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Research Article

Maximum Power Point Tracking with Incremental Conductance and Fuzzy Logic Controller in Solar Energy Systems

Murat Lüy[1a], Nuri Alper Metin[2b] Zafer Civelek[3c]
[1] Kırıkkale University Electrical and Electronics Engineering Kırıkkale, Turkey
[2] Kırıkkale University, Kırıkkale Vocational School, Electronic Communication Program, Kırıkkale, Turkey
[3] Çankırı Karatekin University, Electrical and Electronics Engineering, Çankırı, Turkey

nurialpermetin@kku.edu.tr

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ORCID: [a]0000-0002-2378-0009; [b]0000-0002-9962-917X. [c]0000-0001-6838-3149.

Abstract : Energy benefits both individuals and nations. Humanity's reliance on fossil fuels and inability to respond increases depletion. Energy supplies are rapidly decreasing. Electricity use causes the energy crisis. Sustainable energy essentially meets the energy demand of the growing population. In addition, it benefits the environment by reducing carbon emissions. In this situation, sustainable energy sources have supplemented traditional energy sources and promoted sustainable energy use. Solar, wind, and fuel cell energy are examples of sustainable energy. Power-generating facilities are employed nowadays because of their extended lifespan, inexpensive maintenance, no hazardous waste, and independence from dwindling energy sources. Solar power generation depends on environmental circumstances; hence MPP generation must be observed. MPPT follows the solar panel's highest MPP. This study involves a system comprised of a DC-DC boost converter, a PV panel, and an ohmic load. The IC and FLC MPPT algorithms generate the duty ratio, and the PWM signal is generated by comparing it with the triangle wave. This generated signal is applied to the DC-DC boost converter. This research investigates the effectiveness, variability, and duration required to attain the MPP of the implemented MPPT methods. The system has been developed within the Matlab/Simulink framework. Based on the simulation findings, it has been determined that the FLC MPPT algorithm achieves the MPP faster than the IC MPPT algorithm. Consequently, the fluctuation level is minimal, and the efficiency is high.

Keywords : Fuzzy Logic Controller (FLC), Incremental Conductance (IC), Maximum Power Point Tracking (MPPT).

1 Introduction

Energy is in a crucial position to preserve human existence, satisfy their requirements, and improve the quality of life. Energy is the capacity to accomplish tasks in its most basic form. The amount of energy used globally has significantly increased throughout time for various causes, including an increase in the human population, alterations in societal norms, an increase in productivity, and technical advancements. Energy output should be boosted to fulfill the nation's energy demands. Around 80% of the energy utilized worldwide is generated in power plants using coal and natural gas as the primary fuels [1, 2, 3].

Due to the release of toxic gases like carbon, sulfur, heavy metals included in the soil, and many other waste products into the atmosphere during the production of energy process, it is believed that the finite resources of fossil fuels on earth will have severe consequences on nature and all living things over time. The sun provides more energy daily than is used to supply renewable energy globally, rendering solar energy a viable alternative [1, 2, 3].

Renewable energy sources have garnered significant attention due to oil depletion and other non-renewable fossil fuels. In recent times, solar energy has emerged as a popular choice among various renewable energy alternatives owing to its minimal maintenance needs, non-polluting operation, and absence of fuel expenses. The primary drawback of the PV system is its suboptimal overall energy conversion efficiency. MPP of a PV module is subject to variation due to the non-linear characteristics of the system, which are influenced by changes in irradiation intensity and temperature. Using MPPT algorithms is crucial to effectively monitor and capture the maximum power output from PV modules across varying irradiation levels, thereby ensuring optimal efficiency [1, 2, 3].

DC voltage and current transmit the voltage and current generated by solar panels to the load. However, DC voltage is generated by PV panels. Power electronic circuits are utilized to elevate the magnitude of electrical power, whether high or low, to a suitable level based on the load requirements. The efficacy of solar panels is influenced by various factors such as sun shadowing, panel pollution, solar panel orientation concerning the sun, and voltage and current output. Considering these impacts, the solar panel's efficiency is approximately 20%. Historically, various algorithms such as P&O, IC, open and short-circuit, fuzzy logic, and sliding mode have been employed to optimize the efficiency of solar panels, aiming to achieve MPPT. Integrating heuristic algorithms into MPPT algorithms can offer alternative MPPT algorithms [1, 2, 3].

This study utilizes a DC boost converter to control power transmission in PV systems. The study entailed the implementation of IC and FLC algorithms, MPPT, and simulation analyses under different irradiance levels via the Matlab/Simulink platform. The simulation studies have revealed that the FLC MPPT algorithm demonstrates diminished oscillation at varying irradiation levels at the MPPT and accomplishes quicker attainment of the MPP compared to the IC algorithm. The effectiveness of MPPT in PV systems can be improved by incorporating techniques such as enhanced IC and FLC algorithms. Implementing algorithms can improve the effectiveness of solar power systems by expediting and streamlining the acquisition of the solar panel system's MPPT, particularly when confronted with variable irradiance circumstances.

