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A Comprehensive Review on Microgrid-Based Electric Vehicle Charging Control Using Fuzzy Logic

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Abstract: *This review paper provides a comprehensive overview of microgrid-integrated electric vehicle (EV) charging systems controlled using fuzzy logic. With the rising adoption of EVs and renewable energy sources, efficient control mechanisms are essential to ensure optimal charging performance, power stability, and system reliability. The integration of solar, wind, and diesel energy sources with fuzzy logic controllers allows decentralized decision-making under uncertainty. This review discusses system architecture, battery management, fuzzy controller design, simulation results, and future research directions*

Keywords*:* Microgrid, Fuzzy Logic Controller, Electric Vehicle Charging, SOC Estimation, Renewable Energy, MATLAB Simulation.

I. INTRODUCTION

Preamble:

Electric vehicles (EVs) have emerged as a crucial solution to the global challenges of fossil fuel depletion, pollution, and climate change. However, efficient charging infrastructure is essential to support large-scale EV deployment. Microgrid-based charging stations, integrating renewable sources such as solar and wind, provide an environmentally friendly and sustainable alternative. The variability of renewable sources requires intelligent decision-making systems such as fuzzy logic controllers to determine the optimal energy source for EV charging.

grid disturbances caused by uncoordinated EV charging. Studies highlight the importance of coordinated charging strategies, vehicle-to-grid (V2G) systems, and renewable integration. Fuzzy logic control has gained attention due to its ability to handle nonlinearities, uncertain data, and linguistic decision models. It allows flexible, rule-based operation without requiring exact mathematical models.

The reviewed microgrid model incorporates three primary energy sources: solar photovoltaic arrays, wind turbines, and diesel generators. The solar PV system utilizes DC–DC converters, while the wind subsystem employs a permanent magnet synchronous generator (PMSG) and rectifier. All DC sources are integrated into a common inverter, supplying AC voltage to the charging station. A fuzzy controller dynamically selects the optimal power source based on measured voltage conditions.

Objectives:

- To improve battery management in Electric Vehicles.
- To promote the use of non-conventional and renewable energy sources.
- To develop an efficient Electric Vehicle (EV) charging control system.
- To integrate renewable energy sources into EV charging stations.
- To design and implement a Fuzzy Logic Controller (FLC)-based decentralized control system.
- To propose an SOC estimation model suitable for real-world applications.
- To select appropriate plant parameters using fuzzy logic control.

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Block Diagram

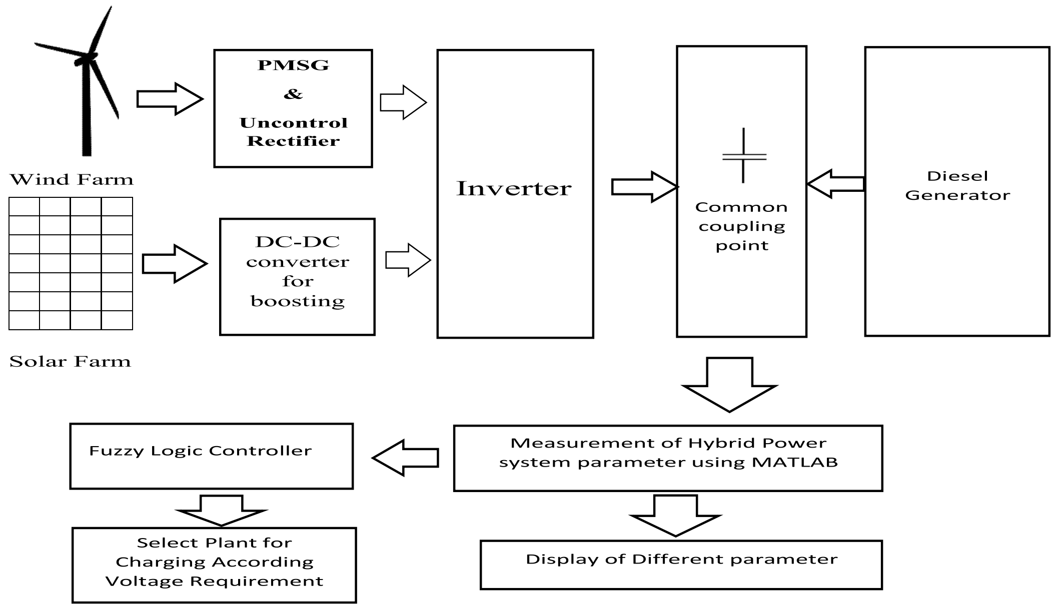

Figure 1:- Block Diagram of Proposed Methodology

The block diagram of the proposed microgrid-based EV charging control system integrates solar PV arrays, wind turbine systems, and a diesel generator. The fuzzy logic controller selects the appropriate power source based on measured voltage inputs. The figure below illustrates the complete architecture.

