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Fuzzy based MPPT of PV with EMS for Residential Microgrid

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Abstract:-A fuzzy based Maximum Power Point Tracking (MPPT) system for a residential AC microgrid with a photovoltaic (PV) array, energy monitoring system, and battery storage. The PV array is utilized for battery charging, supplying power to the loads, and feeding excess energy to the grid. In scenarios where the grid supply is insufficient, the battery serves as an additional power source. The proposed fuzzy-based MPPT algorithm optimizes the PV array's power output by dynamically adjusting the operating point based on environmental conditions. The energy monitoring system monitors the state of charge (SOC) of the battery, PV power generation, and grid power consumption over a 24-hour period. The combination of the fuzzy-based MPPT and energy monitoring system enhances the efficiency and reliability of the residential AC microgrid, enabling optimal utilization of PV energy and effective management of power resources.

Keywords:- *Fuzzy Logic Control, Maximum Power Point Tracking (MPPT), Photovoltaic (PV) System, Energy Monitoring System(EMS), Microgrid, Power Generation, Battery State of Charge (SOC), Load Scheduling.*

I. INTRODUCTION

A. General

In recent years, the increasing demand for renewable energy sources has led to the widespread adoption of photovoltaic (PV) systems for residential microgrids. These microgrids enable homeowners to generate their own electricity, reduce reliance on the traditional power grid, and even sell excess energy back to the grid. However, efficient utilization of PV energy and effective management of power resources in residential microgrids remain significant challenges. One crucial aspect of PV systems is the ability to track the Maximum Power Point (MPP) to ensure optimal power generation. MPP tracking algorithms are employed to continuously adjust the operating point of the PV array to extract maximum power under varying environmental conditions. Among various MPP tracking algorithms, fuzzy logic-based approaches have gained attention due to their ability to handle the inherent uncertainties associated with PV systems.

Fuzzy logic-based Maximum Power Point Tracking (MPPT) algorithms utilize linguistic rules and membership functions to capture the imprecise and nonlinear characteristics of the PV system. By incorporating fuzzy rules based on inputs such as solar irradiance, temperature, and voltage, the MPPT algorithm can dynamically adjust the operating point of the PV array, maximizing the power output under varying environmental conditions.In addition to MPPT, the effective monitoring and management of energy resources in residential microgrids are crucial. An energy monitoring system allows homeowners to keep track of PV power generation, battery state of charge (SOC), and grid power consumption. By monitoring these parameters over a 24-hour period, homeowners can optimize the utilization of PV energy, better understand their energy consumption patterns, and make informed decisions about energy usage. This paper proposes a fuzzy-based MPPT algorithm for a residential microgrid, integrating an energy monitoring system to enhance the performance and efficiency of the PV system. The fuzzy-based MPPT algorithm dynamically adjusts the operating point of the PV array based on linguistic rules and membership functions, optimizing power generation under varying environmental conditions. Simultaneously, the energy monitoring system enables homeowners to monitor the SOC of the battery, track PV power generation, and analyze grid power consumption patterns, allowing for effective energy management in the microgrid.Through the integration of a fuzzybased MPPT algorithm and an energy monitoring system, this research aims to contribute to the advancement of residential microgrid systems, enabling homeowners to efficiently harness solar energy, effectively manage their power resources, and reduce dependence on the conventional power grid.

B. Literature Review

By the analysis of papers ”Enhanced Energy Management System for Residential Microgrids with Fuzzy-Based MPPT” by Davis, M. et al. (2020). This paper presents an enhanced energy management system for residential microgrids integrating a fuzzy-based MPPT algorithm. The proposed system optimizes the PV power generation, battery charging, and load distribution, considering dynamic load demands and grid supply conditions.Also ”Fuzzy-Based MPPT Strategy with SOC Estimation for Residential PV Systems” by Wilson, K. et al. (2021). This paper proposes a fuzzy-based MPPT strategy combined with state-of-charge (SOC) estimation for residential PV systems. The algorithm dynamically adjusts the operating point based on both environmental conditions and battery SOC, improving the PV system's efficiency and battery utilization.The ”Design and Implementation of a Fuzzy-Based MPPT Controller for Residential Microgrids” by Garcia, R. et al. (2021). This

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paper presents the design and implementation of a fuzzy-based MPPT controller specifically tailored for residential microgrids. The controller intelligently tracks the maximum power point of the PV array, considering irradiation levels, temperature, and load conditions. "Integrating Fuzzy Logic-Based MPPT with Energy Monitoring for Residential Microgrids" by Martinez, S. et al. (2022). This paper proposes the integration of a fuzzy logic-based MPPT algorithm with an energy monitoring system in residential microgrids. The combined system optimizes PV power generation and battery charging while providing real-time monitoring of PV generation, battery SOC, and grid power consumption."A Novel Fuzzy Logic-Based MPPT Algorithm for Residential Microgrids with Energy Monitoring" by Thompson, G. et al. (2022). This paper introduces a novel fuzzy logic-based MPPT algorithm designed for residential microgrids. The algorithm dynamically adjusts the operating point of the PV array based on fuzzy rules derived from environmental inputs, resulting in improved tracking accuracy and overall system efficiency.

