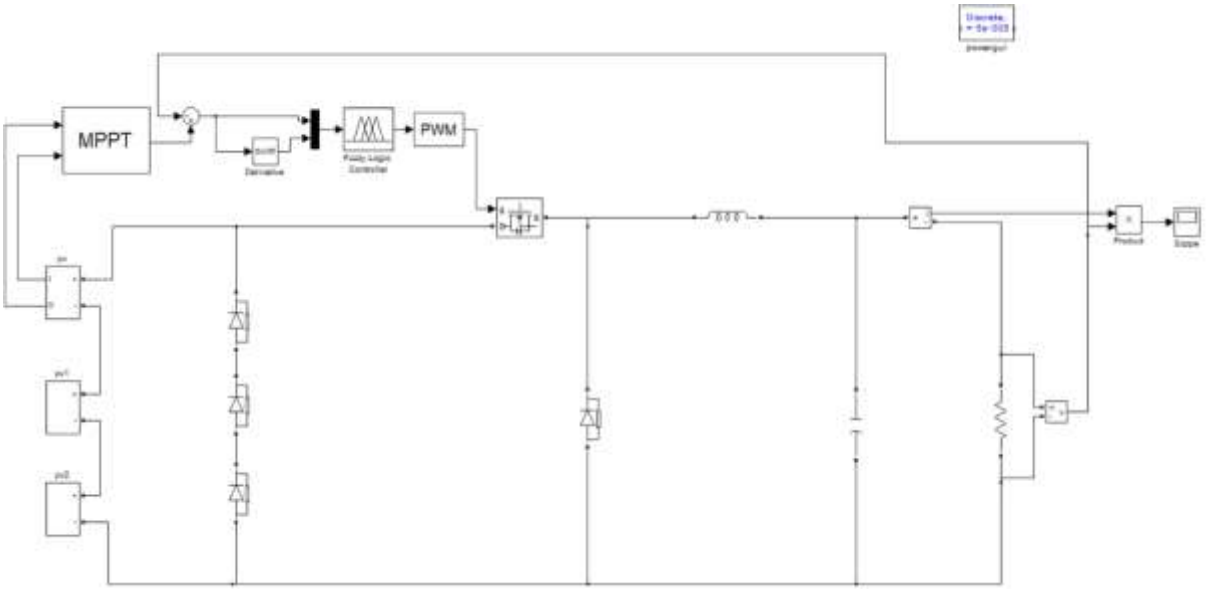

Figure.10: Simulink for MPPT system with fuzzy

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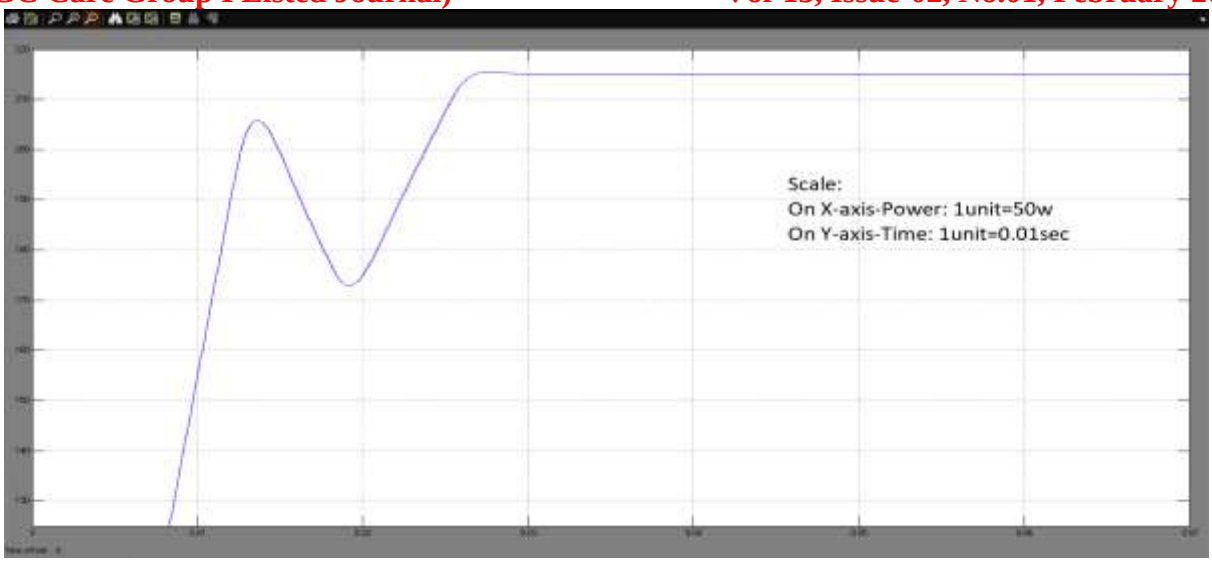

