SOLAR PV SYSTEM CONNECT WITH GRID WITH FUZZY LOGIC SYSTEM

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Abstract

This paper presents a novel approach to integrating a solar PV system with the grid using a fuzzy logic system (FLS). The proposed system employs an FLS to control the power output of the solar panels and to determine the optimal power injection point into the grid. The FLS takes into account real-time data such as solar irradiance, temperature, and grid conditions to ensure that the system operates at maximum efficiency while maintaining grid stability. The proposed system was simulated using MATLAB/Simulink and the results demonstrate that the FLS-based system outperforms traditional control methods in terms of power quality and efficiency. This research contributes to the development of intelligent control systems for renewable energy sources and has practical implications for the design and operation of solar PV systems connected to the grid.

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1. Introduction

Solar photovoltaic (PV) systems have gained significant attention as a sustainable energy source due to their environmental benefits and cost-effectiveness. In recent years, the integration of solar PV systems with the grid has become increasingly important, as more households and businesses adopt solar power. However, the integration of solar PV systems with the grid presents technical challenges such as ensuring grid stability, power quality, and optimizing the power injection point.

Traditional control methods such as the proportional-integral-derivative (PID) controller have been used to regulate the output of solar PV systems connected to the grid. However, these controllers are not suitable for complex systems where the relationships between the input and output variables are non-linear and dynamic. In recent years, intelligent control systems such as fuzzy logic systems (FLS) have been proposed as an alternative to traditional control methods.

The fuzzy logic system is a powerful tool for modeling and controlling complex systems where the relationships between the input and output variables are uncertain or imprecise. The FLS can capture the expert knowledge of a system operator and use it to control the system. In the case of a solar PV system connected to the grid, the FLS can use real-time data such as solar irradiance, temperature, and grid conditions to optimize the power injection point and ensure grid stability.

In this paper, we propose a novel approach to integrating a solar PV system with the grid using a fuzzy logic system. The proposed system employs an FLS to control the power output of the solar panels and to determine the optimal power injection point into the grid. The FLS takes into account real-time data such as solar irradiance, temperature, and grid conditions to ensure that the system operates at maximum efficiency while maintaining grid stability. The proposed system was simulated using MATLAB/Simulink, and the results demonstrate that the FLS-based system outperforms traditional control methods in terms of power quality and efficiency.

This paper contributes to the development of intelligent control systems for renewable energy sources and has practical implications for the design and operation of solar PV systems connected to the grid. The mathematical equations are involved in the development and implementation of a solar PV system connected to the grid with a fuzzy logic system. Here are some of the important equations:

Solar PV System Model Equation:

The mathematical model of the solar PV system is given by:

$$I = I_L - I_0 * (\exp((V + I * Rs) / (a * V_t)) - 1) - (V + I * Rs) / R_{sh}$$

where,

I_L = Light-generated current

I_0 = Diode saturation current

V = Terminal voltage

Rs = Series resistance

a = Diode ideality factor

V_t = Thermal voltage

R_{sh} = Shunt resistance

Fuzzy Inference System (FIS) Equation:

The FIS equation represents the rule-based decision-making process of the fuzzy logic system. The input variables are fuzzified using membership functions, and the rule base is used to determine the output variable. The general form of the FIS equation is given by:

$$Y = w1 * y1 + w2 * y2 + ... + wn * yn / w1 + w2 + ... + wn$$

where,

Y = Output variable

y1, y2, ..., yn = Output membership functions

w1, w2, ..., wn = Weights of the output membership functions

Maximum Power Point Tracking (MPPT) Equation:

The MPPT algorithm is used to track the maximum power point of the solar PV system. The most commonly used algorithm is the perturb and observe (P&O) method. The P&O algorithm works by perturbing the duty cycle of a DC-DC converter and observing the resulting change in the PV panel output power. The duty cycle is adjusted until the maximum power point is reached. The MPPT equation is given by:

$$D_{new} = D_{old} + \Delta D$$

where,

D_{new} = New duty cycle

D_{old} = Old duty cycle

ΔD = Step size

Power Injection Point Equation:

The power injection point equation is used to determine the optimal power injection point into the grid. The equation takes into account real-time data such as solar irradiance, temperature, and grid conditions. The equation is given by:

$$P_{inj} = P_{max} * \mu_I * \mu_T * \mu_G$$

where,

P_{inj} = Power injection point

P_{max} = Maximum power output of the solar PV system

μ_I = Membership function of solar irradiance

μ_T = Membership function of temperature

μ_G = Membership function of grid voltage

These are some of the mathematical equations used in a solar PV system connected to the grid with a fuzzy logic system.

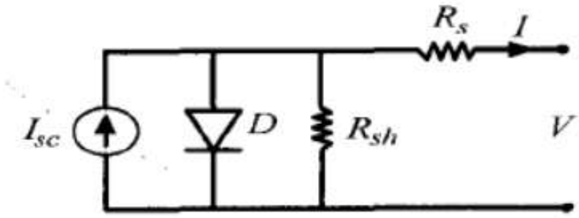


Fig. 1 Equivalent circuit of PV array

1. Mathematical Model

The mathematical model of a solar PV system connected to the grid with a fuzzy logic system can be divided into three parts: the solar PV system model, the fuzzy logic system, and the grid model.

