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RESEARCH ARTICLE

Hybrid fuzzy and fire fly algorithm-based MPPT controller for PV system using super lift boost converter

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Abstract

This study suggests a new simplified firefly algorithm (SFA) for maximum power point tracking (MPPT) of the solar system under conditions of partial shadowing. The disregarded and coefficients are present in the simplified firefly method, which is different from the regular firefly algorithm. The updated β coefficient for each iteration step is the second new feature, which helps to accelerate convergence. This approach is suggested to find the best PV system MPPT solution for three different shaded circumstances. The proposed method produced results with the highest possible power and efficiency. The ripple performed better than the conventional FA under steady-state conditions. The suggested algorithm's key advantages over the conventional firefly algorithm are its simplicity, quicker convergence, and accuracy.

Keywords*:* Simplified firefly algorithm, Maximum power point tracking, PV.

Introduction

This research suggests the firefly algorithm (FA) as a fresh approach for fine-tuning fuzzy logic controller's membership function (Guenounou *et al.*, 2014). The hybrid fuzzy logic controller-firefly algorithm (FLC-FA) was proposed for maximum power point tracking (MPPT) in photovoltaic systems (Jang *et al.*, 1993). Perturbation and Observe (P&O), the fuzzy logic controller (FLC) standard, and the hybrid fuzzy logic controller firefly algorithm (FLC-FA) were three MPPT techniques for photovoltaic (PV) systems that were compared to this work (Luo *et al.*, 2014). The FLC-FA algorithm is developed to find the best MPPT solution among photovoltaic (PV) systems (Palanivel *et al.*, 2020). The proposed FLC-key FA's advantages over the current fuzzy logic controller standard are its efficiency and accuracy.

Xin-She Yang devised the firefly method (FA), a metaheuristic algorithm for global optimization, in late 2007 or early 2008. The fluttering of fireflies in the wild served as its inspiration. The bulk of the thousands of firefly species that have been discovered so far exhibit bioluminescence from their abdomen. Each type of firefly creates its unique flash model. In many species, a stationary female attracts the male. In some species, the female can mimic a different species' signal, attracting the males of that species. Additionally, fireflies communicate with one another through flashing (Ajiatmo & Robandi, 2016). The FA idealizes several features of fireflies in nature and was inspired by the idea of its allure and capacity for information transmission. First, unlike simulated fireflies, which are always glowing, genuine fireflies flash in distinct patterns. The algorithm can then be controlled by three rules to create a model of the firefly behavior.

- Since fireflies are all unisexual, they are all attracted to one another.
- The attractiveness and brightness are inversely correlated and diminish as the distance between them rises (Iqbali *et al.*, 2010). The less brilliant firefly travels to the brighter one when there are two flashing fireflies. The firefly flies at random if there isn't another brighter source nearby.
- The objective function topology is related to the firefly brightness.

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The next sections provide a brief note on a steady state investigation of innovative hybrid fuzzy and firefly algorithm (HFFFA) based MPPT controller under various irradiance circumstances after examining the effects of fluctuations in the energy generated from PV arrays. Fire fly and fuzzy hybrid algorithm (HFFFA).

HFFFA

The proposed hybrid fuzzy and firefly controller is depicted in Figure 1 and was created for MPPT controllers (100 W PV systems). The two main intelligent controllers were created to maximize the DC-DC converter's duty cycle and accomplish the MPPT approaches' goals. The steps for designing an MPPT controller are as follows:

The FLC has two inputs, including PV voltage and PV current. One output signal, such as the PWM generator's duty cycle, is also included in addition to this (Sivakumar *et al.*, 2014). The PWM generator's duty cycle is the fuzzy controller's only output signal. The trapezoidal approach is used to transform the fuzzy output signal from a crisp set to a fuzzy set.

Following the creation of the proposed controller's input and output membership functions, fuzzy interference rules are created using the IF-THEN condition. Finally, the duty cycle-d_{max} output signal from the fuzzy controller is supplied to the firefly controller (Manikannan *et al.*, 2019). The fixed firefly algorithm constants are as follows: β_o, γ, m,α, population size N as below:

$$m > 1 \qquad (1)$$

Where β_o - Initial attractiveness, r is the Cartesian distance between two fireflies, γ is light intensity, and α is the random movement factor, are the variables (Kulaksiz, 2013). The proposed method controls the super-lift boost converter to operate at the ideal duty cycle with respect to MPP. The desired MPPT was accomplished using the subsequent methods (Haji, 2020; Mlakić & Nikolovski, 2016; Arora and Gaur, 2015; So *et al.*, 1996).

