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# Optimizing Electric Vehicle Charging Using a PV-Based Multi-Mode Converter with Enhanced ANN Control for Vehicle-to-Home Applications

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***Abstract*— The rising acceptance of electric cars (EVs) as a sustainable form of transportation has resulted in a greater demand for readily available charging stations. However, fast charging stations—especially the ultra-fast ones—can seriously tax the power grid due to potential overloads during peak hours, unplanned power outages, and voltage dips. This paper presents detailed modeling of a multiport converter-based battery energy storage system and DC power generating system integrated into an EV charging station. The study evaluates the feasibility of deploying Plug-in Electric Vehicles (PEVs) in Vehicle-to-Home (V2H) situations, where the vehicle serves as a backup generator and/or household battery storage system, particularly during temporary distribution system failures or power outages.**

**Simulation and experiment data validate the feasibility of the proposed Multi-Mode Converter (PCMM) and demonstrate its capacity to achieve design objectives. This charger's construction and functionality were assessed using a comprehensive simulation analysis in conjunction with a space vector modulation technique. The results of the simulation indicate that in a typical home, the recommended charger would work well with a sufficient autonomous Energy Management System (EMS). Enhancing performance with an Artificial Neural Network (ANN) Controller strengthens the system's ability to regulate EV charging conditions. In the current system, the Proportional-Integral (PI) Controller is used.**

***Keywords*— Electric Vehicles (EVs), Sustainable Transportation, Artificial Neural Network (ANN) Controller, Proportional-Integral (PI) Controller etc.***

## I. INTRODUCTION

Including sustainable energy sources in The increasing popularity of electric vehicles (EVs) is contributing to the acceleration of the shift towards sustainable transportation. EVs are a vital component in lowering greenhouse gas emissions and decreasing the effects of climate change since they are a greener alternative to conventional internal combustion engine vehicles. But the quick rise in EV use brings with it new difficulties, especially with regard to infrastructure for charging EVs. The need for quick and easy charging stations is growing, yet integrating fast and ultra-fast charging stations puts a lot of strain on the current power system. This may result in unexpected power outages, voltage dips, and overloads during peak hours, requiring creative methods to properly handle these difficulties.

The creation of a reliable and adaptable charging system that makes use of cutting-edge energy management techniques and renewable energy sources, such photovoltaic (PV) systems, is one viable solution to these problems. The design and implementation of a battery energy storage system and a DC power production system integrated into an

EV charging station based on a multiport converter is the main topic of this work. In addition to enabling effective EV charging, the suggested system offers Vehicle-to-Home (V2H) scenarios, in which Plug-in Electric Vehicles (PEVs) can serve as home battery storage systems and backup generators in the event of distribution system failures or power outages.

This study attempts to improve system performance and optimize charging by utilizing a space vector modulation technique in conjunction with a Multi-Mode Converter (PCMM). Additionally, in order to enhance the regulation of EV charging conditions, the integration of an Artificial Neural Network (ANN) Controller is investigated. This approach offers a more responsive and adaptive control mechanism in contrast to conventional Proportional-Integral (PI) Controllers.

In order to confirm the viability and efficiency of the suggested charging mechanism, this research includes both computational and experimental data. The findings show that, in typical home contexts, the PCMM can accomplish the design goals and work well with an independent Energy Management System (EMS). Our goal is to help the wider adoption of electric vehicles and the shift to a more sustainable energy future by advancing the construction of more robust and sustainable EV charging infrastructure through this research.

The organizational framework of this study divides the research work in the different sections. The Literature survey is presented in section 2. In section 3 &4 discussed about Existing & proposed system methodologies. Further, in section 5 shown Results is discussed and. Conclusion and future work are presented by last sections 6.