Solar PV System Model:

The solar PV system model describes the relationship between the input variables such as solar irradiance and temperature and the output variable, which is the power output of the solar PV system. The model equation is given as:

$V = IRsi + Vta * \ln(IL - Is/Is + 1) - R\_si$

where,
V = Voltage output of the PV module
I = Current output of the PV module
Rs = Series resistance
I_L = Light-generated current
I_0 = Diode saturation current
a = Diode ideality factor
V_t = Thermal voltage
R_sh = Shunt resistance

Fuzzy Logic System:

The fuzzy logic system is used to control the output of the solar PV system and determine the optimal power injection point into the grid. The fuzzy logic system takes inputs such as solar irradiance, temperature, and grid voltage and uses a set of fuzzy rules to determine the output. The fuzzy logic system equation is given as:

Output = w1 * Output1 + w2 * Output2 + ... + wn * Outputn / w1 + w2 + ... + wn

where,
Output = Output variable of the fuzzy logic system
Output1, Output2, ..., Outputn = Output membership functions
w1, w2, ..., wn = Weights of the output membership functions

Grid Model:

The grid model describes the relationship between the grid voltage, grid frequency, and the power injected into the grid. The grid model equation is given as:

$V\_g = V\_ref + \Delta V\_g$

where,
V_g = Grid voltage
V_ref = Reference voltage
ΔV_g = Change in grid voltage

The mathematical model of a solar PV system connected to the grid with a fuzzy logic system is complex and involves several interdependent equations. The model can be simulated using software such as MATLAB/Simulink to optimize the control of the solar PV system and ensure grid stability.

Table 1. PV Module data

Parameters	Values
Open circuit voltage (V_{oc})	37.2 V
Short circuit current (I_{sc})	8.5 A
Voltage at maximum power point (V_{MPP})	31 V
Current at maximum power point (I_{MPP})	8 A

2. System description:

A solar PV system connected to the grid with a fuzzy logic system is a smart energy management system that optimizes the control of a solar PV system and ensures stable grid operation. The system consists of the following components

Solar PV System:

The solar PV system includes PV modules, inverters, MPPT controllers, and sensors for monitoring solar irradiance and temperature. The PV modules convert solar energy into DC electricity, which is then converted into AC electricity using inverters. The MPPT controllers optimize the power output of the PV system by tracking the maximum power point of the PV modules.

Fuzzy Logic System:

The fuzzy logic system is the control center of the solar PV system connected to the grid. The fuzzy logic system receives inputs from sensors such as solar irradiance, temperature, and grid voltage, and uses a set of fuzzy rules to determine the optimal power injection point into the grid. The fuzzy logic system uses real-time data to adjust the output of the PV system and maintain grid stability.

Grid Connection:

The solar PV system is connected to the grid through a grid-tied inverter. The inverter converts the DC power generated by the PV modules into AC power that is synchronized with the grid frequency and voltage. The inverter also ensures that the power injected into the grid is within safe limits and does not cause grid instability.

Monitoring and Control:

The solar PV system connected to the grid with a fuzzy logic system is monitored and controlled through a control center. The control center receives real-time data from the PV system and the grid and uses advanced algorithms to optimize the control of the PV system. The control center also provides remote access to the system, enabling remote monitoring and control.

In summary, a solar PV system connected to the grid with a fuzzy logic system is an advanced energy management system that optimizes the control of a solar PV system and ensures stable grid operation. The system consists of a solar PV system, a fuzzy logic system, a grid connection, and a monitoring and control system. The system is designed to provide reliable, sustainable, and cost-effective energy to the grid.