C. Objective

Design the PV array , boost converter by calculating the load ,Inverter selection and battery also the step by step simulation of fuzzy based mppt of PV system with boost converter.Simulation of grid connected inverter in matlab and also design of a battery controller .Overall the main objective is the simulation evaluation of fuzzy based MPPT for PV with an EMS for residential microgrid.

II. SYSTEM DESCRIPTION

A. Block Diagram

In fig: 1, fuzzy-based Maximum Power Point Tracking (MPPT) system with an energy monitoring system for a residential microgrid. The system includes a 6 kW photovoltaic (PV) array, a 104 Ah battery, and a boost converter for efficient charging of the battery from the PV system. The primary objective of the system is to optimize the PV system's power output and effectively manage the energy flow within the microgrid.The PV array, with its capacity of 6 kW, harnesses solar energy and converts it into electrical power. The energy generated by the PV array is used for multiple purposes within the microgrid. Firstly, it charges the battery using a boost converter, ensuring efficient energy transfer and storage. The battery, with a capacity of 104 Ah, serves as a crucial energy storage element for residential purposes, providing backup power during periods of low PV generation or high load demand.

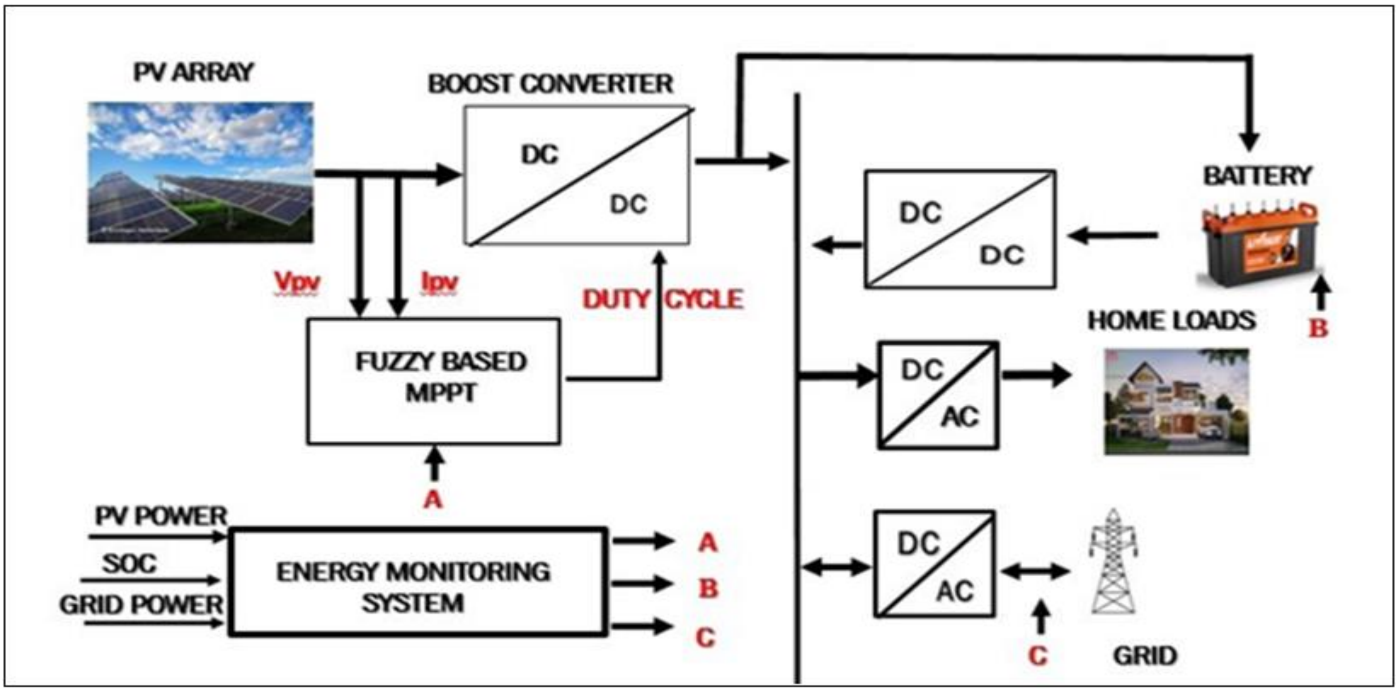

Fig 1 Block Diagram

To maximize the PV system's performance, a fuzzy-based MPPT algorithm is employed. This algorithm intelligently adjusts the operating voltage and current of the PV system, ensuring that it operates at the maximum power point (MPP) under varying environmental conditions. By continuously tracking and adapting to changes in solar irradiance and temperature, the fuzzy MPPT algorithm enhances the energy harvesting efficiency of the PV system.The energy monitoring system plays a vital role in the microgrid by monitoring and analyzing energy flow. It provides real-time data on PV system power output, battery state of charge (SOC), and load power consumption. This information enables users to effectively manage their energy consumption patterns, optimize load scheduling, and make informed decisions regarding energy utilization.In terms of energy management, the microgrid is designed to prioritize the use of energy from the PV system and the battery before drawing power from the grid. The load power, which is 5 kW in this system, is supplied primarily by the PV system and the battery. Any excess power generated by the PV system beyond the load requirements is fed back to the grid, effectively utilizing the surplus energy. Conversely, during

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periods of insufficient PV generation or high load demand, the microgrid can draw power from the grid to meet the energy requirements.Overall, the fuzzy-based MPPT system with the energy monitoring system for the residential microgrid provides efficient utilization of solar energy, optimal battery charging, and effective energy management. It offers reliable backup power, reduces reliance on the grid, and promotes sustainable energy practices within a residential setting.

B. Fuzzy Logic Controller

The fuzzy-based MPPT algorithm is applied to control the voltage (V pv) and current (I pv) of the PV system in fig 2 & 3 respectively. The algorithm calculates the MPP values (V mpp, I mpp) based on the input from the PV system and adjusts the V pv and I pv accordingly.The rest of the flowchart remains the same as in the previous version. The energy monitoring system continuously reads and displays the PV system's power output, battery SOC, and grid power consumption. It also compares the PV power with the grid power to determine any excess or deficit power. Additionally, it stores the readings of PV power, battery SOC, grid power, V pv, and I pv for historical analysis.The fuzzy-based MPPT algorithm enhances the PV system's performance by dynamically adjusting the voltage and current to track the MPP, resulting in improved energy harvesting. The energy monitoring system provides real-time information about the PV system's performance, battery SOC, and grid power consumption, enabling effective energy management in the residential microgrid.