Figure.11: Output response for Pattern-1 Tracking result

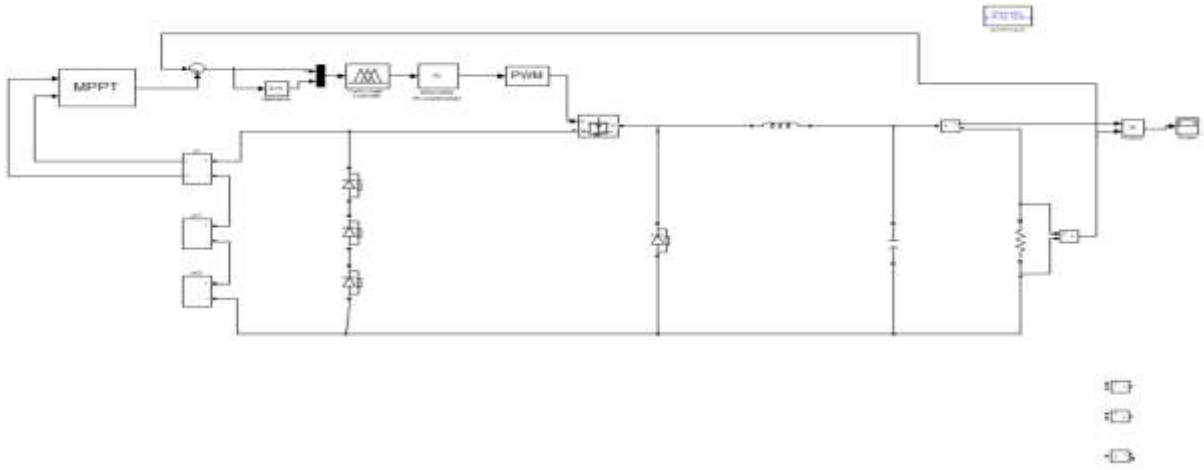

Figure.12: Simulink for MPPT system with fuzzy and PI