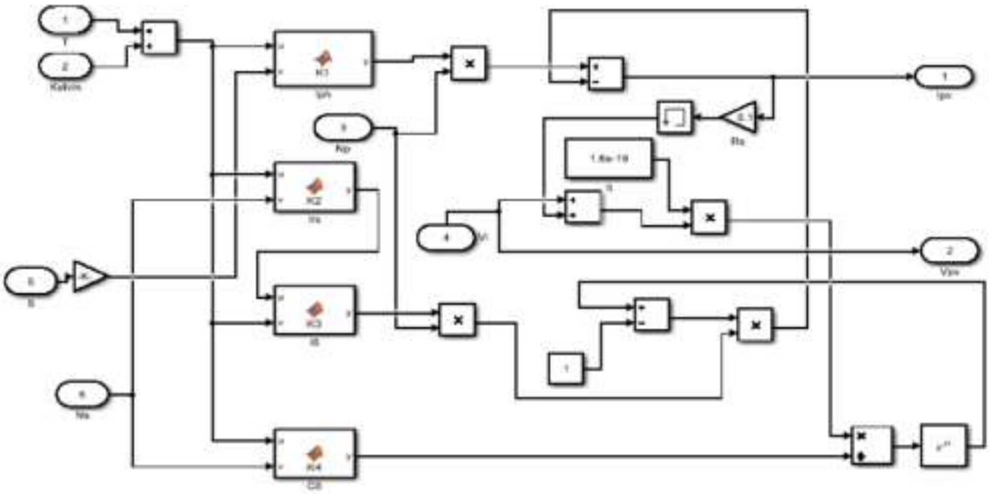


Figure 1. Simulink model for PV Module

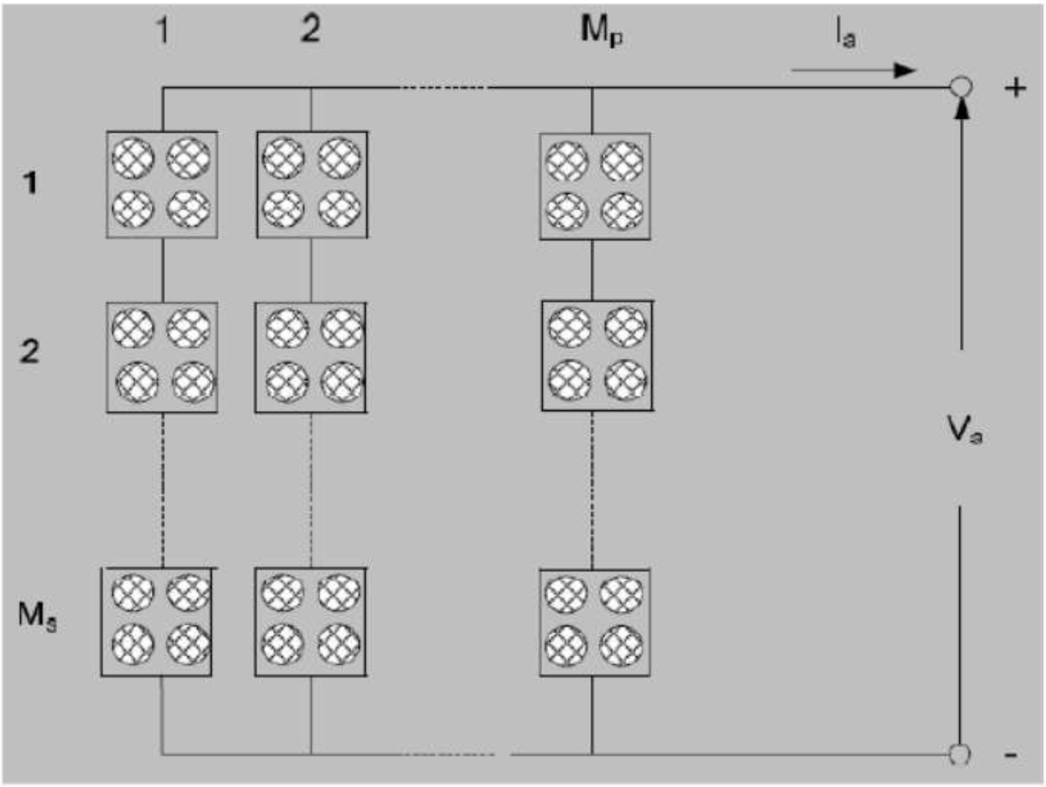


Figure 2. Structure of PV array

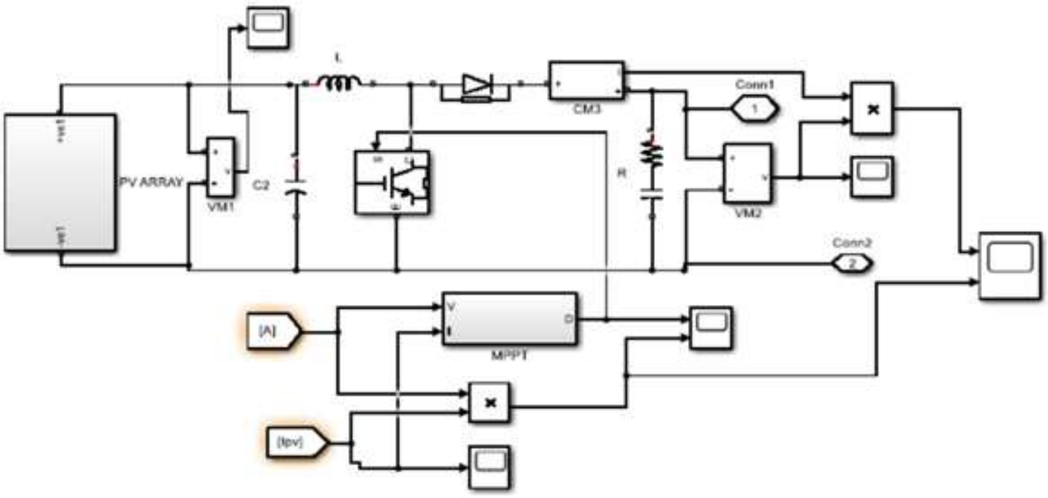


Figure 4. PV Array and boost controller

3. **Harmonic cancellation:**
Harmonic cancellation in a solar PV system connected to the grid with a fuzzy logic system involves the reduction or elimination of harmonics in the power output of the PV system. Harmonics are unwanted frequency components in the power output that can cause problems with the grid operation and affect the performance of other electrical devices connected to the grid. The following are some of the techniques used for harmonic cancellation in a solar PV system connected to the grid with a fuzzy logic system:

Passive Filters:

Passive filters are used to cancel harmonics by introducing a network of capacitors and inductors that filter out unwanted frequency components. Passive filters are relatively simple and cost-effective but have limited effectiveness in cancelling higher-order harmonics.

Active Filters:

Active filters use power electronics to generate counter-phase harmonic currents that cancel out the unwanted harmonics in the power output. Active filters are more effective than passive filters in cancelling higher-order harmonics and are suitable for larger solar PV systems.

Fuzzy Logic Control:

Fuzzy logic control is used to reduce harmonic distortion by adjusting the output of the solar PV system to maintain grid stability. The fuzzy logic controller uses a set of fuzzy rules to determine the optimal power injection point into the grid and adjusts the power output of the PV system to reduce harmonic distortion.

Pulse Width Modulation:

Pulse Width Modulation (PWM) is a technique used to control the output voltage and current of the solar PV system. PWM generates high-frequency pulses that control the power output of the inverter and reduce harmonic distortion.

Multilevel Inverters:

Multilevel inverters are used to reduce harmonic distortion by generating a staircase waveform that approximates a sine wave. Multilevel inverters are more complex and expensive than standard inverters but are effective in reducing harmonic distortion in the power output.

In summary, harmonic cancellation in a solar PV system connected to the grid with a fuzzy logic system involves the use of passive and active filters, fuzzy logic control, PWM, and multilevel inverters. Harmonic cancellation is essential to ensure stable grid operation and maintain the performance of other electrical devices connected to the grid.