1.1 Literature Review

Lüy et al., the exponential increase in the world's population has resulted in a significant upsurge in the investigation and development of sustainable energy alternatives. This initiative aims to alleviate the exhaustion of petroleum and its derivatives, frequently employed for energy production, while also addressing the detrimental consequences of exhaust fumes like carbon monoxide and methane. Renewable energy sources include wind turbines, fuel cells, and solar panels. The study examined solar panel systems, specifically focusing on the configuration of MPPT with a DC boost converter and P&O, IC, and PSO algorithms utilizing a Matlab/Simulink environment. This study involving simulations was carried out using different levels of irradiation. The simulation studies have revealed that the PSO-MPPT algorithm demonstrates decreased oscillation levels across different irradiation levels at the MPPT and attains the MPP more efficiently than the P&O and IC algorithms [4].

Shiau et al., The implementation of MPPT is essential to solar energy deployment, as it optimizes solar power management systems. This study investigates the advancement of MPPT algorithms for solar power by implementing fuzzy logic and incorporating various fuzzy input variables. The present investigation scrutinized six discrete MPPT algorithms that employ diverse input variables. The algorithms encompass the following aspects: (i) the correlation between the slope, solar power, and voltage fluctuations; (ii) the fluctuations in power slope and its variability; (iii) the variability in power and voltage; (iv) the variability in power and current; (v) the summation of conductance and its incremental changes; and (vi) the summation of the angles of the arctangent of conductance and the arctangent of the incremental changes in conductance. Algorithms (i) to (iv) exhibit the property of having two input variables, while algorithms (v) and (vi) are specifically devised to function with a solitary input variable. The implementation of a buck-boost converter is utilized for the deployment of the FLC MPPT function. The current research elucidates the precise determinations and considerations related to fuzzy rules, in addition to evaluating the advantages and disadvantages of distinct MPPT algorithms that depend on the properties of PV cells. The algorithm's input variable (vi) is bounded within a finite range, and the MPP condition is unambiguously specified in a state of equilibrium. Consequently, it can be employed to develop a versatile controller. The validity of the design is confirmed through the utilization of computational simulations [5].

Teke et al., The generation and preservation of electrical energy is a crucial aspect of human existence, necessitating exploring methods to produce and maintain a consistent supply. It is imperative to undertake measures to prevent any potential harm. Using fossil fuels as the primary source of electrical energy has been a longstanding practice. However, the escalating expenses and amplified demand for electrical energy resulting from technological advancements, widespread scarcity, and significant population expansion have underscored the need for renewable and sustainable energy production. Solar power is an effective form of sustainable and eco-friendly energy. Notwithstanding its potential, solar energy exhibits low efficiency, prompting researchers to explore strategies for enhancing its efficiency. The utilization of MPPT methodology is commonly recognized to augment the effectiveness of modern PV systems. To enhance the efficiency of MPPT, researchers should develop and implement a series of algorithms that can be utilized in MPPT technology for PV modules under diverse measurement conditions. The principal aim is to enhance the power output of a DC-DC converter through the regulation of its duty cycle to achieve a predetermined threshold. The objective of the current study is to utilize three discrete algorithms within the framework of the MPPT methodology. The study examines three distinct algorithms: the P&O algorithm, the FLC algorithm, and the PSO algorithm. Matlab/Simulink was employed to simulate the PV system designs, and the results of the simulations were standardized and compared under different testing conditions. The algorithm that demonstrated the highest efficiency was the PSO algorithm. [6].

Vimalarani et al., this study consists of a PV panel, DC-DC converter, and load power stand-alone and grid-connected PV systems. Despite changing solar irradiation and cell temperature, PV panels and DC-DC converters integrate MPPT into MPP production. An efficient and dynamic MPPT method is required to observe and respond to environmental changes while reducing energy losses. This work introduces an intelligent controller-based MPPT method for freestanding PV systems to MPPT. This study uses hybrid P&O, IC, and ANN to achieve the goal. These methods are compared for effectiveness. A deep learning network trains a SAE building component to maximize solar panel power output. SAEs maximize solar panel power.