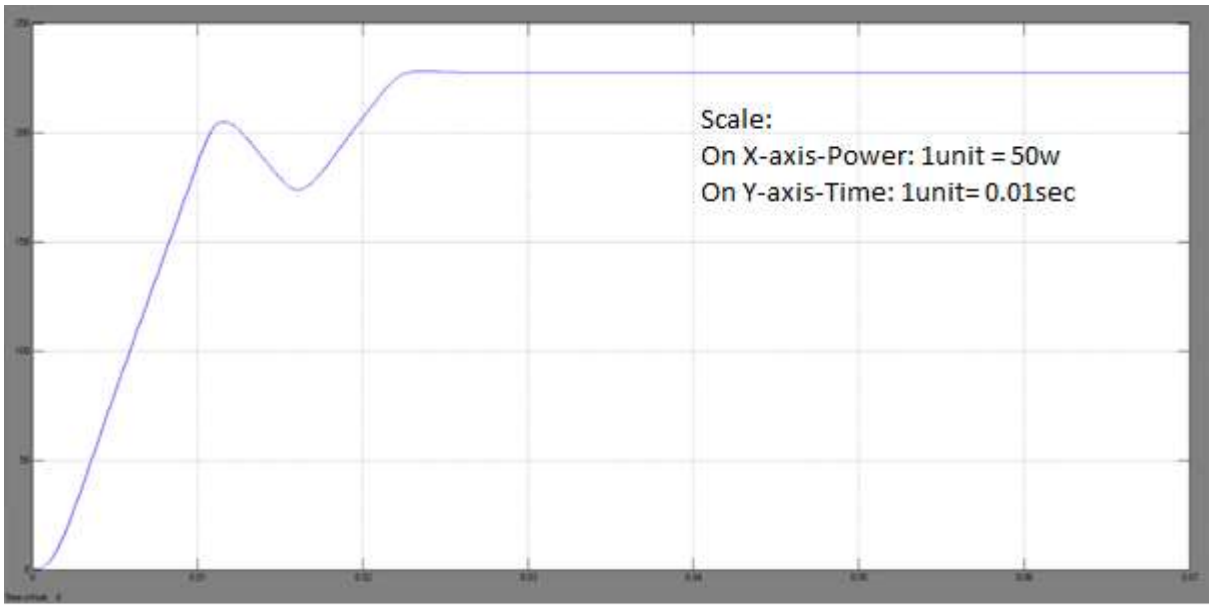

Figure.13: Output response for Pattern-1 Tracking result

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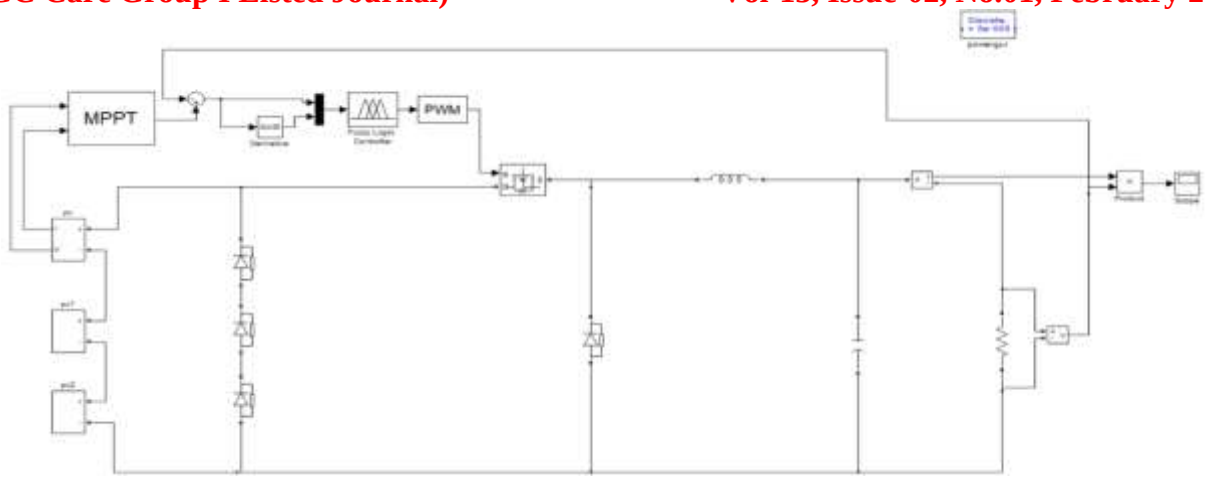