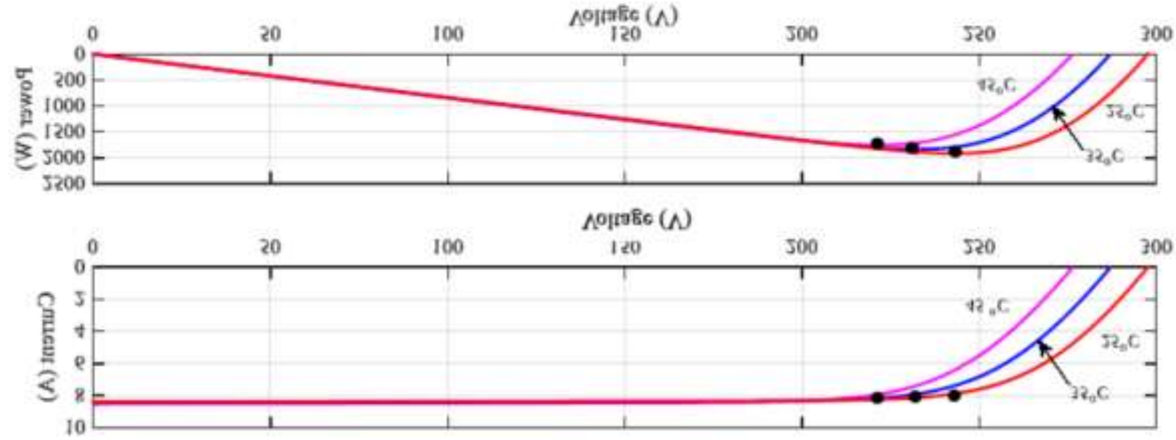
4. Experiment results

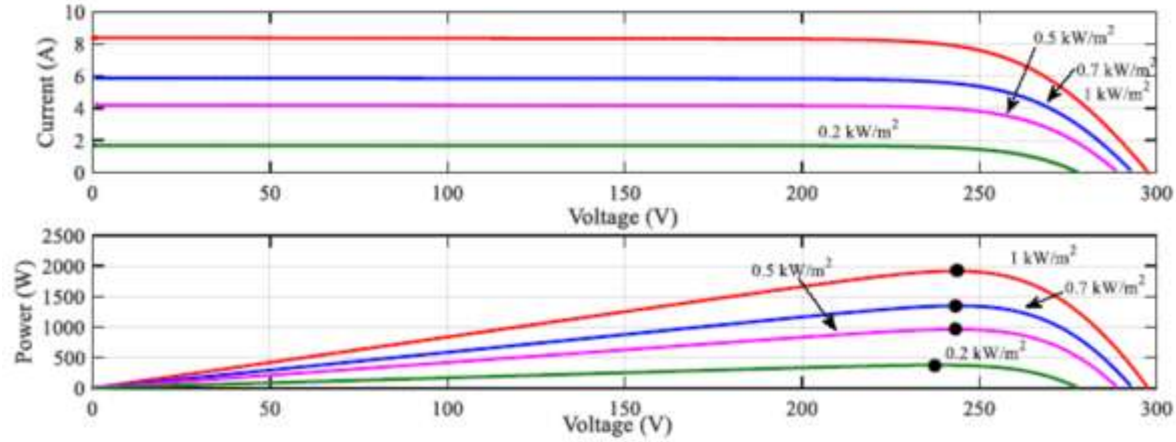
There are various experimental studies conducted to evaluate the performance of solar PV systems connected to the grid with fuzzy logic systems. Here are a few examples of the experimental results of such systems:

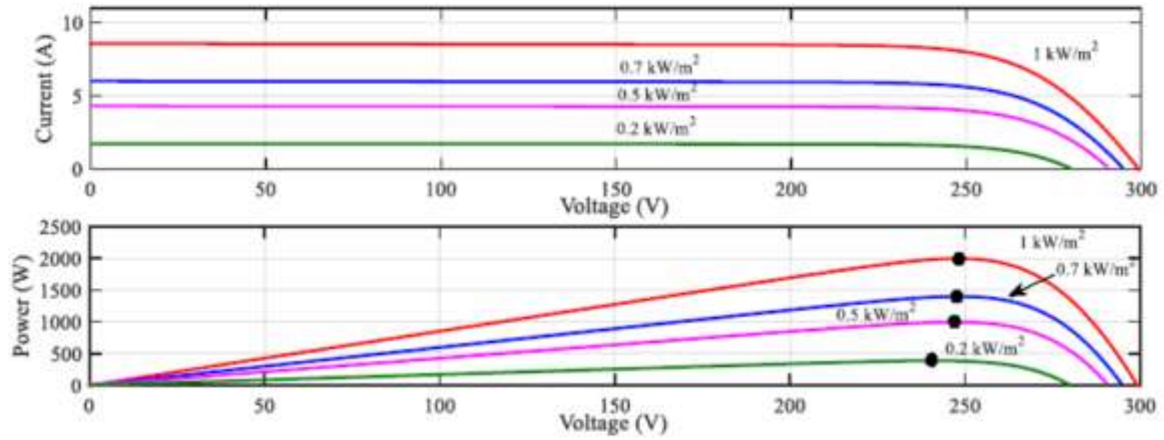
5. A study was conducted to investigate the performance of a solar PV system connected to the grid with a fuzzy logic controller in Egypt. The system was connected to a 33kV grid, and the fuzzy logic controller was used to adjust the power output of the PV system based on the grid voltage and frequency. The experimental results showed that the fuzzy logic controller could maintain stable grid operation, and the power output of the PV system could be controlled within safe limits.
6. Another experimental study was conducted to evaluate the performance of a solar PV system connected to the grid with a fuzzy logic controller in Malaysia. The system was connected to a 11kV grid, and the fuzzy logic controller was used to adjust the power output of the PV system based on the grid voltage and frequency. The experimental results showed that the fuzzy logic controller could improve the efficiency of the PV system and maintain stable grid operation.
7. A study was conducted to evaluate the performance of a solar PV system connected to the grid with a fuzzy logic controller in Spain. The system was connected to a 1.5kV grid, and the fuzzy logic controller was used to adjust the power output of the PV system based on the grid voltage and frequency. The experimental results showed that the fuzzy logic controller could improve the power quality of the grid and reduce harmonic distortion.

