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Efficient Power Management Using Fuzzy Logic For Electrical Vehicle Charging Station Based on Hybrid Energy Source

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Abstract *– This paper presents a comprehensive exploration of efficient power management strategies applied to electrical vehicle (EV) charging stations based on hybrid energy sources, specifically integrating photovoltaic (PV) and wind energy. The study emphasizes the utilization of fuzzy logic controllers (FLCs) to optimize the dynamic and often unpredictable nature of renewable energy inputs in the charging infrastructure.*

The proposed methodology involves the modeling of a hybrid system wherein PV and wind energy serve as primary power sources, complemented by a backup battery for DC power. Fuzzy logic algorithms are employed to intelligently control the charge distribution within the battery bank, ensuring optimal utilization and controlled charging. The study further investigates the role of fuzzy logic in fine-tuning inverter control during power mismatches and implementing pitch control logic to prevent overvoltage situations.

In a departure from traditional Maximum Power Point Tracking (MPPT) methods, the paper introduces a novel approach, illustrating its application in a hybrid wind-battery system through MATLAB/SIMULINK simulations. The results demonstrate enhanced performance, stability, and reduced harmonic distortions, emphasizing the efficacy of the proposed fuzzy logic-based power management strategy.
Keywords: Electrical Vehicle Charging Stations, Power Management, Hybrid Energy Sources, Sustainable Transportation, Renewable Energy Integration Energy Efficiency

I. INTRODUCTION

The continued reliance on petroleum underscores the significance of vehicles in our daily lives, not just for personal movement but also for transporting goods. Alongside this reliance, there's growing unease about escalating fuel costs and the broadening global environmental challenges, notably air contamination and climate shifts. Consequently, some governmental bodies are urging car manufacturers to produce vehicles that are ecologically benign and emit fewer pollutants. [1]. Within this framework, electric vehicles (EVs) have emerged as a solution to cut down on fossil fuel dependence, thereby diminishing greenhouse gas and other emissions. [2]. To further curb the environmental impact of conventional vehicles, emission standards have been instituted. [3]. To combat vehicular emissions, nations such as the US, UK, Japan, and Europe have set benchmarks for their transit systems. Notably, post the Euro 5 emission norms' introduction, there's been a 99% decline in "atmospheric aerosol particles" from vehicle exhaust. Moreover, post the Euro 1 standards, there's been a marked reduction in carbon dioxide and nitrogen dioxide emissions. Predictions suggest that by 2020, vehicular emissions in Europe might reduce by 35 mg/km for nitrogen dioxide and 95 g/km for carbon dioxide. [4].

This shift in perspective has made EVs financially competitive when juxtaposed with vehicles running on internal combustion engines. Several countries, like the US, UK, China, and parts of Europe, have ratified policies and committed substantial funds to boost the widespread adoption of EVs. [5]. Table 1.1 illustrates the prevalence of EVs across different nations. Ambitious future projections indicate that by 2050, the entire EV fleet might run on renewables. [3], [6]. Indeed, advancements in battery tech and the surge in charging facilities account for the increased popularity and utility of EVs. Promoting EVs necessitates an extensive charging network. A critical limitation of the EV charging infrastructure, however, is its environmental footprint due to its grid dependence. It's evident that blending Renewable Energy Sources (RES) with EVs is the way forward, given that renewables are distributable yet intermittent, while EV charging can be managed.

Table 1.1: Global sales of EVs

	Sales(k)	**2018vs2019**
China	430.7	+111%
USA	116.2	+87%
Norway	36.3	+74%
Germany	33	+72%
France	24.3	+38%