Table 1: Literature Review Summary

Literature Review	MPPT Algorithms
Lüy et al. (2022)	P&O, IC, PSO
Shiau et al. (2015)	FLC
Tek et al. (2023)	P&O, FLC, PSO
Vimalarani et al. (2018)	IC-ANN, P&O-ANN
Djalab et al. (2018)	P&O, IC, FLC
Reddy et al. (2018)	P&O, FLC, RBFN
Cheng et al. (2015)	FLC, P&O
Kayisli (2023)	Sliding mode-type2
Abouobaida (2023)	IC
Farah et al. (2020)	FLC, ANFIS

The suggested method uses greedy layer-wise pattern training and backpropagation with supervised learning for fine-tuning. Optimizing the deep ANN for IC and P&O metrics maximizes power. A single-diode model in Matlab/Simulink is used to analyze PV arrays. In contrast to other methods, the hybrid IC-ANN control scheme and SAE's MPPT approach can effectively observe maximum power output with reduced oscillations during weather and load changes [7].

Djalab et al., The optimal operation of the solar system is contingent upon the crucial function performed by the MPPT control module. The directive serves a dual purpose of safeguarding and conserving the MPPT while facilitating the PV generator to produce its optimal power output despite variations in meteorological conditions. The variables being considered are sunshine and temperature. This research aims to perform a comparative evaluation of diverse methodologies employed for monitoring the MPP of a solar panel array. This study utilizes Matlab/Simulink to model the efficacy of P&O, IC, and FLC methodologies under unstable weather conditions, aiming to highlight each approach's benefits [8].

Reddy et al., In power generation systems, DC-DC converters transfer power between the load and PV source. In this research, a three-phase IBC is used in conjunction with a high-voltage-gain stand-alone PV system. Interleaving improves power capacity and decreases voltage stress on power semiconductor devices. MPPT is used in PV systems to identify and maintain the PV panel's peak power production. This research introduces an RBFN-based MPPT algorithm to maximize power drawn from PV panels. This technique maximizes the energy output of PV panels under a wide range of lighting conditions. In this research, a three-phase IBC with high voltage gain and an RBFN-based MPPT controller were tested, and their power output was compared to that of the more common P&O and FLC MPPT algorithms. The analysis calls for varying degrees of irradiation. Using a three-phase IBC with a high voltage gain, Matlab/Simulink compares the P&O, FLC, and RBFN MPPT approaches [9].

Cheng et al., This study proposes asymmetrical FLC-based MPPT for PV systems. Two membership function (MF) design techniques are added to the suggested asymmetrical FLC-based MPPT approaches. The first technique uses PV cell power-voltage (P-V) curves under STC to quickly identify input MF configuration settings. PSO is the second input MF setting optimization method. Because the PSO technique aims to optimize a cost function, a method for designing a cost function that satisfies the performance requirements of the PGS is also presented. An asymmetrical FLC-based MPPT technique effectively addresses the challenge of tracking speed and accuracy, as it exhibits the most optimal fitness value. The recently developed optimal asymmetrical FLC-based MPPT technique performs better than the conventional FLC-based MPPT method. Specifically, it can extend a short duration by 25.8% and improve the MPPT tracking accuracy by 0.98% under STC. [10].

Kayisli, renewable energy demands are increasing even as non-environmental energy consumption decreases. Solar energy is at the forefront. This study uses reliable sliding mode control for MPPT control. A type 2 fuzzy set and super-twisting sliding mode controller reduce chattering. A solar PV system tests the new MPPT control algorithm under different irradiation circumstances. They are optimized super-twisting sliding mode and type 2 fuzzy set parameters. The operation of the super twisting sliding mode-type 2 fuzzy MPPT, the sliding mode MPPT, and the sliding mode MPPT are shown in tables and figures. The observed findings have proven the suggested MPPT system's efficiency. [11].

Abouobaida et al., This study optimizes IC MPPT. The goal is to balance detection time, which defines MPPT speed, and precision, which determines the distance between the operational and target points and efficiency. The offered solution employs a variable step based on the power generated and needed to attain this goal—the burden. The proposed optimization method is simple and inexpensive. The required optimization defines the resistance bridge's PV voltage and duty ratio. A QBC is better since it has a more significant gain and can work with low-voltage PV sources. PV source and QBC simulations are discussed separately. FLC alters PV voltage due to the QBC's nonlinearity. Matlab /Simulink simulations demonstrate that the proposed method works for various irradiation and temperature levels. According to a comparison, the proposed technique outperforms others in speed, accuracy, efficiency, and MPP fluctuation rate. [12].

Farah et al., This study introduces FLC to achieve MPPT in PV systems. The MPPT algorithm is compared to an ANFIS MPPT controller. This method shows how ANN learns and how FLC handles inaccurate data. Matlab/Simulink simulates both methods. Power and current fluctuation inputs reduce processing needs for the recommended controllers. FLC and ANFIS MPPTs are tested to assess PV system dynamics and steady-state performance [13].