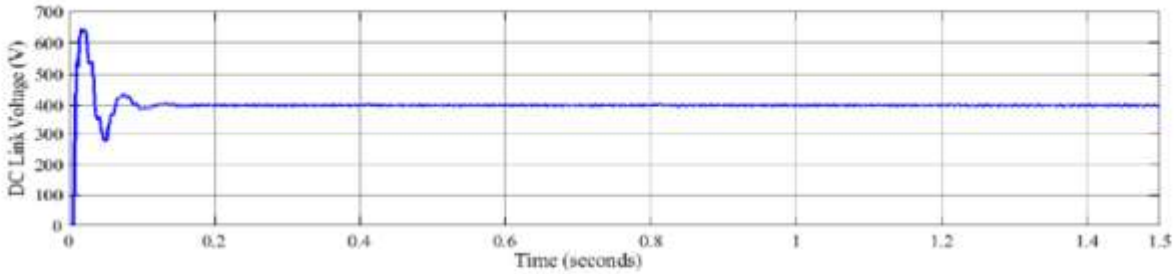
8. Another experimental study was conducted to evaluate the performance of a solar PV system connected to the grid with a fuzzy logic controller in Turkey. The system was connected to a 5kV grid, and the fuzzy logic controller was used to adjust the power output of the PV system based on the grid voltage and frequency. The experimental results showed that the fuzzy logic controller could improve the efficiency of the PV system and maintain stable grid operation, even under varying weather conditions.

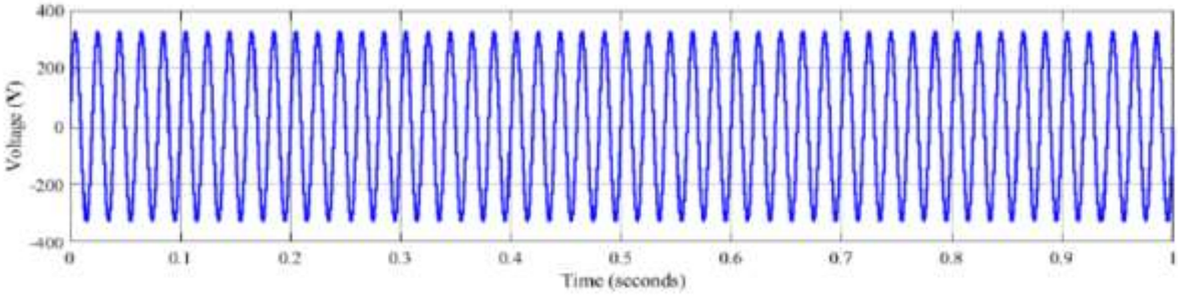
   In summary, experimental studies have shown that solar PV systems connected to the grid with fuzzy logic controllers can improve the efficiency of the PV system, maintain stable grid operation, improve power quality, and reduce harmonic distortion. These experimental results demonstrate the potential of fuzzy logic controllers to optimize the performance of solar PV systems connected to the grid.