## II. LITERATURE SURVEY

G. Aswani, V. S. Bhadoria, Y. Saw, The potential and difficulties of adopting electric vehicles (EVs) in India are examined in this essay. It draws attention to the gaps in policy frameworks, technological obstacles, and infrastructure that prevent EV adoption. The report contends that in order to overcome these obstacles and encourage the widespread adoption of EVs in India, supporting laws, government initiatives, and developments in battery technology are essential.[1] Giri and Isha examine the effects on power quality of different non-isolated EV charging strategies. They evaluate several topologies according to their harmonic distortion, power factor correction, and efficiency. The results show that non-isolated systems can be adjusted for increased performance, however there are still issues with minimizing negative effects on power quality. [2]

A flexible voltage bus converter is introduced by Kim and Kwak and is intended for use with dual 48V/12V supply systems found in electrified cars. The suggested converter has a high handling flexibility and efficiency for various voltage requirements. This study emphasizes how crucial flexible power conversion options are to raising EV efficiency and performance.[3] A digital PFC control technique designed for digital signal processors (DSP) is presented by Tousi et al. The effective operation of EV chargers depends on this method's improvement of power factor and reduction of total harmonic distortion in power electronics systems. The precision and flexibility provided by the digital control technique improve system performance as a whole.[4]

K. Raggl, T. Nussbaumer, and Comprehensive design guidelines for interleaved single-phase boost PFC circuits are presented in this work. In order to attain high efficiency and low electromagnetic interference—two crucial design factors for EV chargers—Nussbaumer et al. concentrate on optimizing the design. The interleaved method enhances converter performance overall by dispersing the heat load.[5] Different AC-DC converter topologies utilized in EV battery charging are compared by Indalkar and Sabnis. They evaluate converters according on their performance, cost, complexity, and efficiency. According to the study's findings, choosing the right topology has an impact on customer satisfaction and cost in addition to being essential for ensuring dependable and efficient EV charging.[6]

A technique and system for recharging plug-in hybrid electric vehicles (PHEVs) are proposed by Song et al. The system's main goal is to maximize battery longevity and efficiency during charging. The control strategy guarantees efficient power management, meeting grid stability requirements as well as the needs of the vehicle.[7] Moulali, S. and Muni, Vijay This work presents a flying capacitor multilevel inverter topology with Phase Opposition Disposition (POD) and Alternate Phase Opposition Disposition (APOD) pulse width modulation for photovoltaic (PV) systems. The study demonstrates how this topology, which is relevant to PV-based EV charging stations, can improve the output quality and efficiency of PV systems.[8]

Srikanth et al. create and model a hybrid energy system that combines wind and photovoltaic power. Using the advantages of both renewable energy sources to reduce intermittency, this hybrid strategy offers EV charging stations a more dependable and steady power supply.[9] Sai Sri Vidya, T., and Vijay Muni The hybrid power system dynamic model with Maximum Power Point Tracking (MPPT) under rapidly varying solar radiation circumstances is presented in this work. The results emphasize how crucial dynamic modeling and MPPT are to hybrid system performance optimization, which is necessary to keep renewable energy-powered EV charging stations stable and effective.[10]

## III. EXISTING SYSTEM

There are three main types of EV charging systems now in use: Level 1, Level 2, and Level 3 (DC Fast) chargers. Each type of charger has advantages and disadvantages of its own. Although they are handy for use at home and have a modest charging rate, Level 1 chargers—which use a typical 120V domestic outlet—are insufficient for urgent recharging demands. At 240V, level 2 chargers provide a quicker charging rate that is appropriate for overnight charging in both public and home settings. Direct current (DC) level 3 chargers offer quick charging that drastically cuts down on recharging time, but they also place a heavy load on the electrical system. Particularly during peak hours, this increased power demand may put strain on the system and result in overloads, power outages, and voltage dips.

Current systems frequently employ non-isolated charging schemes, which can have a negative impact on power quality by introducing harmonics and resulting in low power factor, which raises operating costs. Furthermore, a lot of current systems don't integrate renewable energy sources well enough, which results in missed possibilities for more environmentally friendly operation. Even though they are straightforward and simple to use, traditional controllers like proportional-integral (PI) controllers might not be able to offer the adaptive performance required for dynamic charging situations. The trend for future advancements is indicated by advanced characteristics found in contemporary systems, such as interleaved boost PFC circuits, digital control techniques, and hybrid energy systems that combine wind and photovoltaic (PV) energy. Nevertheless, despite these obstacles, the current systems have laid the groundwork for EV adoption, highlighting the necessity for continual innovation to improve efficiency, sustainability, and grid stability.