Nether lands	17.8	+118%
Korea	17.7	+63%
Canad a	13.1	+37%
UK	12.7	+62%

To maintain a stable grid operation, it's crucial to harmonize electricity production with EV charging. A primary challenge for the future stability of the electricity grid is the inconsistent output of Renewable Energy Sources (RES). Traditional methods for controlling load fluctuations often fall short in maintaining grid balance, operational tactics, and power distribution across varied load conditions. As precise electricity production scheduling is essential for power system stability, modulating the output of RES has been proposed as a possible solution. Moreover, EVs have showcased their potential in assisting the main grid to achieve a balance between demand and supply, paving the way for increased RES integration. Studies, referenced in [7], delve deeper into this topic. Notably, since EVs don't substantially heighten the overall load, the introduction of photovoltaic (PV) production might promote higher EV adoption [8]. Proper strategies are required to incorporate EVs and PVs into the grid, either individually or in tandem, to avoid jeopardizing system dependability. The unpredictable nature of PV production timing poses a challenge for grid operators [9]. An additional concern with EVs is their potential to strain the grid and disrupt demand patterns, thus compromising grid robustness and power quality. Integrating EVs and PVs into the grid should be a meticulously planned and regulated process, potentially through a scheduled load, as mentioned in [10].

II .CHARGING STRUCTURE DESIGN

A Building a dependable and efficient charging station that can meet the expanding power needs of EVs at the chosen location while also recharging the grid or using it for conventional loads is the aim of studying and analyzing EVs charging system design. However, in this case, installation location, seasonal variations, daily weather changes, problems with the stability of the power grid (such as variations in power quality and voltage), and storage system capacity are all important factors to take into account. As a result, the integrated system design for an EVs charging hybrid PV/grid/storage system is implemented in this thesis.

We look at the discrepancy between energy supply and demand and its effects on the design of charging systems. An analysis of EV users' daily travel habits and comprehensive meteorological data modeling, including solar irradiation and temperature, are also necessary. When designing the EV charging system, the nominal power of the PV/grid/BSS should be taken into consideration in order to determine the necessary power conversion steps. The ESS can simultaneously control changes in the electricity grid or solar energy production, as well as store energy during times of excess production to power the charging system during times of low production. To ensure that the EV charging process adheres to the production variables of the power source, modern charging systems use intelligent charging techniques.

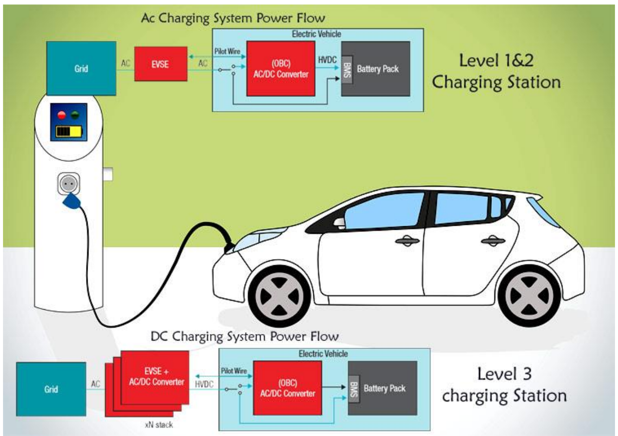

Fig. 1.1: Charging station structure design

III. METHOD

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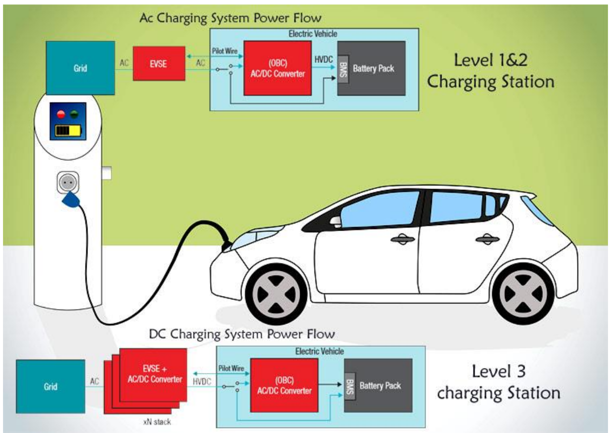

Fig. 1.2: Charging station structure design

IV. Result

This is Simulation result and discussion section of proposed model as show on figure 3. In this figure is basically divided three part one is source that we used PV and wind renewal energy source to reduce power demand from conventional source. This is our primary power source. In this proposed model also used batter as a storage and alternate dc power source of proposed model then we are using converter come controller fuzzy logic and last section we connect EV's charging station as a load of proposed system.