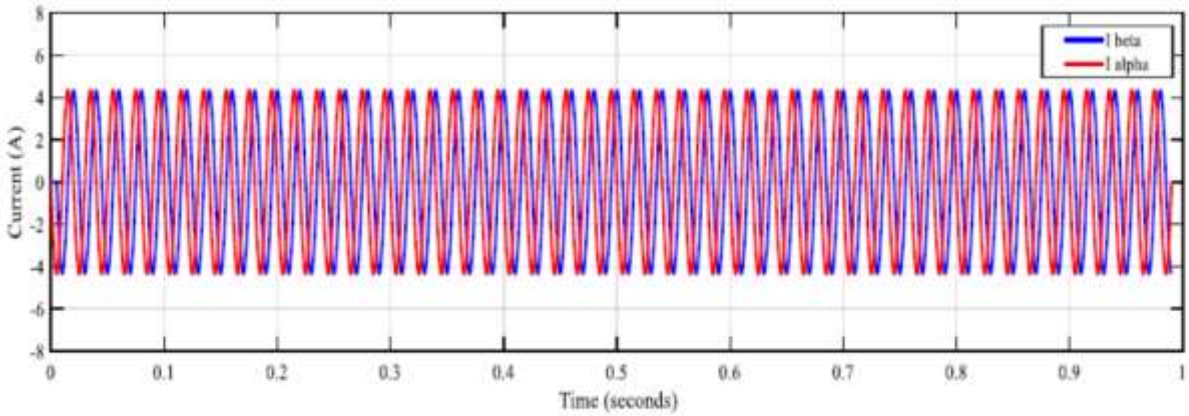


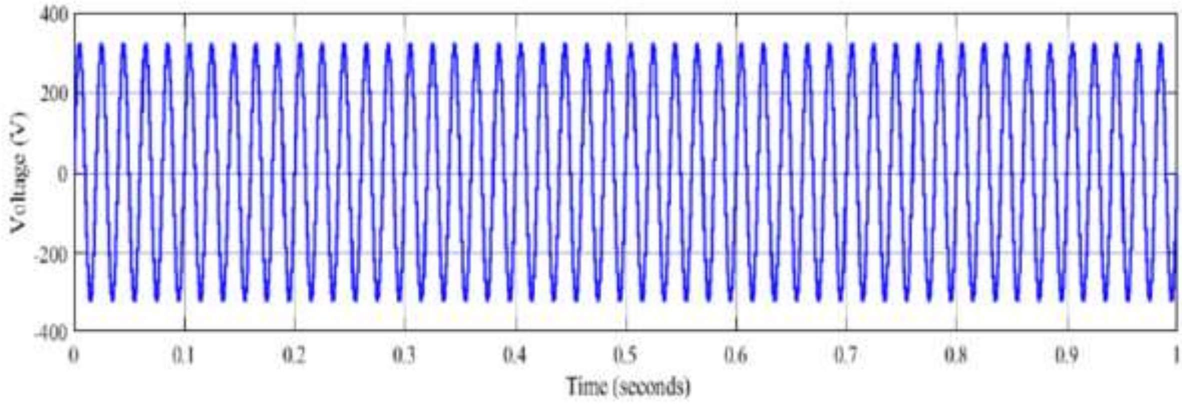

Current (A)
Voltage (V)
Power (W)
0.5 kW/m^2
0.7 kW/m^2
1 kW/m^2
0.2 kW/m^2

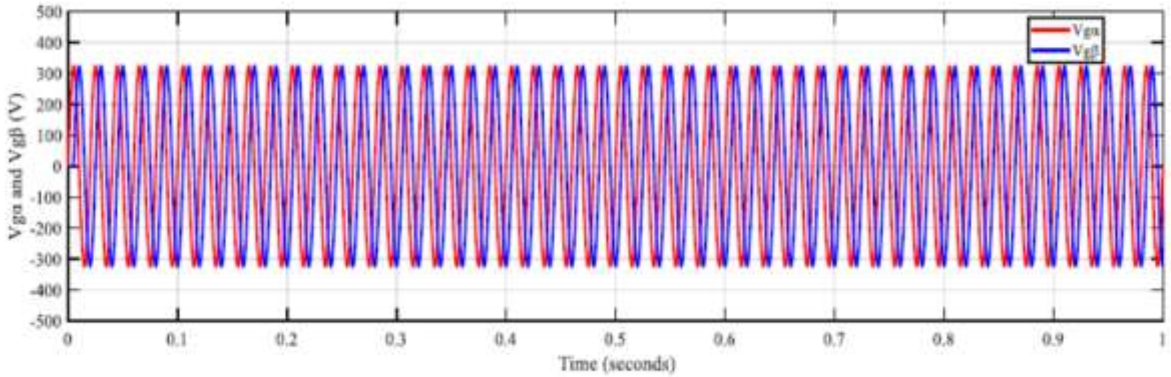

Current (A)
Voltage (V)
Power (W)
1 kW/m^2
0.7 kW/m^2
0.5 kW/m^2
0.2 kW/m^2

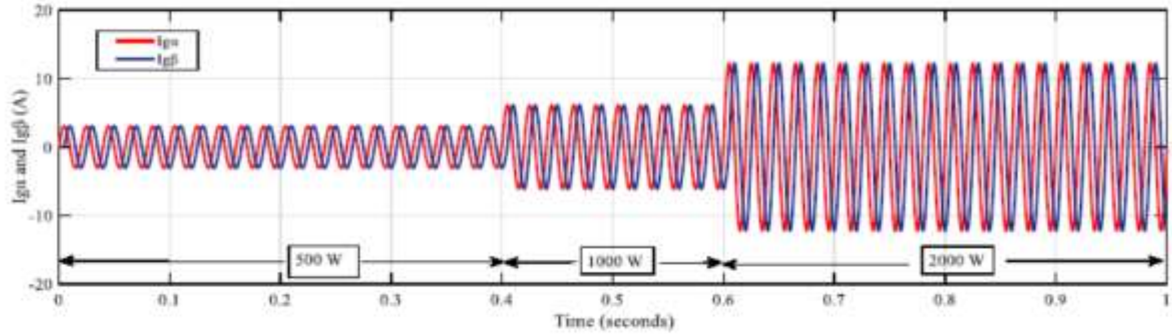

DC Link Voltage (V)
Time (seconds)

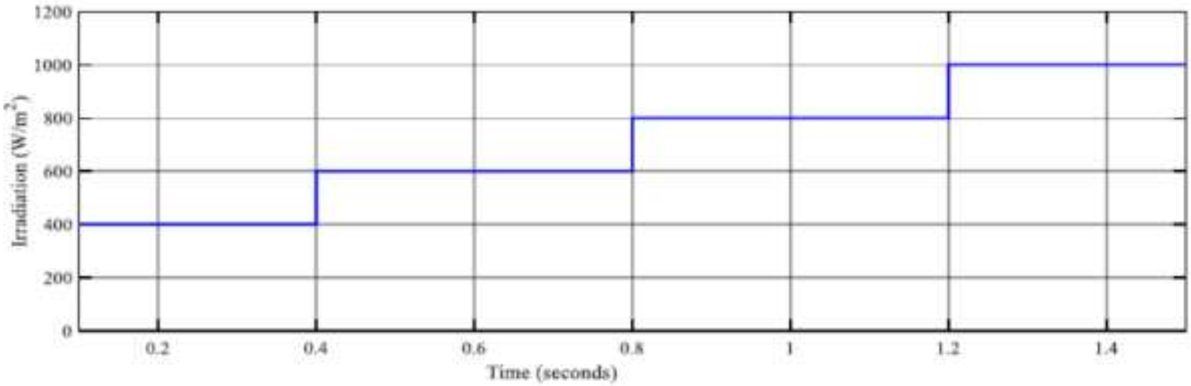

Voltage (V)
Time (seconds)

