FLC-Based MPPT for a PV Boost Converter System: A Study with Real Climatic Data

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Abstract. The maximum power point (MPPT) tracking control algorithm is a critical factor that affects the system's ability to use photovoltaics to capture the most energy from the sun. Fuzzy logic stands out as one of the most commonly employed MPPT techniques due to its combination of rapid response to changing conditions and its stable operation with minimal power loss. The objective of this work was to assess the performance of a mppt. To achieve this, a simulation system was implemented.

1 Introduction

Today, photovoltaic systems are increasingly connected to the electricity grid, marking a major evolution in energy production and consumption [1]. This trend is driven by the significant reduction in PV module costs, the increasing efficiency of inverters, and growing political support for renewable energy. This not only helps reduce electricity bills for consumers and businesses but also lessens dependence on fossil fuel sources and stabilizes the grid.

To achieve the best connection between a non-linear source and load and produce the best power, Maximum Power Point Tracking was developed [2,3]. It intelligently identifies and maintains the optimum power production point of the PV modules under varying environmental conditions, ensuring that the solar panels always produce the maximum possible power, improving the efficiency and overall electricity production of the system, mppt for photovoltaic networks has led to the development of various control methods in research and practical applications around the world [4].

There are different types of MPPT controllers. Generally, each of these controllers has been designed for a specific application, trading off between convergence speed, tracking accuracy, implementation complexity, and cost. For instance, some studies prioritize stability under partial shading conditions, while others focus on maximizing efficiency under rapidly changing atmospheric patterns. This is evidenced by the variety of approaches in the literature, ranging from simple traditional methods to more sophisticated intelligent controls. For example, researchers like Yilmaz et al. (2018) designed a Fuzzy Logic-based MPPT specifically for battery charging in standalone systems [5]. More recently, comparative analyses, such as the one by Çakmak et al. (2025), the development of hybrid algorithms for high-performance applications where energy yield is paramount [8,9]. Therefore, the choice of an MPPT strategy is highly dependent on the specific requirements and constraints of the photovoltaic system in question.

This paper presents a PV system integrated with a DC-DC boost converter and an FLC-based MPPT controller to enhance energy harvesting efficiency. Section 2 provides a descriptive of the photovoltaic (PV) system architecture and the components used in this study. Section 3 explains the FLC design for MPPT; Section 4 presents simulation results; and Section 5 concludes with future research directions. The primary goal of the system is to validate the performance of the proposed Fuzzy Logic Controller (FLC) for Maximum Power Point Tracking (MPPT).

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2 PV System & Converter Design

The PV system consists of a photovoltaic generator as the primary energy source, a DC-DC converter with and a 20 Ω resistive load. Table1 lists the values of the parameters required for modeling and simulating of our system

Table 1. PV panel and Boost converter parameters.

N_P	Ns	V_{OC}	I_{CC}	Pmax	L	C	f_S	ΔV	ΔI
23	10	64.2V	5.95 A	305 W	1.9672e-4 H	8.73e-5F	8kHz	1%	5%

The PV array was modeled using the single-diode mathematically represented by the equation:

$$I = I_{ph} - I_o\left[exp^{\frac{V+IRs}{Vt}} - 1\right] - \frac{V+IRs}{Rp} \quad (1)$$

To estimate a PV panel's maximum power point, first determine its power-voltage and current-voltage curves. Increasing irradiance increases PV panel power and voltage, whereas increasing temperature decreases both.

The heart of the power conversion stage is boost converter because it controls the power flow from the PV panel to the load. The design and selection of the converter's passive components are critical for ensuring regulating the voltage and current output of PV source. It offers several key advantages that enhance overall performance and reliability. The application 's block Diagram is display in Figure 1.

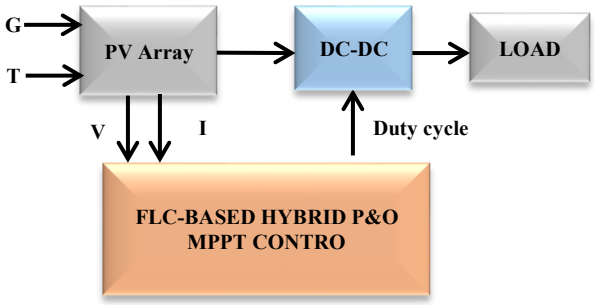

Fig 1. Synoptic diagram of a photovoltaic system with MPPT control by fuzzy logic

3 Fuzzy logic controller

Fuzzy logic controllers (FLCs) are advanced control systems that utilize fuzzy logic principles to manage complex processes without requiring precise mathematical models. They are particularly effective in environments where uncertainty and imprecision are prevalent. FLCs operate by evaluating input variables through a set of fuzzy rules, allowing for flexible decision-making and control across various applications. In our proposed system, we integrate hybrid algorithm MPPT. the Perturb and Observe (P&O) method with FLC

[6,7]. Fig.2 illustrates the MPPT block system in MATLAB/SIMULINK

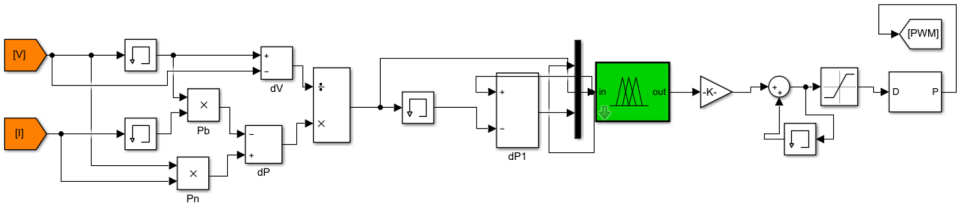

Fig. 2. Simulink Circuit Diagram of our MPPT Controller

In our case, we have two inputs $\Delta E(k)$ and E(k) determined from the equations:

$$E(k) = \frac{P(k)-P(k-1)}{V(k)-V(k-1)} \quad (1)$$

$$\Delta E(k) = E(k) - E(k-1) \quad (2)$$

The first part, which will translate the digital voltage and current data from the panel into a linguistic variable, is called fuzzification [8]. Triangle-type membership functions are created, as illustrated in Figure 3.