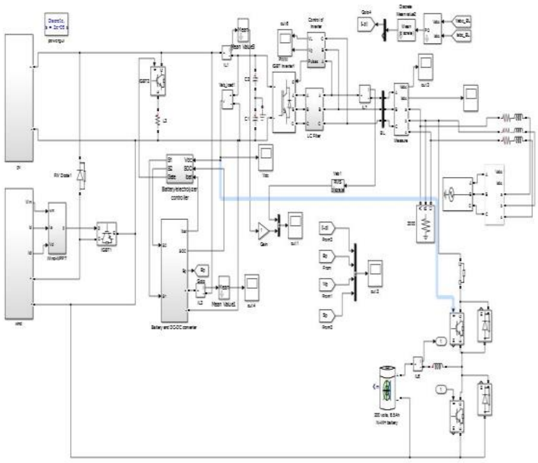

Fig.3 Proposed model

Figure3 is show proposed complete model. This is hybrid model basically depend upon renewal energy and constant generate high quality output from the source.
In proposed work designed hybrid power system. That is connected battery, PV and Wind. This is result section for proposed model. Here we are analysis our proposed architecture design and analysis with different operation like source variation and load variation.

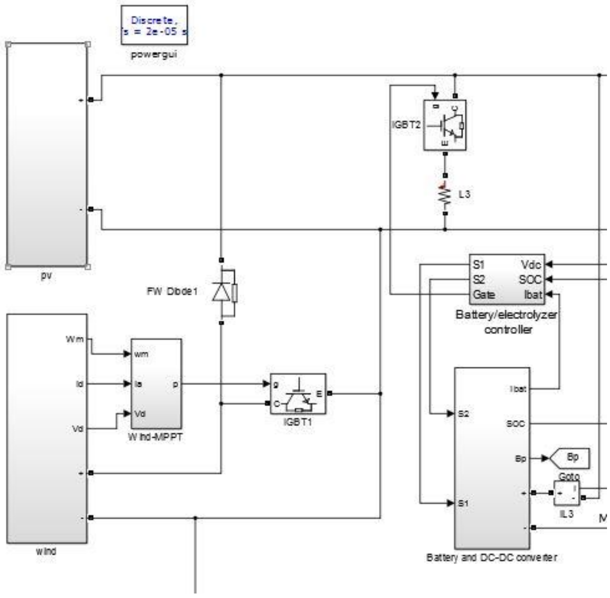

Fig. 4: Source section of proposed model

Figure 4 is show renewal energy source along with DC-Dc converter and Battery controller. In this figure is show renewal energy source is initial source of system and that is connected with Dc-Dc converter and battery controller. That battery controller is design for battery charging and discharging as for model demand to main power requirement of proposed model.

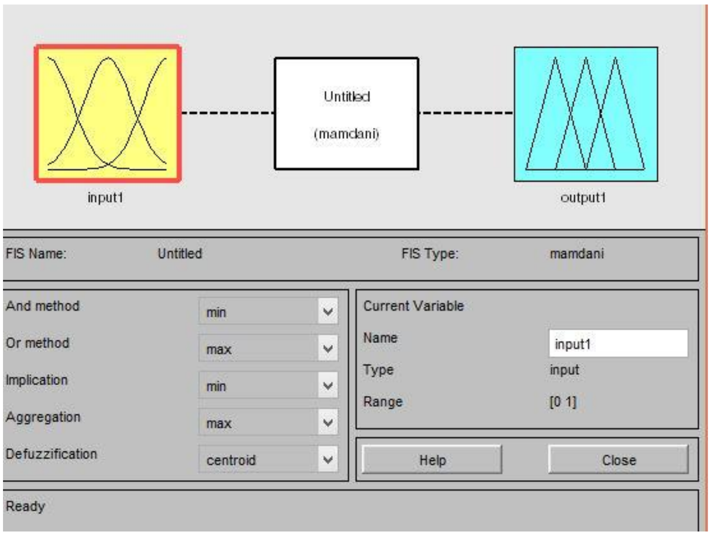

Fig. 5: Initial Fuzzy Model in proposed system

Figure 5 shows the initialization window of fuzzy for optimization of power quality in the proposed system, this is divided into three sections one is input, another is output and mid fuzzy controller section that measures a different and according to rule generated output.