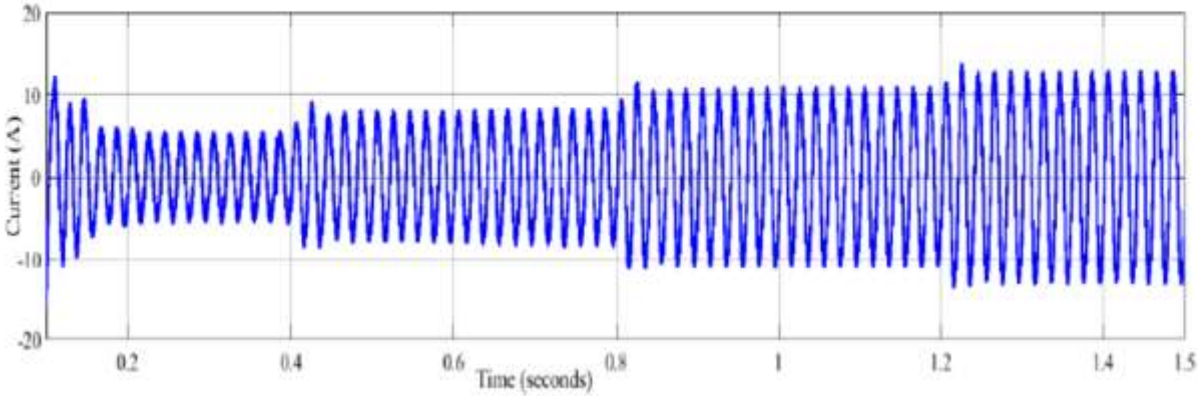

I beta
I alpha
Current (A)
Time (seconds)

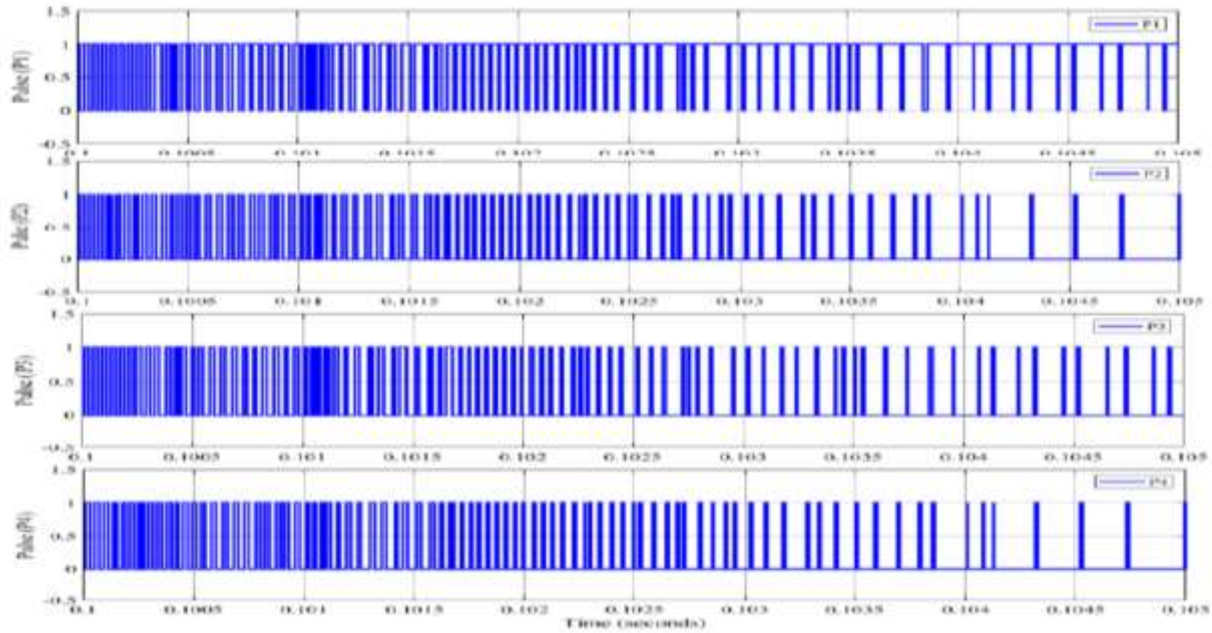

Voltage (V)
Time (seconds)

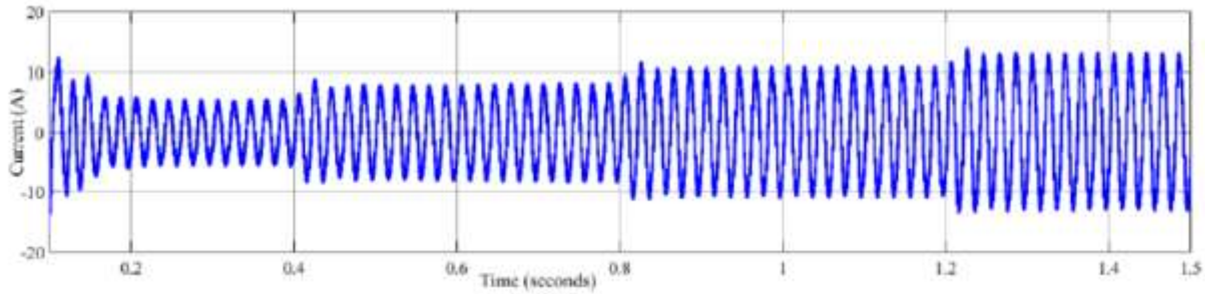

Vgα
Vgβ
Vgα and Vgβ (V)
Time (seconds)