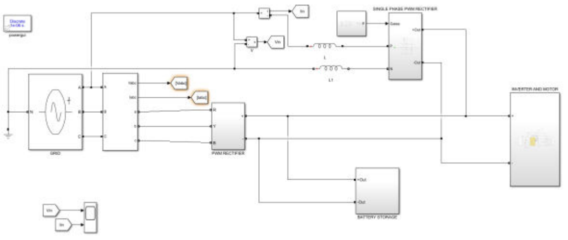


Fig. 1. Cnfiguration of existing method

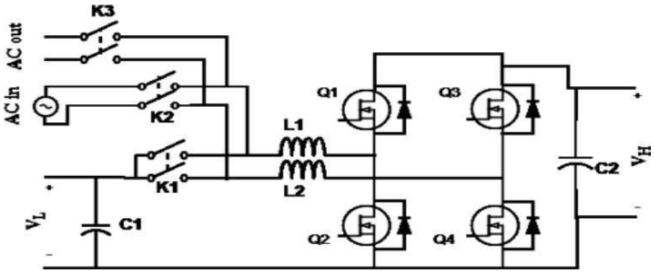


Fig. 2. Existing MMPC Topology

Power management functionality, a power factor of 1 to ensure efficient power utilization, minimal impact on power quality (PQ), compatibility with standard 16 A single-phase plugs, bidirectional power flow capability for Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) applications, and simplicity in design and topology are among the main requirements that the proposed charger seeks to meet. The highest safe output for a single-phase wall outlet plug is 2.3 kW, and fast charging is not possible due to grid constraints and safety rules. This restriction is essential to maintain compliance with EU standards and prevent negative effects on low voltage (LV) grids.

L-category vehicles—which include two-, three-, and four-wheel vehicles like motorcycles, mopeds, quads, and minicars—are given priority in the design. If required, it can be adjusted to operate at different voltage levels. These needs can be satisfied by the current Multi-Mode Power Converter (MMPC) architecture, which uses an interleaved boost Power Factor Correction (PFC) technique. Through the use of this technology, lower pair IGBTs can be gated during AC-DC operation, allowing the AC mains to provide continuous input current. This method minimizes the effect on power quality, guarantees effective power conversion, and permits bidirectional power flow for V2G and G2V applications.

## IV. PROPOSED METHOD

To improve the charging system's performance and adaptability, an Artificial Neural Network (ANN) Controller is included in the suggested technique. The ANN Controller is an intelligent control mechanism that may dynamically optimize charging operations by learning from data and modifying its parameters.

The ANN Controller works by using a network of interconnected nodes that imitates the structure and operation of biological neurons to process input data, such as grid conditions, car battery status, and user preferences. The ANN "learns" to map input data to desired output actions through a process called training, thereby "learning" the best charging techniques based on historical data and environmental factors.

The capacity of an ANN controller to adjust to changing situations and gain experience is one of its main benefits. An artificial neural network (ANN) controller may continually update its internal parameters based on input from the environment, in contrast to traditional control methods like proportional-integral (PI) controllers, which rely on predefined rules and parameters. The charging system's efficiency and performance are enhanced as a result of its capacity to adapt to changes in user behavior, battery state-of-charge, and grid load.

Moreover, the ANN Controller improves the system's capacity to control grid stability, optimize charging schedules, and handle bidirectional power flow. The ANN Controller can dynamically allocate power resources, prioritize charging duties, and prevent possible difficulties like voltage by continuously analyzing data and modifying control signals in real-time.

In general, the incorporation of an artificial neural network (ANN) controller into the suggested charging system signifies a noteworthy progression in control technology, permitting more intelligent and adaptable charging processes. The system can increase efficiency, dependability, and user happiness by utilizing machine learning techniques, which will further support the development of sustainable transportation infrastructure and the broad adoption of electric vehicles.

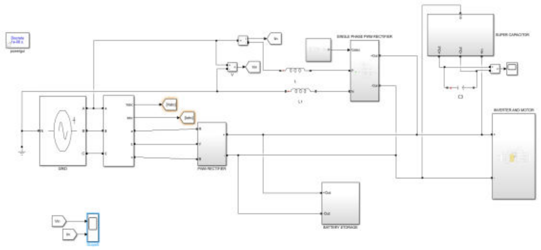


Fig. 3. Cnfiguration of Proposed method

In the proposed method, the inverter and motor circuit play a crucial role in facilitating bidirectional power flow between the electric vehicle (EV) battery and the grid. The inverter converts DC power from the battery into AC power for grid connection during Grid-to-Vehicle (G2V) charging, while during Vehicle-to-Grid (V2G) operation, it converts AC power from the grid into DC power for charging the EV battery. The inverter circuit typically consists of power semiconductor devices such as Insulated Gate Bipolar Transistors (IGBTs) or Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs), along with control circuitry to regulate voltage, current, and frequency. During G2V charging, the inverter converts DC power from the grid into AC power with the required voltage and frequency to charge the EV battery. Conversely, during V2G operation, the inverter converts AC power from the EV battery into DC power suitable for grid connection.