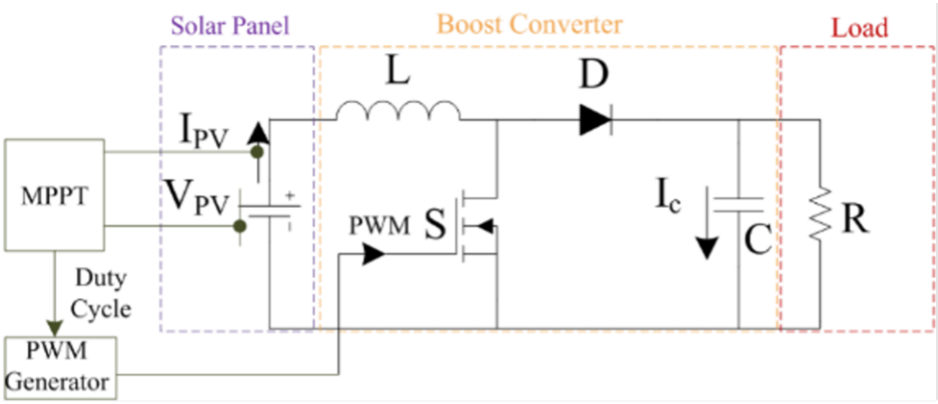


Figure 1: System description diagram

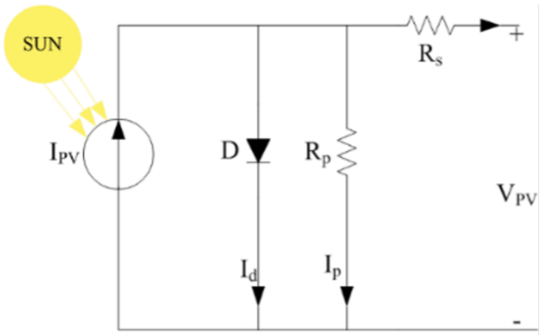


Figure 2: PV panel equivalent circuit

2 Materials and Methods

2.1 System Description

The system comprises a solar panel, DC-DC boost converter, MPPT algorithm, and ohmic load. The DC-DC boost converter and MPPT algorithms directly take the voltage and current produced by the PV panel. The duty ratio is obtained from the MPPT algorithms. The resulting duty ratio is compared with a triangle wave with a unit amplitude switching frequency. After the comparison process, the PWM signal is generated. This way, voltage and current values can be measured at the desired level over the ohmic load. Figure 1. The system diagram is shown.

2.2 PV Mathematical Model

PV panels include P-N connections. PV panel equivalent circuit is shown in Figure 2. The diagram shows the solar panel module current (I_{PV}), the reverse parallel diode current (I_d), the series resistance (R_s) of semiconductor materials, and the resistance of the shunt (R_p) of current-leakage losses through the P-N junction [14, 15, 16, 17].

Figure 2 shows a PV cell as the current source, diode, shunt (R_p), and series resistor (R_s). The mathematical expression of a single diode PV cell is given in Equation (1).

$$I = I_{PV} - I_0 \left[exp\left[\frac{V + R_s I}{N_s V_t a} \right] - 1 \right] - \frac{V + R_s I}{R_p} \tag{1}$$

PV module output current is I, voltage is V. I_{PV} is the solar module current, and I_0 is the saturation current. The thermal voltage of a solar module is V_T=kT/q, where k is the Boltzmann constant, T is Kelvin temperature, and q is the electron's electric charge, Diode ideality constant is a. Temperature, irradiance, and mathematical formulae affect the photovoltaic module's energy production. Equations (2-4) are given irradiation and temperature-dependent change [14, 15, 16, 17].

$$I_{PV} = I_{PV,n} + K_I \left(T - T_n \right) \frac{G}{G_n} \tag{2}$$

$$V_{oc} = V_{oc,n} + K_V \left(T - T_n \right) \tag{3}$$

$$I_0 = \frac{I_{sc,n} + K_I (T - T_n)}{exp\left[\frac{V + R_s I}{N_s V_t a} \right] - 1} \tag{4}$$

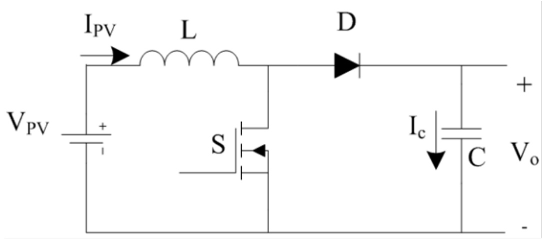


Figure 3: Circuit diagram of the DC-DC boost converter

2.3 DC-DC Boost Converter

A DC-DC boost converter is a power electronic device that periodically switches to generate load voltage that lifts the PV voltage. The boost converter is powered by the accumulation of energy in the inductor. The boost converter comprises an inductor, diode, MOSFET, and capacitor [15, 16]. Figure 3 shows the DC-DC converter.