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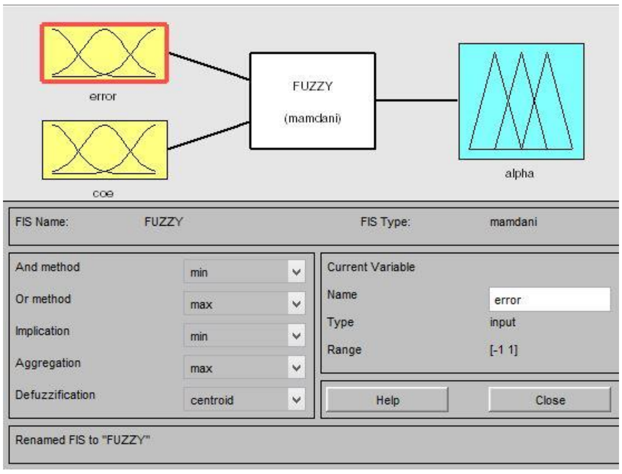
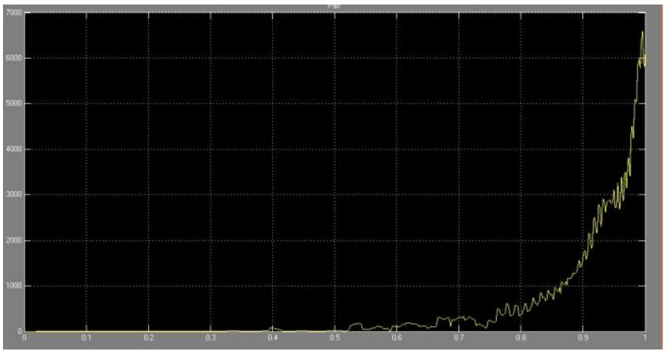


Fig. 6: After the apply fuzzy model in proposed system

Figure 6 shows the after-initialization window of fuzzy for optimization of power quality in the proposed system, this is divided into three sections one is input, which has two parameter errors and coefficient, another is output alpha which is the resultant of fuzzy and mid-fuzzy controller section that measures a different and according to rule generated output.


(a) Wind Power Generation

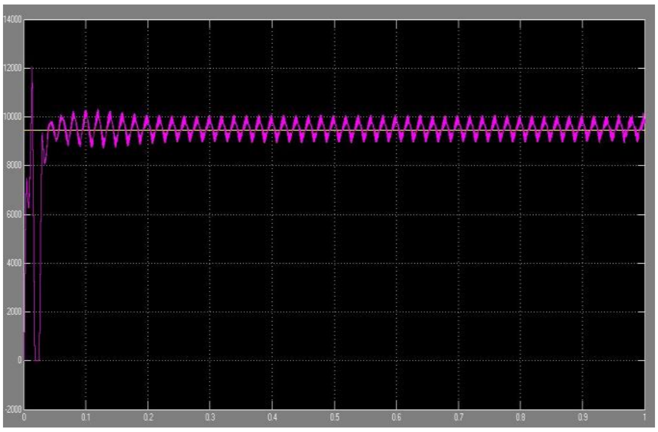

(B) PV Power Generation

Fig. 7: Power Generation Graph by (a)Wind (b)Solar

Figure 7 shows the power generation by renewal energy source in a proposed model where (a) Wind power generation is 6133 W and (b) Solar power generation is 9464 W.