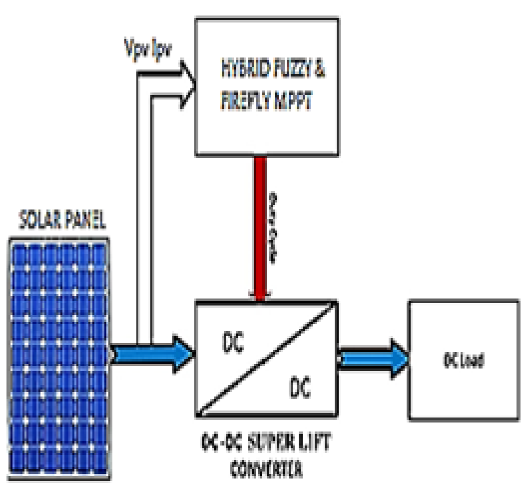

Figure 1: Hybrid firefly and fuzzy based MPPT

Step 1: Initialization of N, and the size of the population. Here, the converter's duty cycle is represented by a firefly in flight.

Step 2: To get the greatest brightness, firefly 1 goes to firefly 2.

Step 3: Continue using the projected approach in this manner until the maximum brightness is attained (Abdullah *et al.*, 2017).

Step 4: The optimization process is repeated up to the last iteration.

Implementation of the Proposed Controller

The overall MATLAB simulation circuit is depicted in Figure 2. The firefly's level is considered as a duty cycle d of the super lift boost converter in this proposed technique (Ansari *et al.*, 2012). Each firefly's brightness is tied to the PV system's spawned power P_{pv}, which corresponds to the firefly's position. The permitted range of the duty minimum (d_{min}) to duty maximum is marked on the fireflies (d_{max}). As illustrated in Figures 2 and 3, the suggested hybrid fuzzy and firefly control-based MPPT of the DC-DC super lift boost converter was also constructed in the MATLAB environment for a 100W PV panel (Manikannan *et al.*, 2020).

Under various irradiation conditions, including 250, 500, 750 and 1000 W/m^2, the proposed MPPT control of the super lift converter was simulated and assessed (Kumaresh *et al.*, 2014). The proposed controller model is presented in Figure 3.

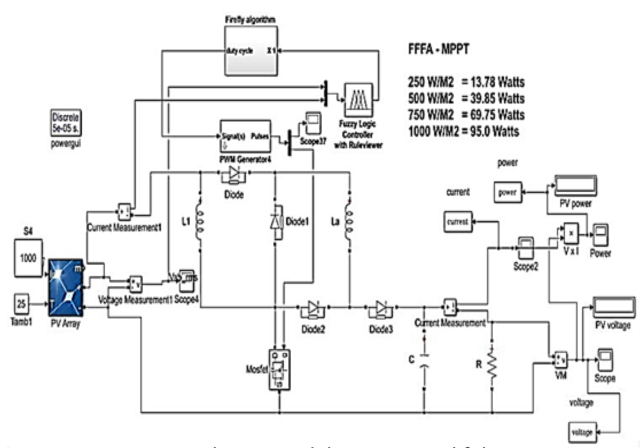

Figure 2: MATLAB simulation model using super lift boost converter-HFFFA

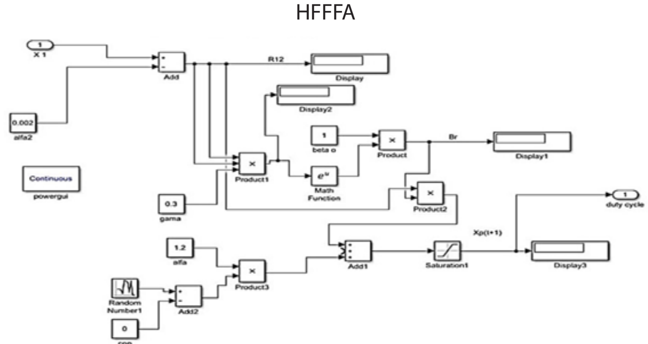

Figure 3: Firefly Controller model for MPPT

Simulation Results and Discussions

The suggested HFFFA-based MPPT control has also been modeled and examined for a 75W PV system. The output voltage and output current of a 75W under various irradiations are shown in Figures 4 and 5, respectively. Under the 1000 W/m² irradiance conditions, it generates a maximum output of 71.5. 75W of PV system produced power is shown in Figure 6. Similar to this, the 100 W PV panel's output power at 750, 500, and 250 W/m² is 56.2, 34.4, and 12.35 W, respectively. Figures 7, 8, and 9 show the current, voltage, and power waveforms of the 100 W PV system simulation using a hybrid fuzzy and firefly algorithm.