DC-DC Boost converters are switching-mode regulators that lift voltage from input to output. DC-DC boost converters are responsible for regulating the voltage of the load. The duty cycle determines the PV array's MPP. Equation (5) gives the duty ratio [15, 16].

$$V_o = \frac{V_{PV}}{(1-D)} \tag{5}$$

Knowing the critical inductance and critical capacitance values for the continuous conduction mode is essential to producing continuous current across the load. The critical value of inductance for the boost converter to operate in continuous mode is given in Equation (6) [15, 16].

$$L \geq \frac{V_{PV} \cdot D}{\Delta i_L \cdot f_s} \tag{6}$$

The inductor's critical value, L, is the point at which the load current begins to flow steadily. For optimal performance, choose an inductance value higher than the critical value. [15, 16].

The capacitance value denoted by C is the minimum requirement for the capacitor voltage to exhibit continuous behavior. The capacitance value must exceed the critical value. The critical value of capacitance for the boost converter to operate in continuous mode is given in Equation (7) [15, 16].

$$C = \frac{V_o \cdot D}{2 \cdot f_S \cdot R \cdot \Delta \mathrm{V}} \tag{7}$$

2.4 MPPT Algorithms

MPPT is an acronym for the specific point at which PV panels generate the highest power output level. MPPT systems and equipment are employed to determine the MPP. The MPPT technique includes the determination of the maximum voltage (V_{MPP}) and current (I_{MPP}) values that result in the maximum possible power output (P_{MPP}) from a solar panel based on a particular level of solar irradiation [18, 19, 20].

The MPPT of solar panels is subject to variation due to a range of environmental factors, including the amount of solar irradiation, the angle of irradiation, the temperature of the panel, the presence of shading, and the cleanliness of the panel surface. The fluctuating parameters associated with solar panels prevent the continuous attainment of maximum power. Various techniques for MPPT have been devised to consistently achieve maximum power output from solar panels [18, 19, 20].

MPPT algorithms are indispensable in PV applications due to the variability of the MPP of a PV panel in response to changes in irradiation and temperature. Therefore, MPPT algorithms are imperative to achieve a PV array's highest possible power output. The P&O and IC algorithms are widely utilized due to their ease of implementation, rendering them the most prevalent algorithms among the available options. Under typical circumstances, the P-V curve exhibits a solitary point of maximum value, thereby precluding any issues. In the event of partial shading of the PV array, the curves exhibit multiple maxima [21].

2.4.1 IC MPPT Algorithm

The utilization of the IC algorithm is aimed at regulating the terminal voltage of the PV panel in conformity with the voltage at the MPP. Once the MPP is attained, the IC algorithm terminates its motion and stabilizes at the designated operating point. The MPP is achieved by assessing the rapid conduction (I/V) concerning incremental conductance (I/V). The determination of MPP can be accomplished by utilizing the inverse relationship between the power derivative concerning voltage (dP/dV) and the placement of the MPPT concerning the MPP. The power derivative concerning voltage, dP/dV, exhibits a negative value

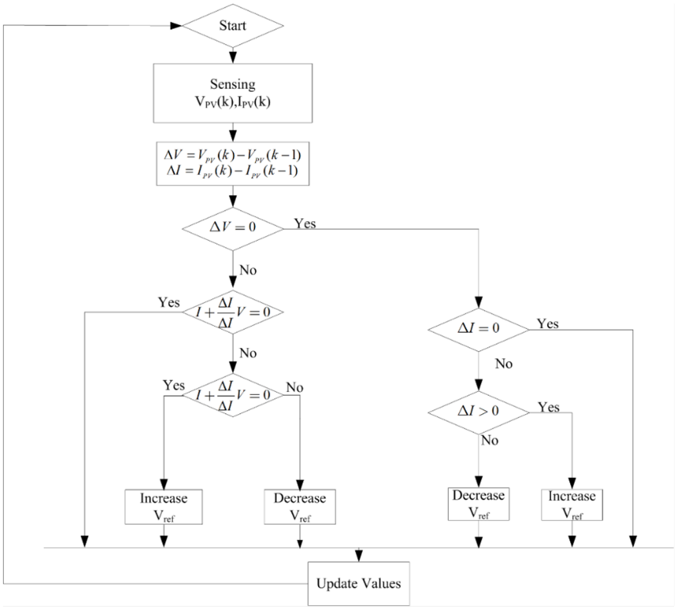


Figure 4: Flowchart of IC algorithm

when the MPPT is positioned to the right of the MPP. Conversely, it displays a positive value when the MPPT is situated to the left of the MPP [18, 19, 20].