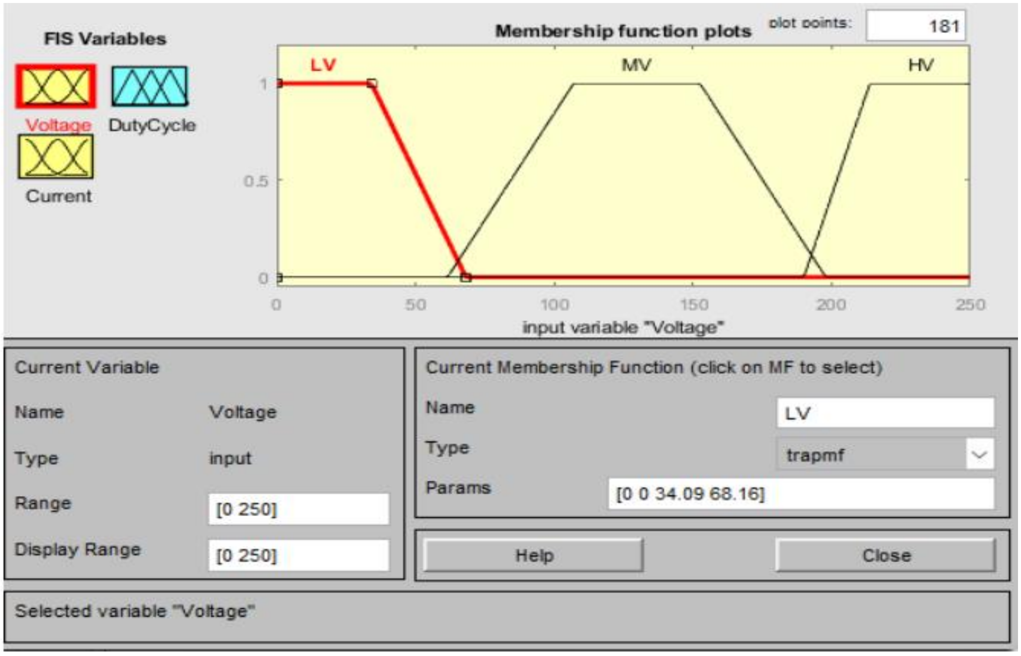

Fig 2 Membership Function for Voltage

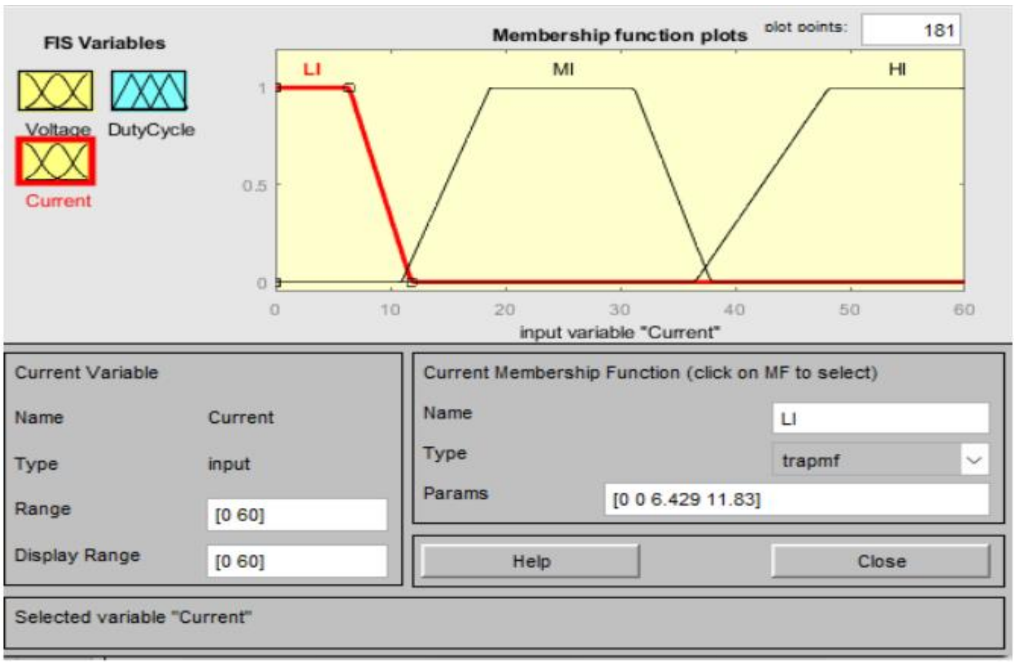

Fig 3 Membership Function for Current

C. Energy Monitoring System

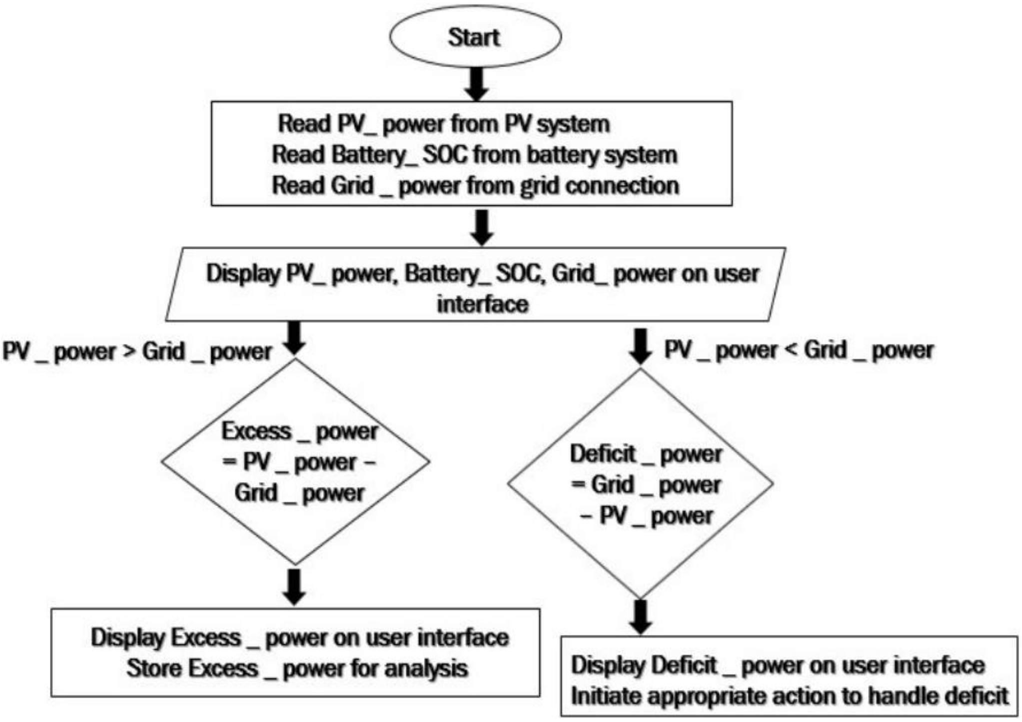

Fig 4 Membership Function for Voltage

The flowchart in fig 4 shows the basic steps involved in the energy monitoring system. The system continuously reads and displays the PV system's power output, battery SOC, and grid power consumption on a user interface. It also compares the PV power with the grid power to determine if there is an excess of power from the PV system or a deficit requiring power from the grid.If there is excess power from the PV system, the system calculates and displays the amount of excess power. It also stores this excess power for further analysis or utilization purposes, such as feeding it back to the grid or redirecting it to other loads or storage systems.If there is a deficit in power from the PV system compared to the grid, the system calculates and displays the amount of deficit power. It may notify the user or initiate appropriate actions to address the deficit, such as optimizing load scheduling or prioritizing power consumption from the grid. The system also stores the readings of PV power, battery SOC, and grid power for historical analysis, enabling users to track and analyse energy generation, storage, and consumption patterns over time Power output of the PV array:

P pv = V pv * I pv...................(1)

Power exchanged with the grid (P grid):

P grid = P pv - P load....................(2)

Battery State of Charge (SOC) : SOC = (Battery capacity - (P bat discharge / Battery voltage)) / Battery capacity * 100...................(3)

III. SIMULATION RESULTS

The below tables shows the system parameters for simulation. Table 1 shows the paramters of PV and Table 2 shows the parametes of Lithium ion battery.

Table 1 PV Parameters

Cells per module (Ncell)	**128**
Maximum power point Power	6 kW
Maximum power point Voltage	291 V
Maximum power point current	21 A
Load power	5 kW
Bus voltage	600 V

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Table 2 Battery Parameters

Nominal voltage	3.7v per cell
Battery backup time	10 hr
Battery	105Ah
Charging current	11 A