The motor circuit, on the other hand, is responsible for controlling the speed and torque of the EV motor during operation. It typically consists of power electronic devices such as inverters, along with sensors and control algorithms to regulate motor speed and torque. During V2G operation, the motor circuit may also function as a generator, converting mechanical energy from the vehicle's drivetrain into electrical energy for grid injection.

The integration of advanced control algorithms, such as Field-Oriented Control (FOC) or Direct Torque Control (DTC), allows for precise control of motor speed and torque, maximizing efficiency and performance. Additionally, regenerative braking systems can be incorporated into the motor circuit to capture and store kinetic energy during braking events, further enhancing energy efficiency and extending vehicle range.

Overall, the inverter and motor circuit in the proposed method enable seamless bidirectional power flow between the EV battery and the grid, supporting both charging and discharging operations while ensuring efficient and reliable operation of the electric vehicle. Through careful design and integration, these components contribute to the overall effectiveness and sustainability of the EV charging system.

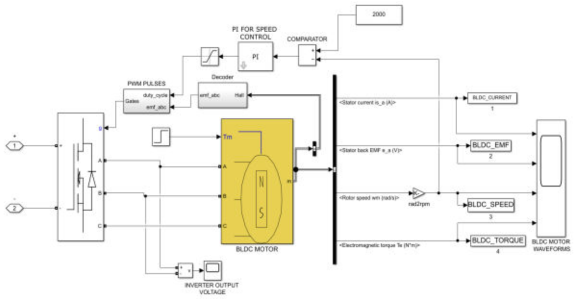
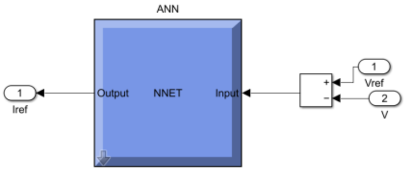


Fig. 4. Inverter and Motor Circuit

## ANN Controller

In this project, the integration of an Artificial Neural Network (ANN) Controller serves as a crucial component to enhance the efficiency, adaptability, and intelligence of the charging system. The need for an ANN Controller arises from the complexity and variability of the charging process, as well as the dynamic nature of grid conditions and user preferences. Traditional control methods, such as Proportional-Integral (PI) controllers, may struggle to effectively manage the diverse and fluctuating parameters involved in electric vehicle (EV) charging, including grid load, battery state-of-charge, and user behavior. By contrast, an ANN Controller offers the ability to learn from data and adjust its parameters in real-time, enabling it to adapt to changing conditions and optimize charging strategies accordingly. This adaptive capability is particularly valuable in scenarios where grid constraints, renewable energy integration, and user demand fluctuate unpredictably. Furthermore, the ANN Controller enhances the system's capability to manage bidirectional power flow, prioritize charging tasks, and maintain grid stability, thereby maximizing efficiency and reliability. Overall, the inclusion of an ANN Controller in this project represents a significant advancement in control technology, providing a versatile and intelligent solution to address the complex challenges of EV charging in a dynamic and evolving energy landscape.



## V. RESULTS AND DISCUSSION

### A. *Existing Method*

The simulation results for the existing method provide a comprehensive understanding of the system's behavior and performance under various operating conditions.

This figure 5 displays the waveforms of the input DC voltage and current supplied to the charging system. It provides insights into the voltage and current levels supplied from the grid or renewable energy sources, showing any fluctuations or variations over time.