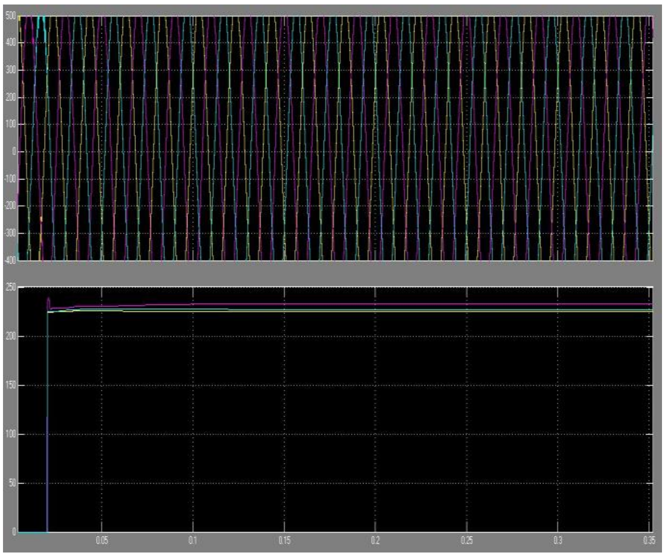
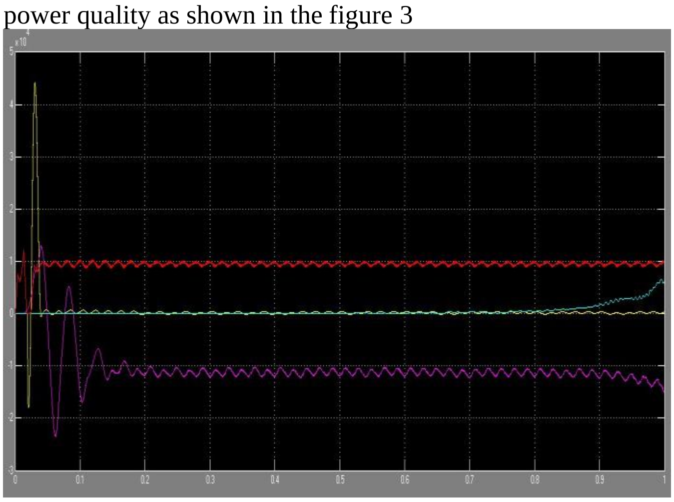


Fig. 8: PWM output of proposed model

Figure 8 shows PWM out of the proposed model. In this figure, PWM controls the voltage and current of the proposed model. This is a system associated with fuzzy to control power quality as shown in the figure 3


(a)Load power with respect to all source

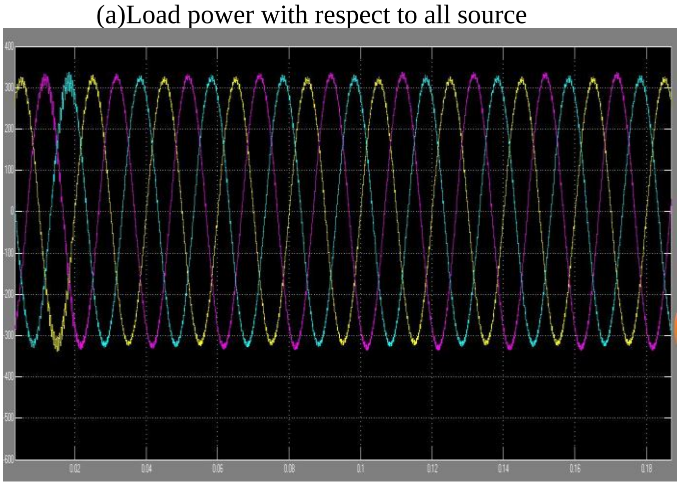

(b)Voltage

Fig. 9: Load power with respect to all source (a) Load power and source power(b) Output voltage

V. CONCLUSION

This paper has focused on the development of a hybrid renewable energy-based charging station, integrating photovoltaic (PV) and wind energy sources as primary power inputs, with a backup battery serving as an alternative source of DC power. The central theme of this work revolves around the modeling of a DC hybrid system, featuring wind and solar energy inputs.

The control logic of the hybrid setup incorporates a Fuzzy algorithm for battery charge control. The charge controller, driven by the Fuzzy algorithm, continuously monitors errors, optimizes charging, and facilitates controlled access to the battery bank. In instances of power mismatches, the inverter control is finely tuned, and the pitch control logic prevents overvoltage situations in the rectifier voltage. Additionally, the converter is safeguarded from overcurrent scenarios through a current-programmed control method.

An innovation in this work involves the replacement of the widely used P&O algorithm for Maximum Power Point Tracking (MPPT) with a more effective approach. The dissertation details the creation and simulation of a hybrid wind-battery system, employing MATLAB/SIMULINK and tested using a wind profile. The results of the simulation experiments indicate improved system performance and stability, notably in reducing voltage flickers and harmonics.

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