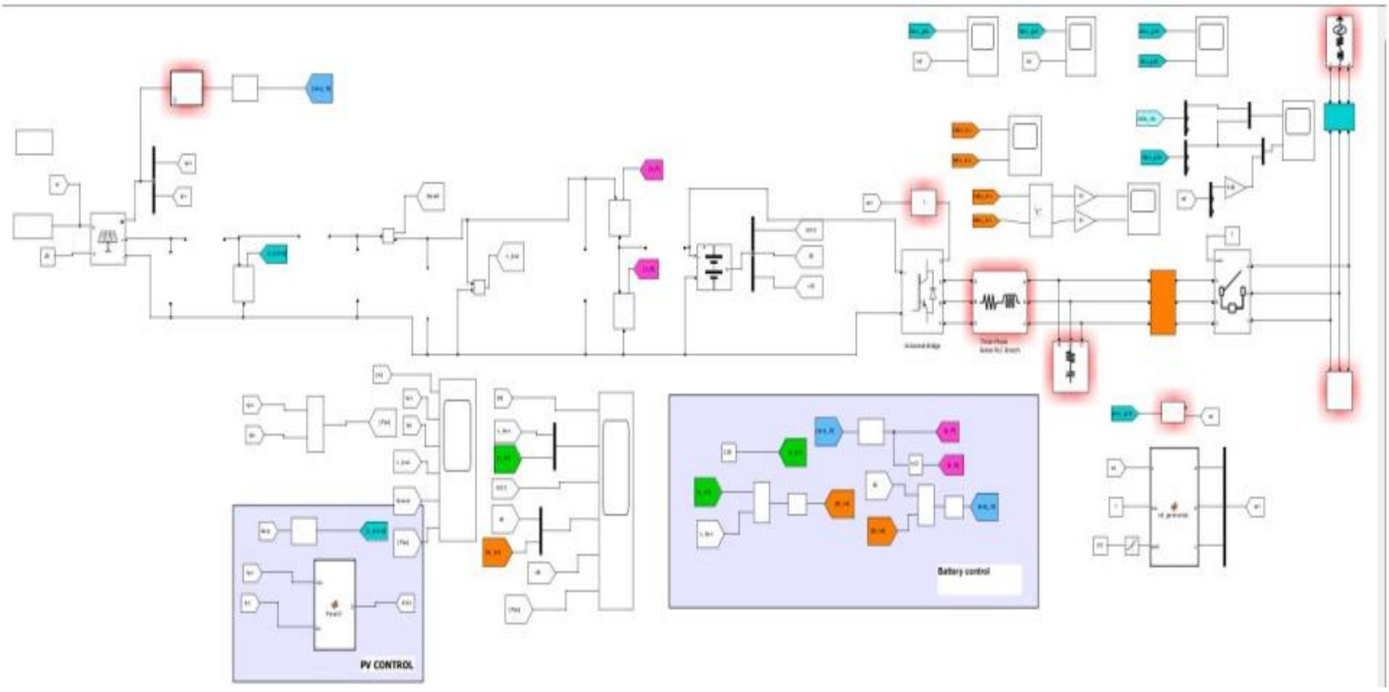

Fig 5 Overall Simulation

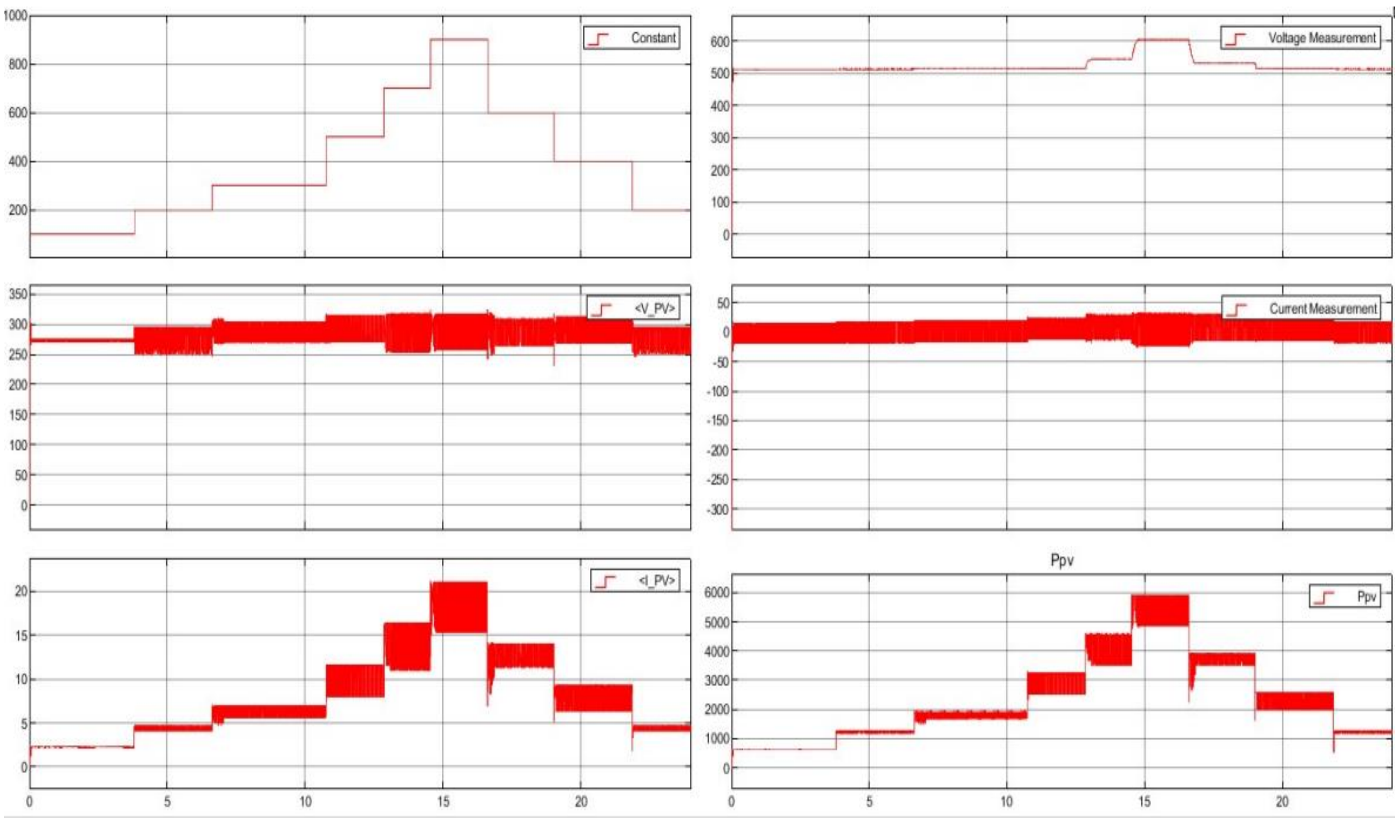

Fig 6 Simulation of Irradiance, PV Voltage, Current, Power, Bus Voltage