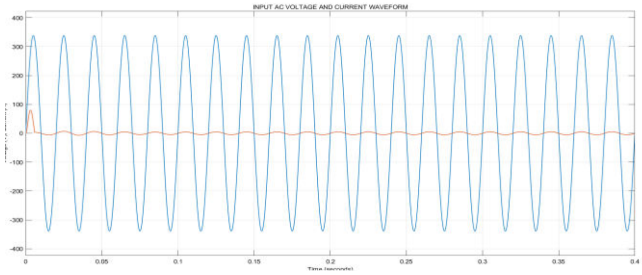


Fig. 5. Input DC Voltage and Current Waveform

This figure 6 presents the state-of-charge (SOC) of the battery alongside the voltage and current waveforms during charging and discharging cycles. It illustrates how the battery SOC evolves over time in response to charging and discharging operations, as well as the corresponding voltage and current profiles.

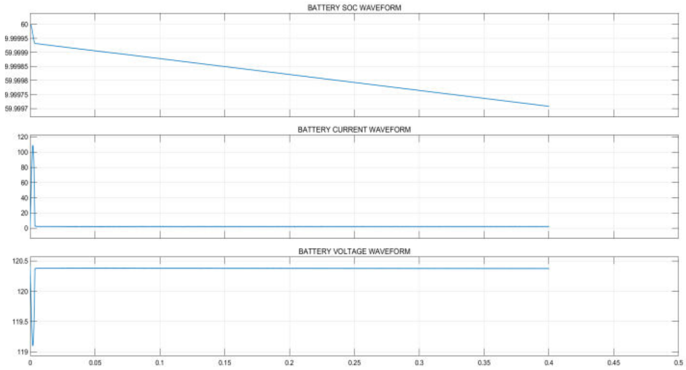


Fig. 6. Battery SOC and voltage and current waveform

This figure 7 depicts the waveforms of various parameters related to the Brushless DC (BLDC) motor, including motor current, back electromotive force (EMF), speed, and torque. It provides insights into the dynamic behavior of the motor during operation, showing how current, speed, and torque vary over time.

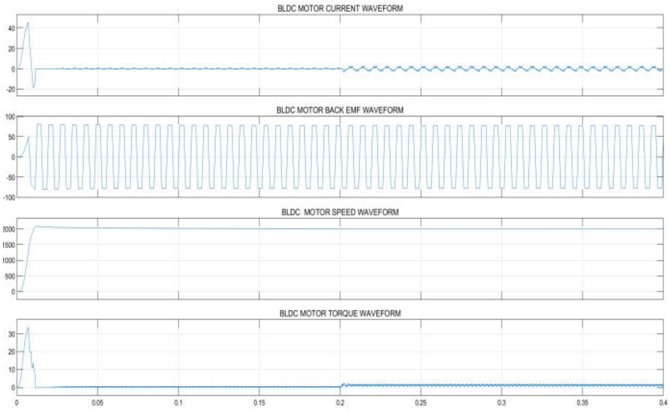


Fig. 7. BLDC Motor Current, Back EMF, Speed and Torque waforms

This figure 8 displays the waveforms of the DC voltage and current output from the Pulse Width Modulation (PWM) rectifier. It illustrates the rectification process and the resulting DC voltage and current waveforms, showing any ripple or distortion in the output.

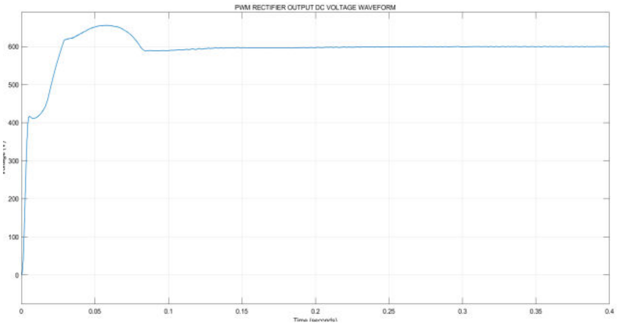


Fig. 8. PWM Rectifier DC Voltage and Current Wavefonn

This figure specifically focuses on the output DC voltage waveform of the single-phase PWM rectifier. It provides a detailed view of the rectified DC voltage, highlighting its stability and consistency over time.