Figure.14: Simulink for MPPT system with fuzzy

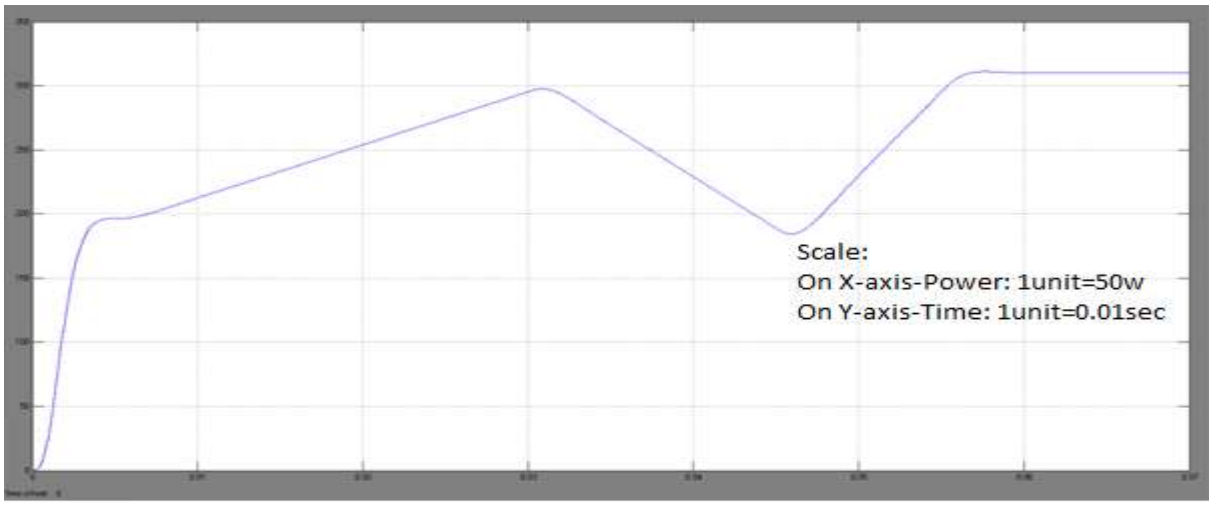

Figure.15: Output response for Pattern-2 Tracking result

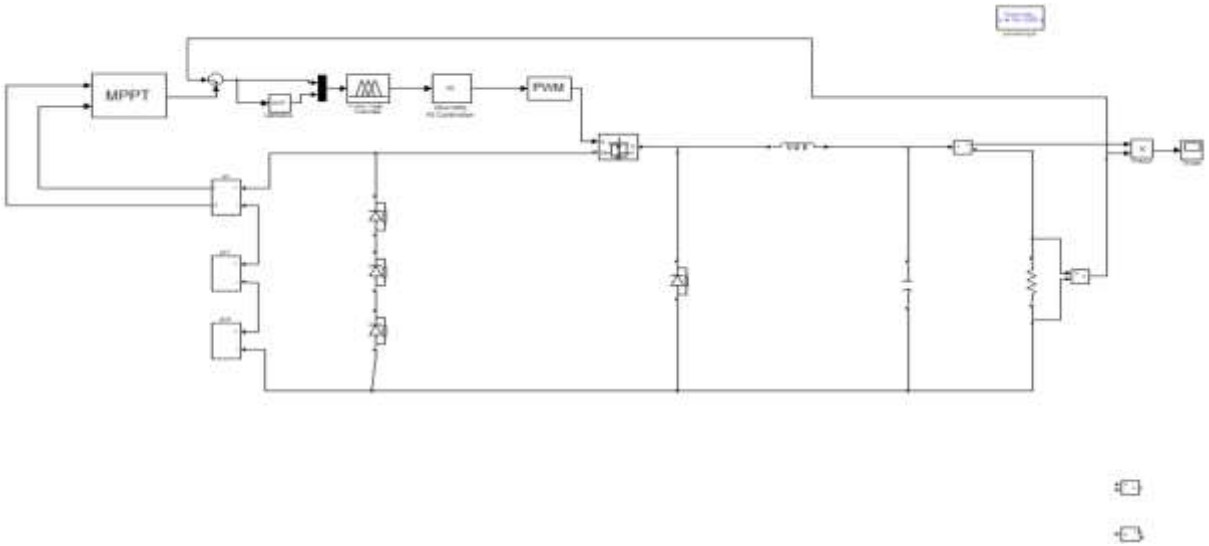