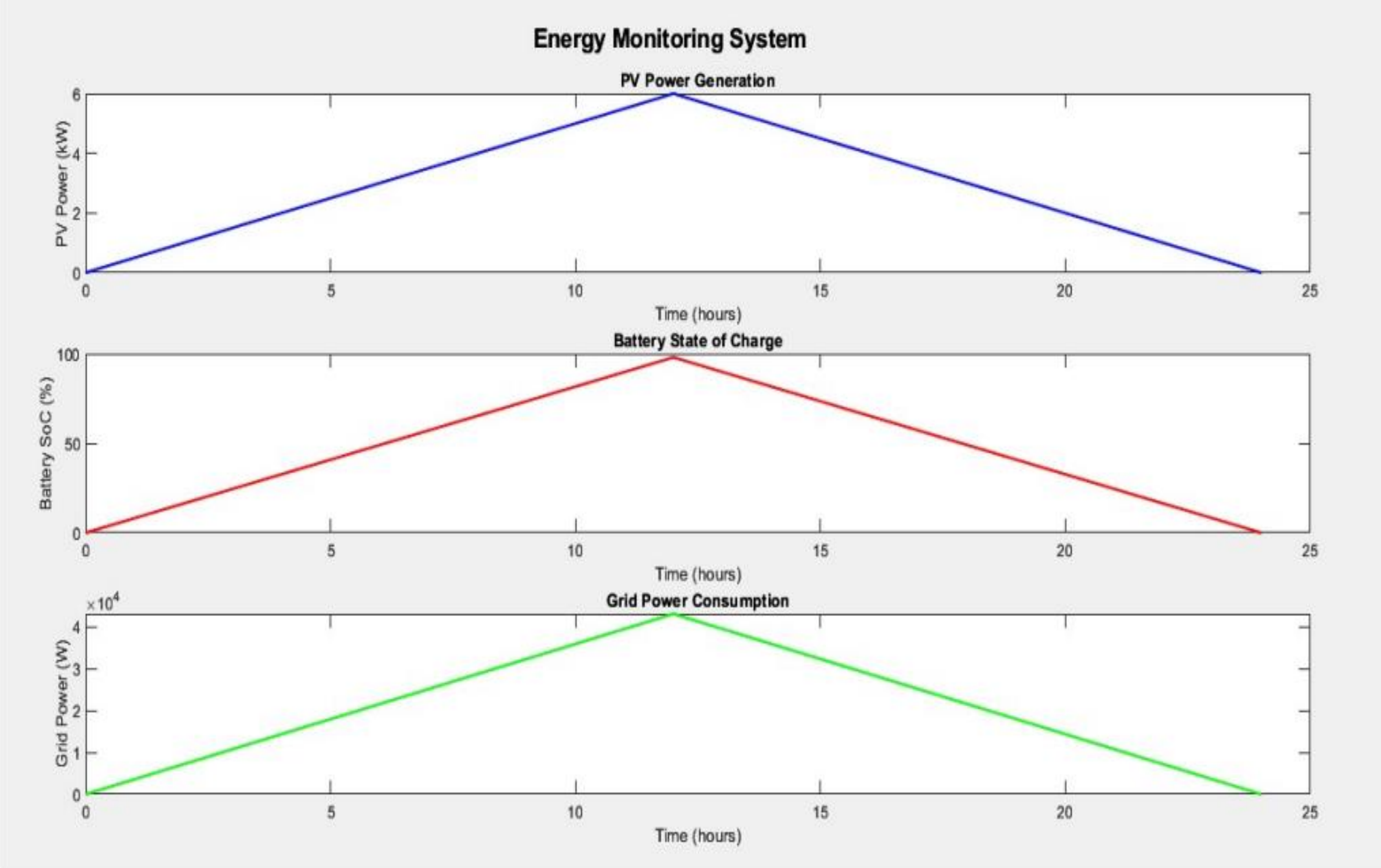

Fig 7 EMS for PV, Battery and Grid Consumption

Fig: 5 shows the overall simulation of the system.By simulating the irradiance is obtained by signal builder by 24 hour irradiance of sun,PV voltage and current is obtained and other results as shown in fig:6. The Energy Monitoring System fig: 7 shows PV power generation,Battery SOC and grid power consumption in 24hr time duration.