II. FUZZY LOGIC CONTROL

A fuzzy logic control (FLC) system is an intelligent control system that has found application in various fields of science and engineering [21]. A basic structure of a FLC system is shown in Fig. 3. It consists of a fuzzification process where the crisp input is converted to a fuzzy input, an inference engine that uses the rule base system to determine the fuzzy output and a defuzzification process that converts the fuzzy output into the crisp output is needed by the system. The rules in a FLC are determined by the IF-THEN statements.

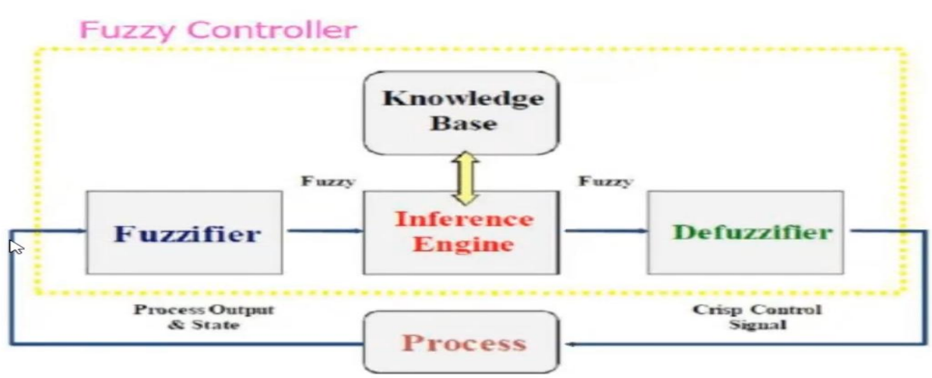

Figure 2:- Basic structure of a FLC system.

In this work, Fuzzy logic controllers (FLCs) simulate human reasoning by defining input variables using linguistic levels such as Low, Medium, High, and Very High. In the reviewed project, three-phase voltages Va, Vb, and Vc are used as input variables. Membership functions classify these inputs into suitable fuzzy sets. The

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controller applies rules to determine whether the system should select wind, solar, diesel, or all sources for EV charging.