The IC algorithm analyses the gradient of the power characteristics of the PV array to observe the MPP. Once the gradient of the power curve of the PV panel reaches zero, the MPP is determined. The equations of the IC MPPT algorithm are given in Equations (8-10) [18, 19, 20].

$$\frac{dP}{dV} = 0 for V = Vmpp \tag{8}$$

$$\frac{dP}{dV} > 0 \quad for V < Vmpp \tag{9}$$

$$\frac{dP}{dV} < 0 \quad for V > Vmpp \tag{10}$$

The IC algorithm determines where the slope of the output power of the solar panel is zero as the MPPT, where the slope is positive as the left of the MPP, and where the slope is negative as the right of the MPP [18, 19, 20]. The diagram of the IC MPPT algorithm is shown in Figure 4.

2.4.2 FLC MPPT Algorithm

Fuzzy systems are founded on the principles of fuzzy set theory and related methodologies that Lotfi Zadeh originally introduced. The proposed approach is a non-linear control methodology that aims to incorporate the expertise of a skilled operator in developing a fuzzy logic controller. The FLC consists of four regions. The fuzzification process involves mapping precise numerical values onto fuzzy input sets, subsequently utilized to activate rules. The regulations delineate the controller's conduct using a series of IF-THEN clauses. The inference engine executes rules to map fuzzy input sets to fuzzy output sets during fuzzy set mapping. On the other hand, the defuzzifier is responsible for mapping fuzzy output values to crisp values[22, 23, 24]. The FLC block diagram is shown in Figure 5.

FLC is a method that facilitates the development of non-linear controllers by utilizing heuristic data obtained from expert knowledge. Figure 5 shows the block diagram of an FLC. The fuzzification block is responsible for processing the input signals and assigning them a fuzzy value. The assemblage of directives is based on procedural expertise and facilitates the management of a linguistic depiction of the factors. The mechanism responsible for interpreting data while considering the rules and their corresponding membership functions is known as the inference mechanism. The defuzzification block transforms the imprecise information generated by the inference mechanism into precise information that can be effectively utilized for process management [22, 23, 24].

Equations (11 and 12) respectively, depict the two input parameters of FLC, namely error (E) and change of error (C_E) at discrete time instances denoted by k. The generated result is a PWM signal which regulates the DC-DC boost converter [22, 23, 24].

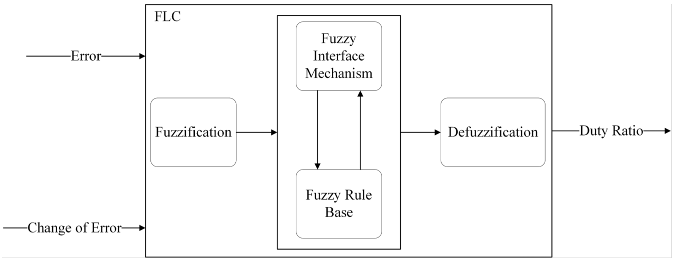


Figure 5: Block diagram of FLC

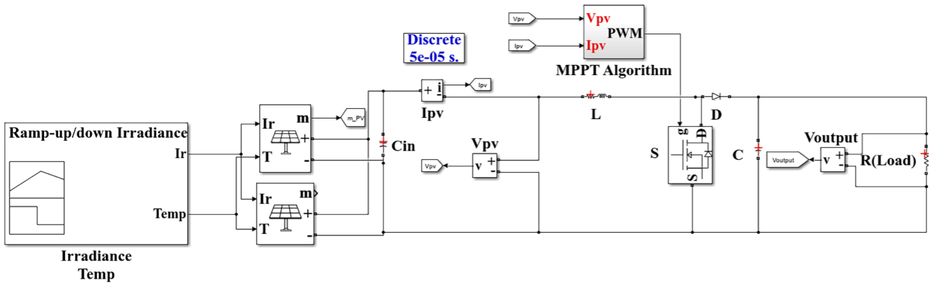


Figure 6: Matlab/Simulink circuit diagram

$$E(k) = \frac{P_{pv}(k) - P_{pv}(k-1)}{V_{pv}(k) - V_{pv}(k-1)} \tag{11}$$

$$C_e(k) = E(k) - E(k-1) \tag{12}$$

where PV panel power and voltage are $P_{pv}(k)$ and $V_{pv}(k)$, respectively.

3 Result and Discussion

In this study, MPPT was carried out using FLC MPPT algorithms and IC following varying irradiance values. The panel power and power values over the load in the system were studied at various irradiance levels. The maximum power access time and MPPT of the FLC and IC MPPT algorithms were compared by utilizing panel and output power. Matlab/Simulink was used for the system design process. The system's Matlab/Simulink circuit diagram is shown in Figure 6.