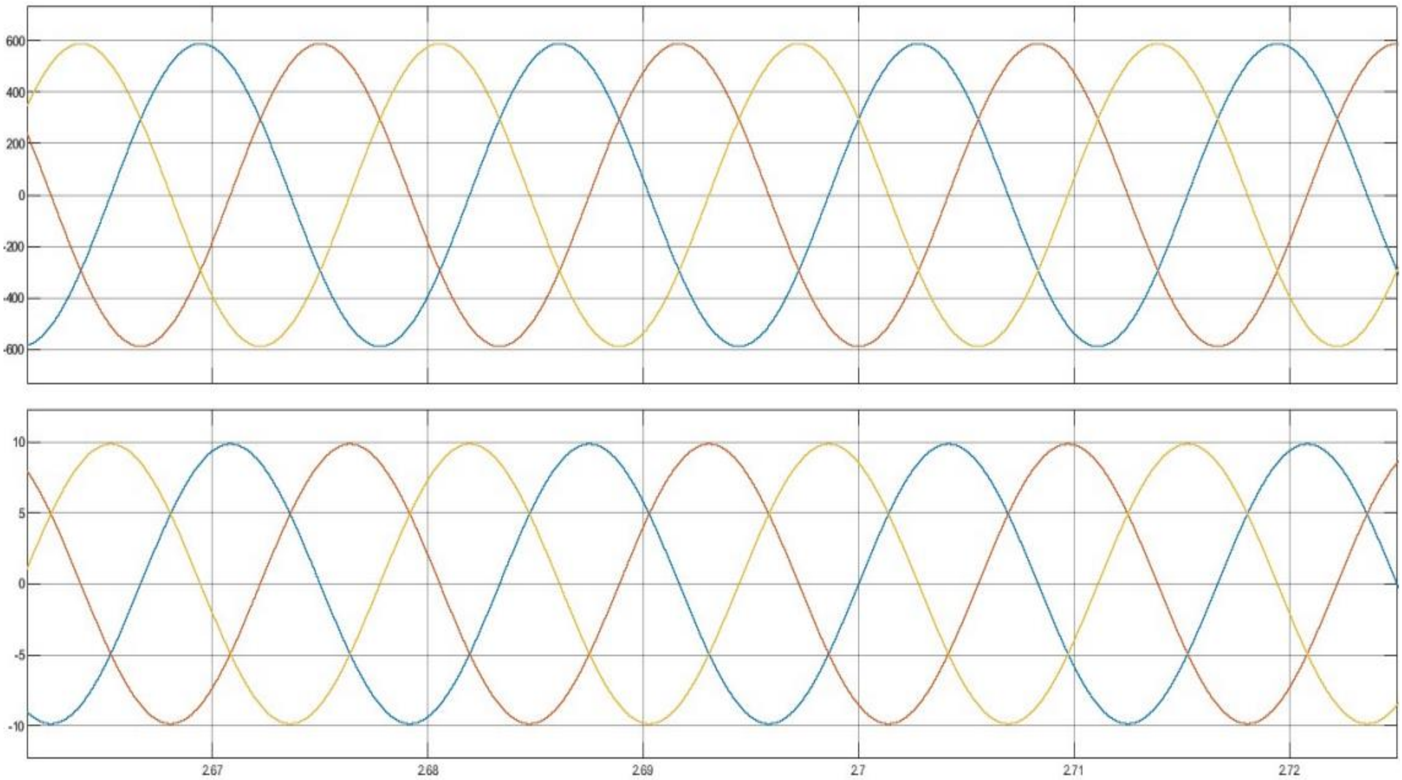

Fig 8 Grid Voltage and Current

IV. CONCLUSION & FUTURE SCOPE

The fuzzy-based MPPT system coupled with an energy monitoring system for a residential AC microgrid offers significant benefits in terms of optimizing PV power generation, improving energy management, and enhancing overall system efficiency. The proposed solution provides accurate tracking of the maximum power point, ensuring optimal utilization of the PV array under varying environmental conditions. The energy monitoring system enables real-time monitoring of PV battery state of charge (SOC) and grid power consumption, facilitating informed decision-making for load management and energy storage.

As for future work, several areas can be explored to further enhance the system's performance and capabilities. Firstly, incorporating predictive algorithms or machine learning techniques can improve the accuracy of the MPPT system by considering historical data and weather forecasts. This would enable better anticipation of environmental changes and optimization of the PV system's operation. Additionally, integrating demand response strategies and smart grid technologies can enable bidirectional communication between the microgrid and the utility grid, allowing for more effective energy exchange and load balancing. Furthermore, exploring advanced battery management techniques, such as battery aging prediction and adaptive charging algorithms, can extend the lifespan of the battery storage system and optimize its performance. Lastly, investigating the integration of renewable energy sources other than PV, such as wind or biomass, into the microgrid can enhance the system's resilience and further reduce dependence on the utility grid

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