Figure.16: Simulink for MPPT system with fuzzy and PI

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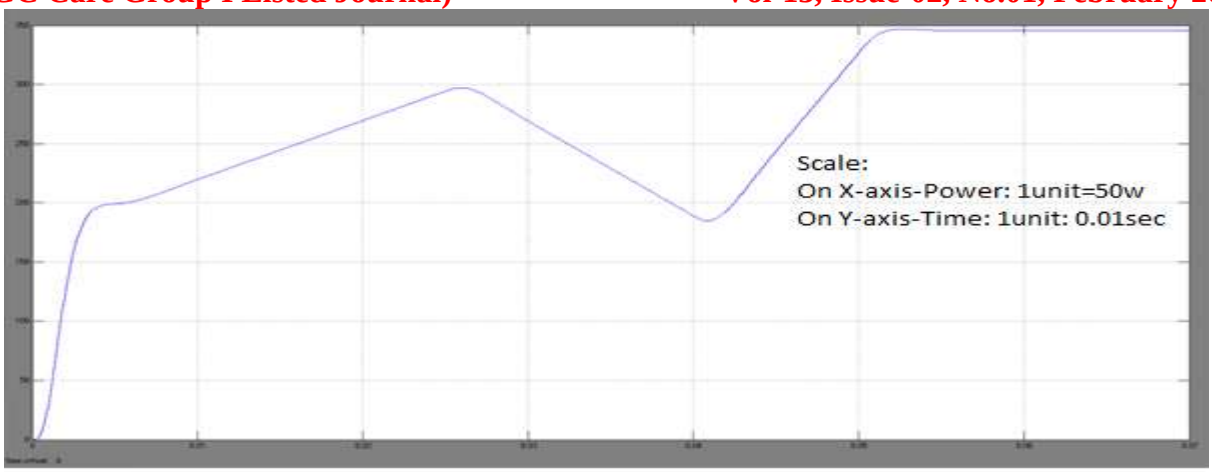