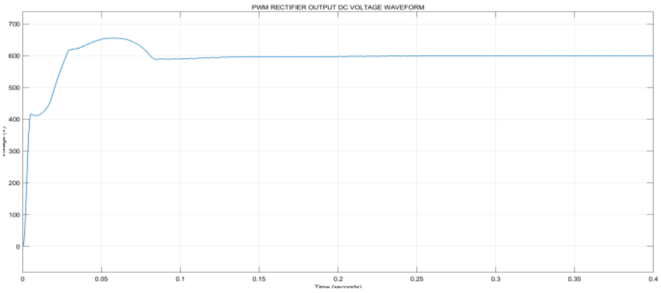


Fig. 9. Single Phase PWM Rectifier Output DC Voltage

This figure shows the waveforms of the output voltage and current supplied to the load (e.g., the EV battery). It illustrates how the charging system delivers power to the load, showing the voltage and current profiles and any variations or disturbances in the output**.**

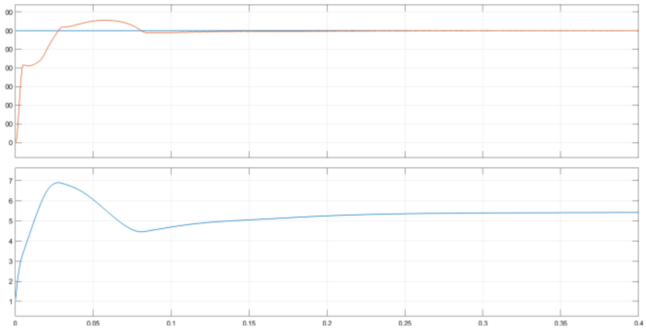


Fig. 10. Output Votage and Current waveform

## B. *Proposed System*

The simulation results for the proposed method system provide a detailed understanding of the system's behavior and performance under different conditions

This figure 11 illustrates the waveforms of the input AC voltage and current supplied to the proposed charging system. It shows the voltage and current profiles from the grid or renewable energy sources, indicating any variations or fluctuations over time.

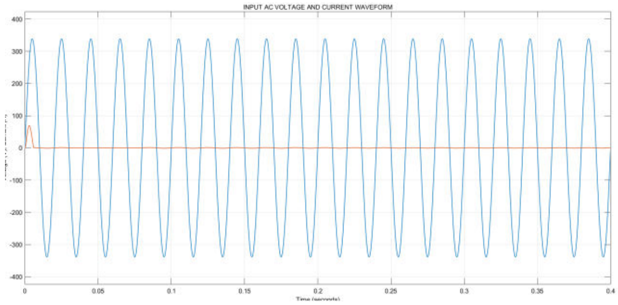


Fig. 11. Input AC Voltage and Current waveform

This figure 12 displays the state-of-charge (SOC) of the battery alongside the current and voltage waveforms during charging and discharging cycles. It demonstrates how the battery SOC evolves over time in response to charging and discharging operations, as well as the corresponding current and voltage characteristics.

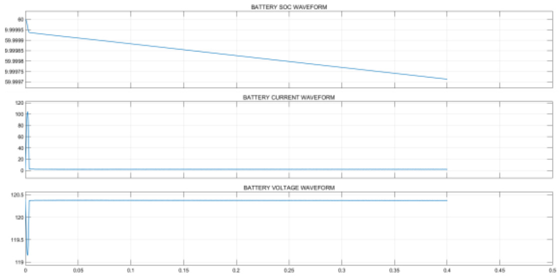


Fig. 12. Battery SOC , current and Voltgae Waveform

This figure 13 presents the waveforms of various parameters related to the Brushless DC (BLDC) motor, including motor current, back electromotive force (EMF), speed, and voltage. It provides insights into the dynamic behavior of the motor during operation, showing how current, speed, and voltage vary over time.

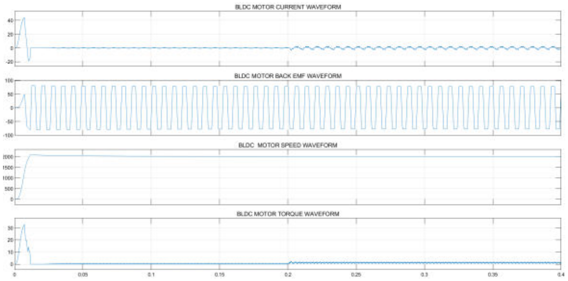


Fig. 13. BLDC Motor Current ,Back EMF,Speed and Voltage waveform

This figure 14 displays the waveform of the DC voltage output from the Pulse Width Modulation (PWM) rectifier. It illustrates the rectification process and the resulting DC voltage waveform, indicating any ripple or distortion in the output.