Table 1: Comparative analysis of different MPPT Controllers for 75W PV system

Irradiation (W/m²)	IC-based MPPT of SLBC (W)	Fuzzy-based MPPT of SLBC (W)	ANFIS based MPPT of SLBC (W)	Hybrid Firefly and Fuzzy MPPT of SLBC (W)
250	9.3	11.57	11.33	12.35
500	21.37	25.76	33.85	34.47
750	48.8	54.37	55.45	56.2
1000	51.78	67.2	70.5	71.5

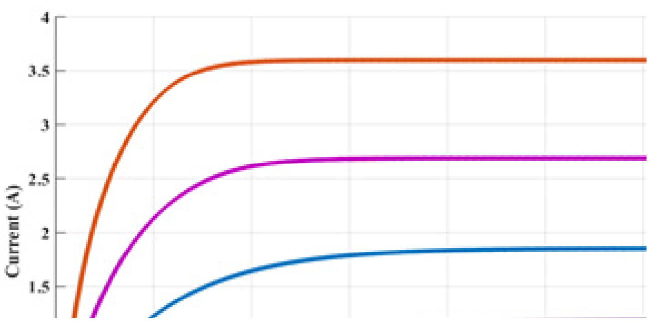

Figure 4: Current curve with HFFFA - MPPT controller at various Irradiations

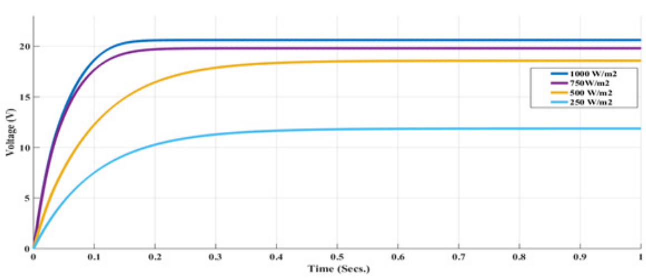

Figure 5: Voltage curve with HFFFA - MPPT controller at various Irradiations

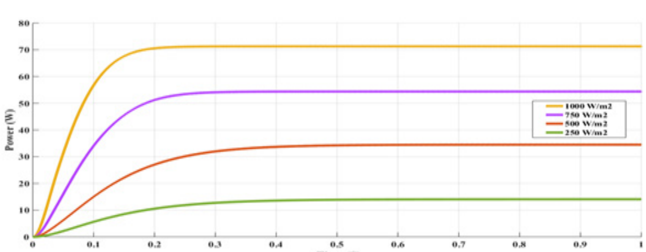

Figure 6: Power curve with HFFFA - MPPT controller at various Irradiations

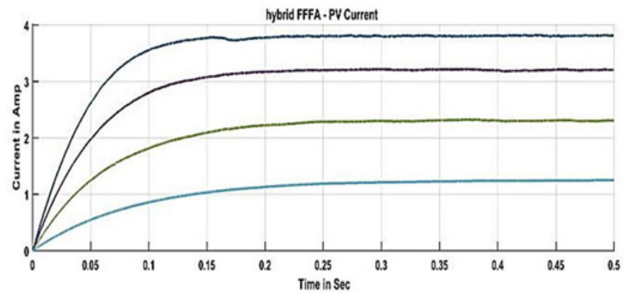

Figure 7: Photovoltaic current curve with HFFFA at various Irradiations (100W)

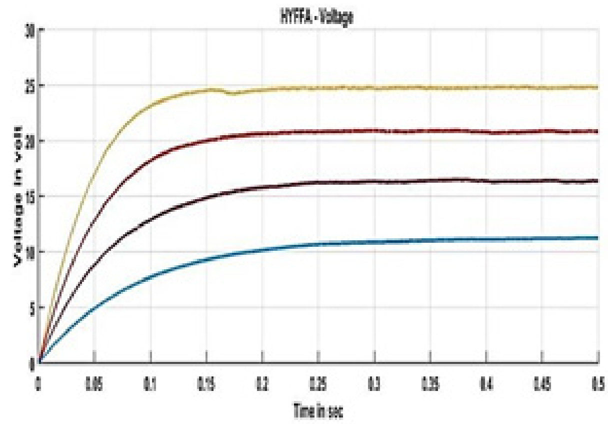

Figure 8: 100W PV voltage curve at various Irradiations

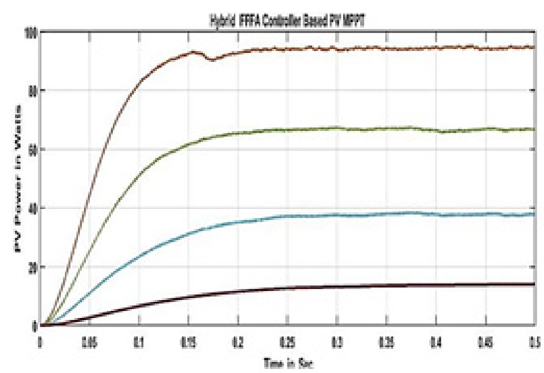

Figure 9: PV power curve at various Irradiations

Simulation is also carried out using the incremental conductance (IC) technique, fuzzy logic controller (FLC) and artificial neuro-fuzzy inference system methods for comparison purposes. The obtained values are tabulated below to prove the proposed algorithm's robustness and effectiveness.

Conclusion

The outcomes were then contrasted with MPPT results based on IC, Fuzzy, and ANFIS. Table 1 in this article compares the studies of several intelligent controller-based MPPT performances. The inquiry outcomes for the suggested super lift converter using MATLAB/Simulink with various MPPTs demonstrate that both the hybrid fuzzy and firefly algorithms are more advanced than IC, Fuzzy, and ANFIS.

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