Figure.17: Output response for Pattern-2 Tracking result

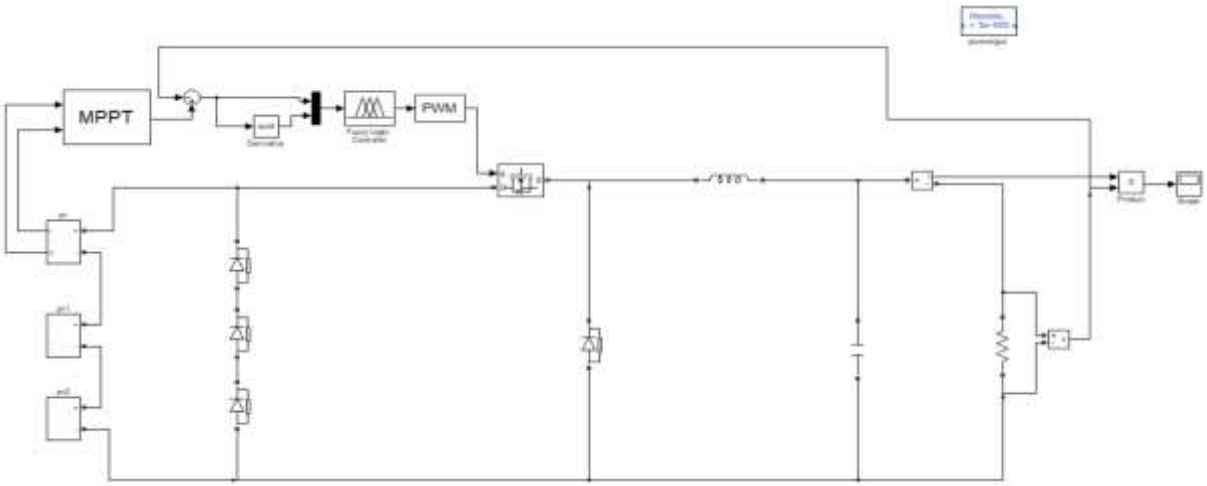

Figure.18: Simulink for MPPT system with fuzzy

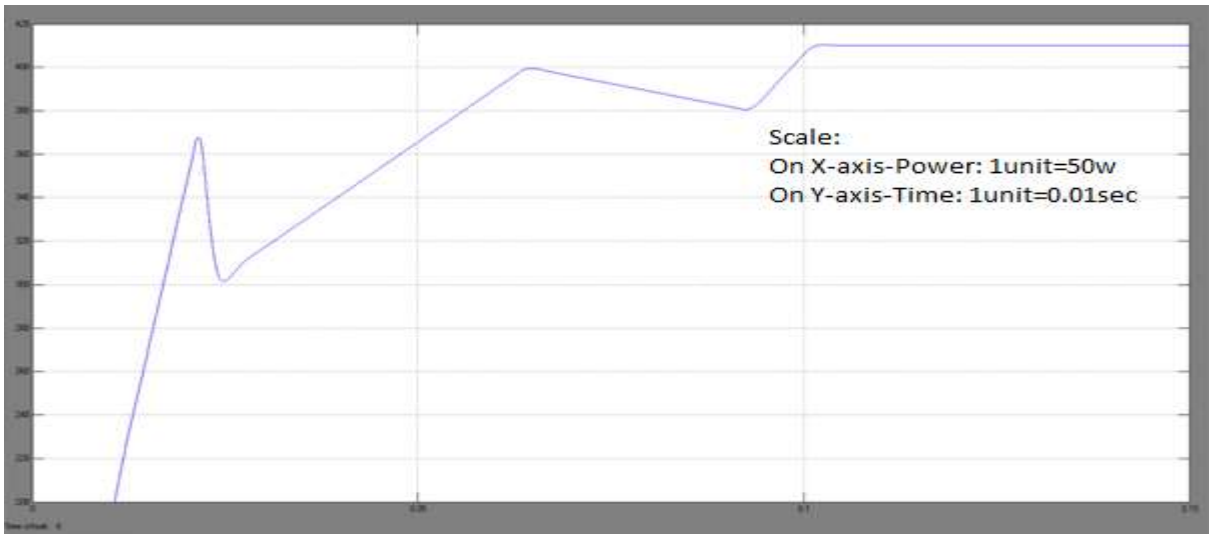

Figure.19: Output response for Pattern-3 Tracking result

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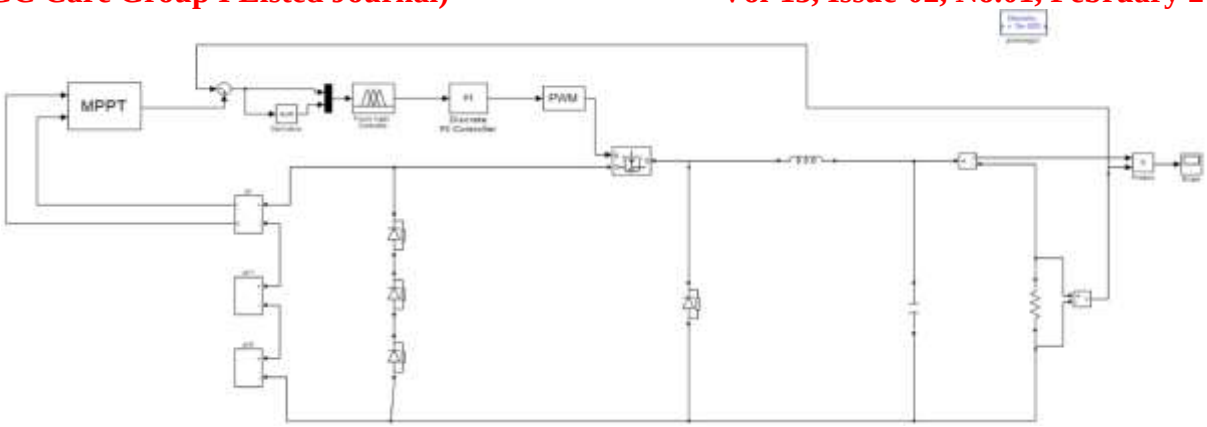