III. RESULTS DISCUSSIONS

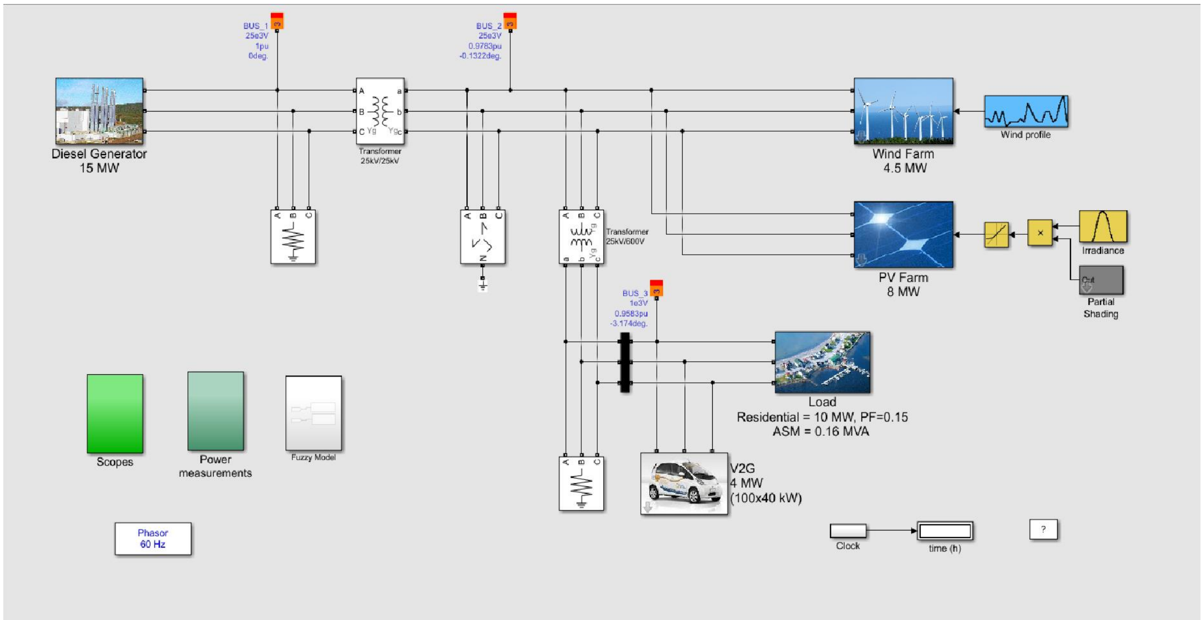

Figure 3:- MATLAB Simulink model of proposed methodology

Above figure shows the MATLAB simulation model of microgrid based electrical vehicle charging station control by using fuzzy logic controller. Above model consist of solar pv array, wind system, diesel generator, electrical vehicle, residential and industrial load dark green color is consisting of bus bar measurement subsystem for bus bar three phase voltage and current Measurement also white color subsystem consist of fuzzy logic controller to select respective plant for charging electrical vehicle according to voltage requirement.

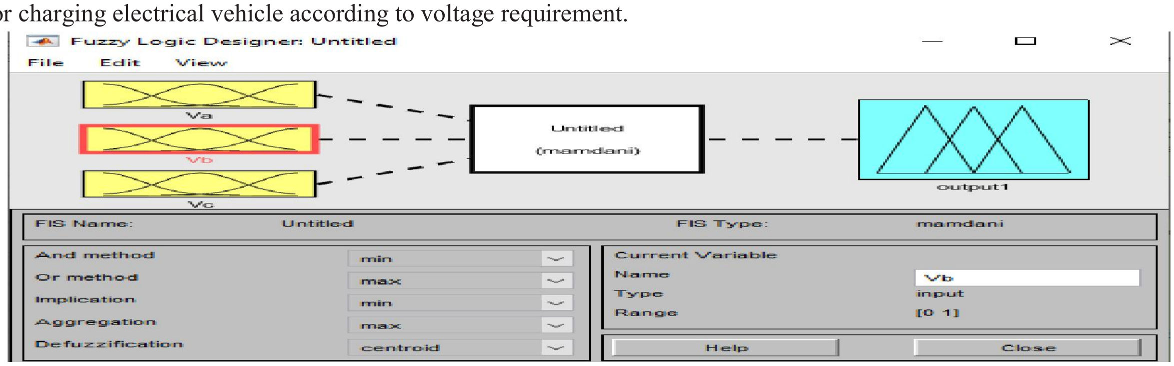

Figure 4:- Fuzzy controller design tool in matlab Simulink

Table 1:- Inputs and target for fuzzy controller

Sr No	Va	Vb	Vc	Power supply system
1	215	216	217	Wind system
2	330	334	334	Solar PV system
3	515	516	517	Diesel Generator System
4	590	584	589	All sources

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Table 2:- Inputs Va, Vb, Vc membership functions

Va, Vb, Vc	Low range	Medium range	High Range
Low	200	215	230
Medium	300	330	380
High	480	515	560
Very High	560	580	600

Table 3:- Fuzzy logic rules base

Va, Vb, Vc	Low range	Medium range	High Range
Low	200	215	230
Medium	300	330	380
High	480	515	560
Very High	560	580	600

IV. CONCLUSION

The results demonstrated that the fuzzy logic DCM achieved better results in the controlled variables and in the response of the whole system under study, while smoothing the operation transition of the CS components (the connection and disconnection of the components to the MVDC bus) with regard to classical controllers. Fuzzy logic controller successfully selects the plant for charging electrical vehicle according to voltage requirement for charging. With the rising importance for battery, both in the automotive industry and the energy sector, it is of critical importance to develop more accurate algorithms for SOC estimation of the battery. SOC estimation is crucial for many applications of batteries. Accurate SOC estimation is the main problem with battery management systems.

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