A PV panel design is created by joining 8 serial and 8 parallel modules. Table 2 gives the panel specifications. Figure 7 shows the solar panel's MPP, current, and voltage curves under constant temperature and varying irradiance levels.

Between the PV panel and the load, a power electronics circuit with a DC-DC boost converter measures how partial shading affects the system and ensures that the load receives maximum power at varying irradiance. Circuit parameters and switching frequency of the boost converter are given in Table 3.

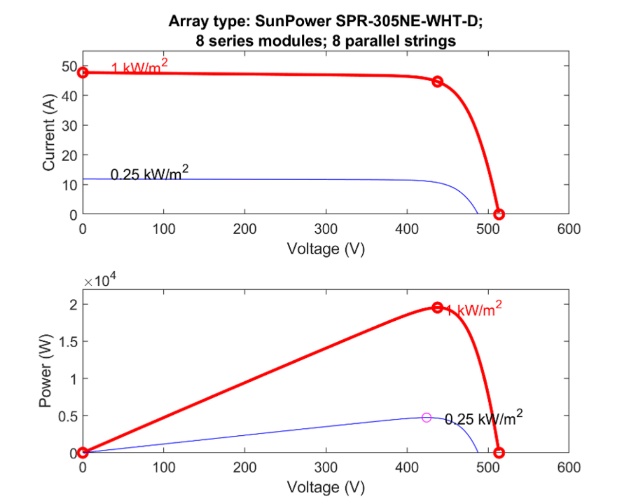


Figure 7: MPP, current and voltage curve of the solar panel at a constant temperature, variable irradiance values

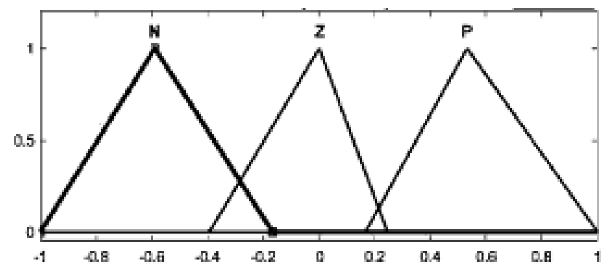
Table 2: Parameters of Sunpower SPR-305 NE-WHT-D PV Cell

Parameter	Symbol	Value	Unit
Maximum Power	Pmax	305.226	Watt (W)
Open Circuit Voltage	Voc	64.2	Volt (V)
The voltage at MPP	Vmp	54.7	Volt (V)
Short Circuit Current	Isc	5.96	Amper (A)
Current at Maximum Power	Imp	5.58	Amper (A)

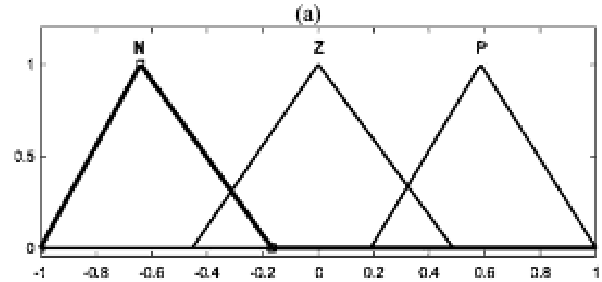
Table 3: DC-DC Boost Converter Circuit Parameters

Parameters	Symbol	Value	Unit
Inductance	L	5	Milihenry (mH)
Input Capacitor	Cin	1	Mikrofarad (F)
Output Capacitor	Co	5	Milifarad (mF)
Load	R	75	Ohm
Switching Frequency	fs	50	kHz

FLC membership functions are defined as P (Positive), Z (Zero), and N (Negative) for error, change of error, and duty ratio. A triangular membership function is used. Error, change of error, duty ratio, and surface are shown in Figure 8.



(a)



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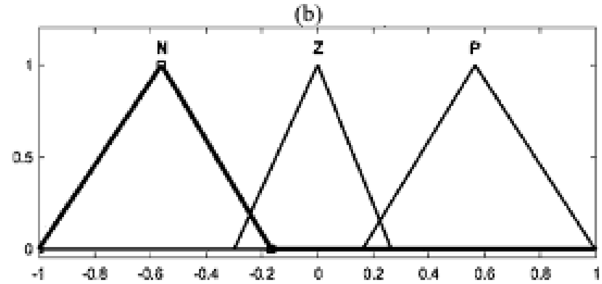