Figure.20: Simulink for MPPT system with fuzzy and PI

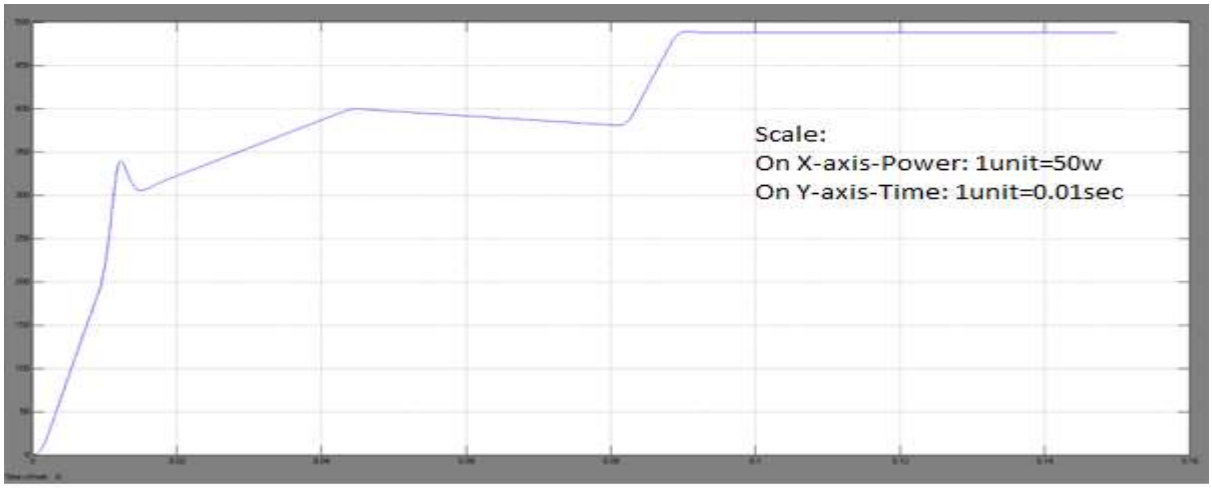

Figure.21: Output response for Pattern-3 Tracking result

- ✓ The simulation results are examined, and the results of using partial shading are discussed.
- ✓ The efficiency of a photovoltaic system can be increased in partially shaded environments by employing the hybrid maximum power point tracking (MPPT) method that has been proposed.
- ✓ The following tables provide an explanation of the output response for the Pattern/Irradiance analysis and comparisons.

Table IV: Output response for Pattern/ Irradiance analysis

Pattern/Irradiance	Max Power (watt)		Settling Time (sec)	
	FLC	PI + FLC	FLC	PI + FLC
Pattern 1	211.48	227.45	0.0288	0.0285
Pattern 2	310.27	345.98	0.061	0.0543
Pattern 3	409.86	487.89	0.1048	0.0921

V. CONCLUSION

This project presents a hybrid method for tracking the maximum power point for photovoltaic (PV) energy generators in environments that have some level of partial shading (MPPT). Even though the perturb and observe (P&O) algorithm is frequently utilized for maximum power point tracking (MPPT), there is a possibility that it will not converge to the global maximum power point if the P-V curve has multiple peaks that are affected by partial shading

carries out an investigation into the effects of partial shading, and then discusses how the model reacts to those results.

With the hybrid MPPT method that was just proposed, the efficiency of a photovoltaic system can be increased while at the same time the amount of time needed to implement the technique can be reduced through the use of simulation, it has been shown that the proposed algorithm is efficient.

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