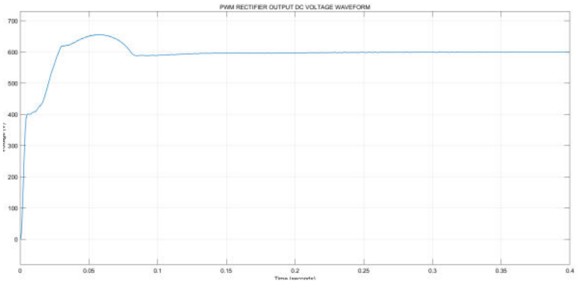


Fig. 14. PWM rectifier output DC Voltage

This figure 15 depicts the structure of the Artificial Neural Network (ANN) implemented in the proposed system. It illustrates the architecture of the neural network, including the number of layers, neurons, and connections, providing insights into how the ANN processes input data and generates output commands.

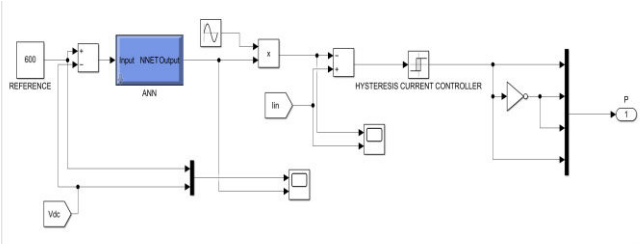


Fig. 15. ANN shown in proposed blcock

This figure 16 shows the waveforms of the output voltage and current supplied to the load (e.g., the EV battery) by the proposed charging system. It demonstrates how the charging system delivers power to the load, indicating the voltage and current profiles and any variations or disturbances in the output.

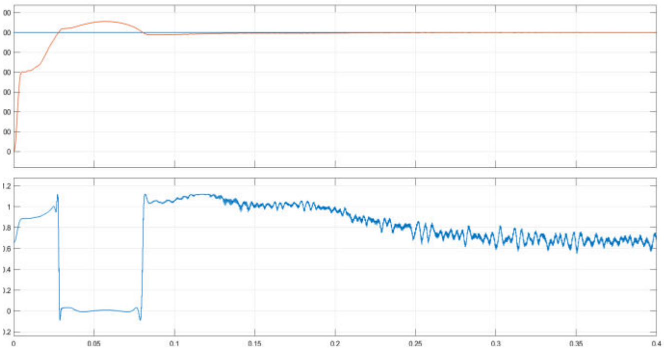


Fig. 16. Output Voltage and Current wveforms

These simulation results offer valuable insights into the operation and performance of the proposed charging system, demonstrating its ability to efficiently charge electric vehicles while maintaining grid stability and optimizing energy utilization.

## VI. CONCLUSION

The proposed charging system, with its advanced features and intelligent control algorithms, demonstrates promising performance in efficiently charging electric vehicles (EVs) while ensuring grid stability and optimizing energy utilization. The simulation results illustrate the system's capability to manage bidirectional power flow, prioritize charging tasks, and adapt to changing grid conditions and user requirements.

The integration of an Artificial Neural Network (ANN) controller enhances the system's adaptability and intelligence, allowing it to dynamically adjust charging strategies and optimize energy management in real-time. Additionally, the use of a Multi-Mode Power Converter (MMPC) topology, combined with an interleaved boost Power Factor Correction (PFC) method, enables efficient power conversion while minimizing the system's impact on power quality.

Future scope for this project includes several areas of improvement and expansion. Firstly, further refinement and optimization of the ANN controller can enhance its learning capabilities and adaptability to a wider range of operating conditions and user preferences. Additionally, the integration of advanced energy management algorithms and predictive analytics can improve the system's ability to forecast grid demand and optimize charging schedules.

In conclusion, the proposed charging system represents a significant advancement in EV charging technology, offering a comprehensive solution for efficient, intelligent, and sustainable charging infrastructure. Continued research and development in this field hold great potential for addressing the challenges of EV adoption and accelerating the transition to a greener and more resilient transportation ecosystem.

### *Future Scope*

In future the proposed method can be extended with the integration of energy storage systems, such as batteries or supercapacitors, can enhance the system's energy storage capabilities and provide additional flexibility in managing peak demand and grid stability. Moreover, exploring novel charging technologies, such as wireless charging or fast-charging solutions, can address the growing demand for faster and more convenient charging options for EVs.

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