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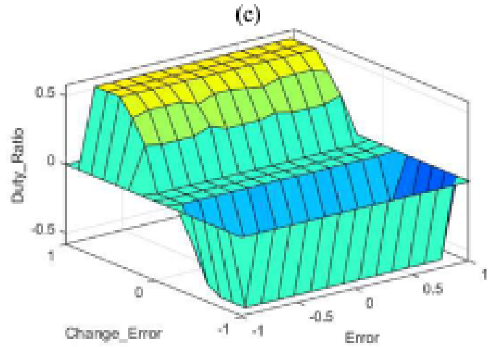

(d)

Figure 8: a) Error b) Change of Error c) Duty Ratio d) Surface

Figure 9 shows the irradiance and temperature values utilized for the solar panel. Figure 10 shows the PV voltage, load voltage, power, and efficiency for the FLC and IC MPPT algorithms.

Table 4: FLC Rule Table

Error	Change Error		
	N	Z	P
N	N	Z	P
Z	N	Z	P
P	N	Z	P

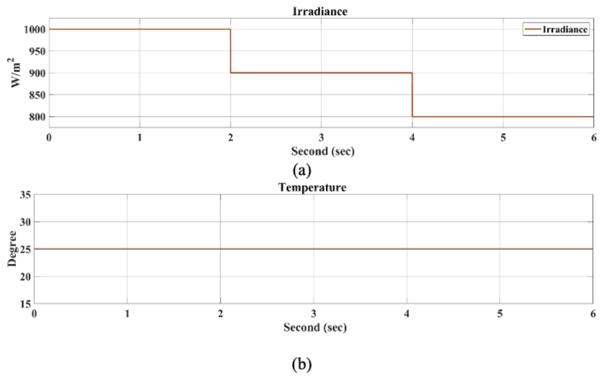

Figure 9: a) Irradiance b)Temperature

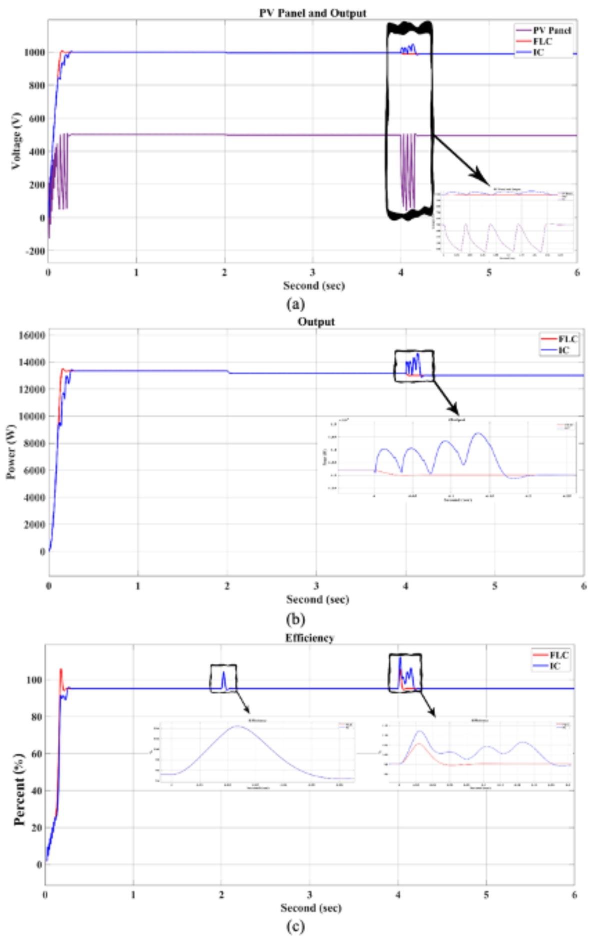

Figure 10: a) PV panel and Output Voltage b) Power c) Efficiency

4 Conclusions

Efficient solar energy utilization is essential to effectively address pollution problems and the rising demand for energy resources. Due to their increased efficiency, significant improvements in MPPT algorithms have encouraged the use of PV panel technology for home power generation. Consideration of different methodologies based on the number of control variables affected, types of control techniques, circuits, and applications can help the selection of a MPPT technique for specific use in either grid-tied or island mode of operation. In the world of PV systems, the MPPT process is crucial. This study offers a comparative analysis through the simulation of two MPPT algorithms. The algorithms are FLC and IC. The simulation results show decreased oscillation at the appropriate voltage and power level, increased stability under various irradiance situations, and higher efficiency than the FLC IC.

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Authors' Contributions

The authors confirm their contribution to the paper: study conception and design: NAM, ML; data collection: NAM, ML, ZC; analysis and interpretation of results: NAM, ML, ZC; draft manuscript preparation: NAM. All authors reviewed the results and approved the final version of the manuscript.

Competing Interests

The authors declare that they have no competing interests.

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