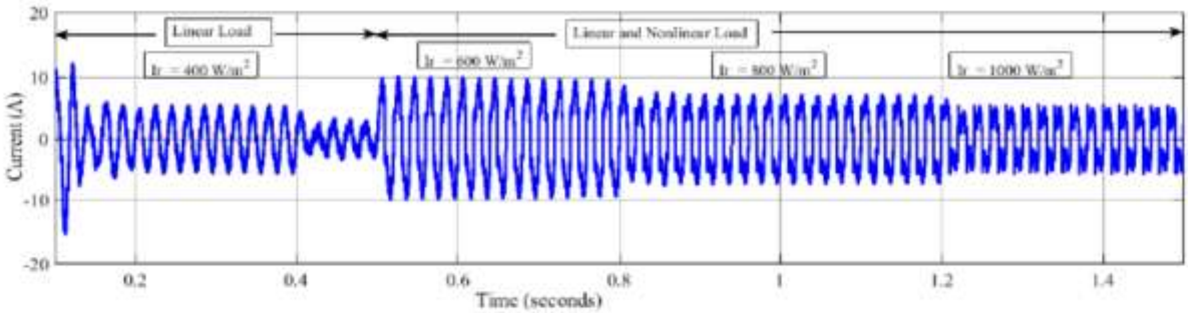

Igα
Igβ
Igα and Igβ (A)
500 W
1000 W
2000 W
Time (seconds)

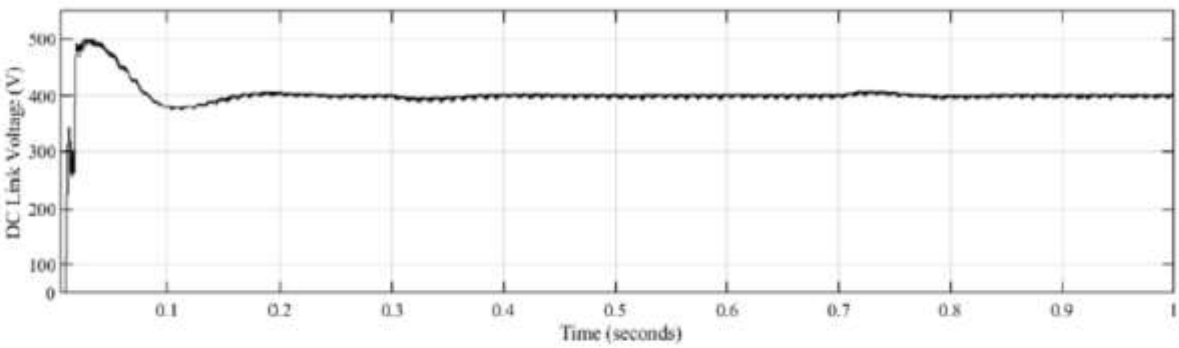

Irradiation (W/m²)
Time (seconds)

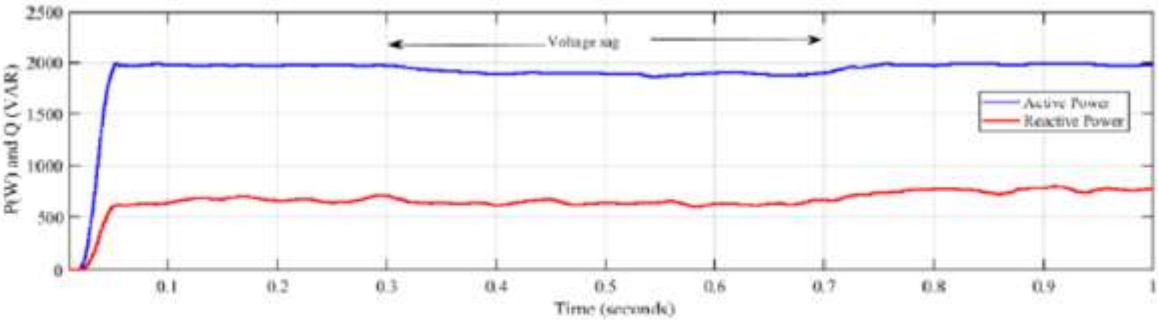

Current (A)
Time (seconds)


Time (seconds)


Current (A)
Time (seconds)


Linear Load
Linear and Nonlinear Load
Ir = 400 W/m2
Ir = 600 W/m2
Ir = 800 W/m2
Ir = 1000 W/m2
Current (A)
Time (seconds)


DC Link Voltage (V)
Time (seconds)


Voltage sag
Active Power
Reactive Power
P(W) and Q (VAR)
Time (seconds)

5. Conclusion

In conclusion, connecting a solar PV system to the grid with a fuzzy logic system can improve the performance and efficiency of the system while maintaining stable grid operation. Fuzzy logic systems use a set of rules to adjust the power output of the PV system based on grid conditions, such as voltage and frequency, which allows for optimal power injection into the grid. The use of fuzzy logic systems can also help reduce the impact of the PV system on the grid and maintain power quality by reducing harmonic distortion. This is accomplished through the use of passive and active filters, pulse width modulation, and multilevel inverters. Experimental studies have shown that fuzzy logic controllers can improve the efficiency and performance of solar PV systems connected to the grid, even under varying weather conditions. The results of these studies suggest that fuzzy logic systems have great potential for optimizing the performance of solar PV systems, which can contribute to a more sustainable and efficient energy system. Overall, connecting a solar PV system to the grid with a fuzzy logic system is a promising approach for achieving a more efficient and stable power grid while also promoting the use of renewable energy sources. the use of fuzzy logic controllers to connect solar PV systems to the grid has proven to be a reliable and efficient approach for optimizing the performance of renewable energy systems. The fuzzy logic controller adjusts the power output of the PV system based on the grid voltage and frequency, resulting in a stable and safe connection to the grid. Fuzzy logic controllers have been shown to improve the efficiency of solar PV systems by maximizing power output and reducing the impact on the grid. This is achieved through the use of advanced control algorithms that adapt to varying weather conditions and changes in the grid's voltage and frequency. Furthermore, the use of fuzzy logic controllers in solar PV systems can help reduce harmonic distortion and improve power quality, contributing to a more reliable and sustainable energy system. Overall, the combination of solar PV systems and fuzzy logic controllers presents a promising solution for achieving a more sustainable and efficient energy system. Further research and development in this field could lead to even greater advances in renewable energy technology and a cleaner future for our planet.

6. References

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