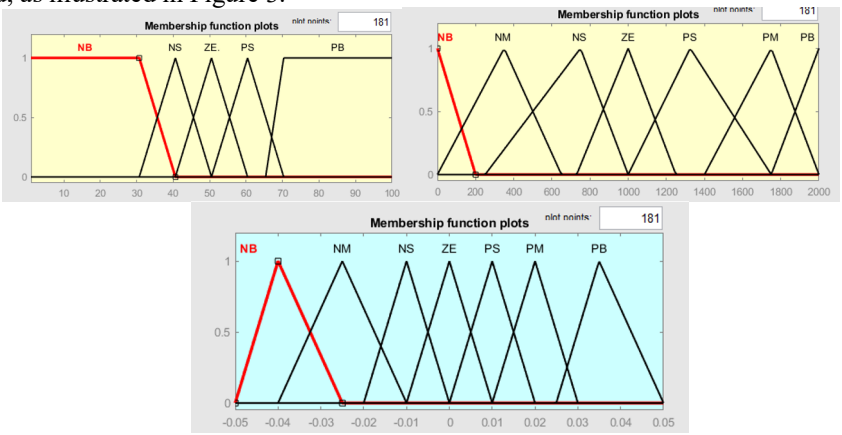

Fig. 3. Membership functions for the (a) converter input current, (b) converter input voltage, and (c) output duty cycle of the fuzzy controller.

In the inference stage, decisions are made. In fact, a logical relationship is created between the inputs and outputs while defining the membership rules. Next, the table of inference rules is established. Finally, in defuzzification, the fuzzy output subsets are converted into numerical values. Table 2. shows the rules for the membership functions.

Table 2. Fuzzy Logic Rule Base.

ΔP(k) /// ΔI(k)	**NB**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
NB	PB	PB	PM	NM	NM	NB	NB
NS	PB	PM	PS	NS	NS	NM	NB
ZE	NB	NM	NS	ZE	PS	PM	PB

PS	NB	NM	NS	PS	PS	PM	PB
PB	NB	NB	NM	PM	PM	PB	PB

4 Simulations resulats

Showing in figure 4 how the two main weather conditions affect the performance of the PV system and how the MPPT controller reacts. The output power (P) of the panel increases significantly when solar irradiance increases and decreases when the temperature rises.

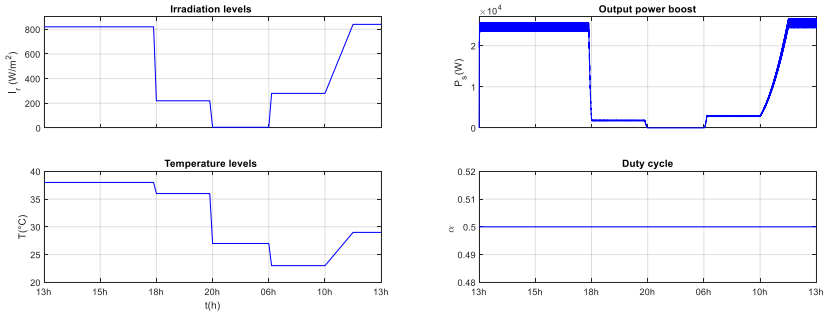

Fig 4. Impact of Solar Irradiance and Temperature Variations on Photovoltaic System Output and Duty Cycle

A stable and rapid response in panel voltage and current in Figure 5, confirming that the maximum power point is reached and maintained accurately under changing conditions. Current (I) is the most dynamic curve. It must closely follow variations in solar irradiance, while voltage (V) is stable, with sudden drops during increases in current.

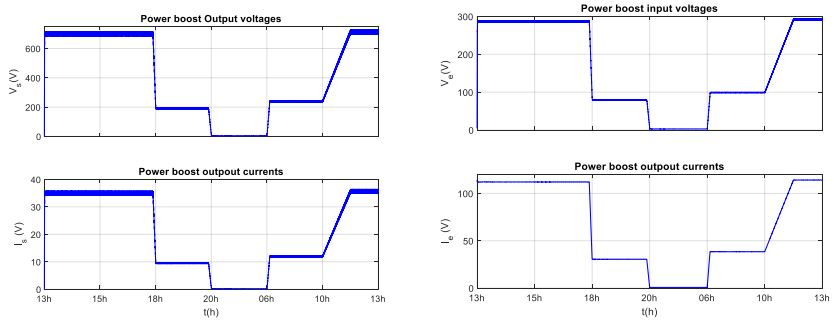

Fig 5. Photovoltaic Array Voltage and Current

5 Conclusion

The MPPT control algorithm is implemented using a Fuzzy Logic Controller (FLC), whose design is detailed and presented in this work. The simulation results reveal the effectiveness of the proposed method, even in the presence of various irradiation experiments, operating times and photovoltaic field configurations. This is clearly an important area for further research, involving new technologies based on artificial intelligence tools that can overcome the limitations of incremental algorithms.

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