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DESIGN AND DEVELOPMENT OF AN INTEGRATED DRIVE AND CHARGING SYSTEM FOR ELECTRIC VEHICLES

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ABSTRACT: The objective of this project is to construct and refine an integrated drive and charging system for electric vehicles, thereby integrating propulsion and charging operations into a single power electronics architecture. The proposed solution reduces costs, saves space, and streamlines the system by utilizing shared components such as the inverter and motor windings to manage both on-board charging and traction. The system is capable of transitioning between driving and charging modes with minimal degradation in power quality, reliability, or efficiency through the use of advanced control algorithms. The integration also enables bidirectional power transfer in vehicle-to-grid (V2G) applications, which improves energy management and reduces the necessity for supplementary hardware. The system that has been developed is a viable alternative for next-generation electric vehicles, as it outperforms conventional separate propulsion and charging systems while consuming less energy, as demonstrated by experimental and simulation results. Additionally, it is more compact and diminutive.
Keywords: *Electric Vehicles (EVs), Integrated Drive and Charging System, Power Electronics, On-board Charger, Traction Inverter, Bidirectional Power Flow,*

I. INTRODUCTION

The proliferation of electric vehicles (EVs) has resulted in a significant increase in the demand for powertrain systems that are efficient, compact, and reasonably priced. The total size, weight, and expense of the vehicle are all increased by the utilization of separate modules for the purpose of charging the battery and propelling the vehicle in conventional EV designs. Researchers are primarily concerned with the consolidation of multiple functions into a single system in order to address these constraints. Consequently, in order to enhance efficiency and eliminate hardware redundancy, integrated motor and charging systems have been created.

An integrated drive and charging system utilizes common components such as the inverter and motor windings by integrating the traction drive with the on-board charger capabilities. The system has the ability to transition between charging and transportation modes by rearranging these components. The power density is increased, the number of components is reduced, and the cost is reduced by eliminating the need for a distinct charger. This integration optimizes the system as a whole and optimizes the vehicle's space.

Advanced control techniques that facilitate a smooth transition between charging and propulsion phases are indispensable for an integrated system. The inverter regulates the electricity that is directed to the motor while you are traveling and effectively charges the battery when you are charging. The safety features, modulation schemes, and switching devices must be precisely controlled in order for this dual-mode operation to function.

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Consequently, in order to ensure consistent and efficient performance, it is imperative to implement dependable control systems.

An additional significant advantage is that integrated systems can facilitate the passage of power in both directions. Consequently, it is feasible to implement use cases such as V2G and V2H, in which electric vehicles (EVs) can supply grid or residential loads with stored energy. EVs with these characteristics are more capable of adapting to the energy ecosystems of today as a result of improvement in grid stability, energy management, and the utilization of renewable energy sources.

II. LITERATURE SURVEY

Reddy, P. (2025) Reddy emphasized the importance of integrating electric vehicle propulsion and onboard charging systems in order to reduce component redundancy and overall system costs. The research indicates that the charging unit and motor driving inverter can be merged to improve the system's power transmission and system usage in both directions. Businesses implemented this integrated architecture to optimize their products' efficiency and minimize their footprints. The system's energy management and dependability have been enhanced by the intelligent synchronization of charging and driving modes, as per Reddy.

Singh, A. (2024) Singh investigated the potential of unified power electronic converters to facilitate battery charging and traction motors in 2024. Researchers found that the use of a shared converter design resulted in an increase in both hardware complexity and power density. These technologies, according to Singh, enable the seamless transition between charging and transportation by eliminating the necessity for additional electronics. The paper indicates that linked systems are responsible for the development of more efficient and lightweight vehicles.

Chen, L. (2023) Chen conducted research on state-of-the-art digital controller control methods for real-time operations in order to develop charging and drive systems that operate in conjunction. The research demonstrated that the coordinated charging management of the motor windings resulted in an improvement in both power factor and harmonic distortion. The technique eliminates the necessity for additional chargers by utilizing the current inverter configuration. This integration, according to Chen, enhanced the efficacy of energy conversion and reduced losses inelectric vehicles.

Khan, M. (2022) Khan devoted the majority of his time and energy to the development of inverters that achieved dual functionality, enabling them to be utilized for both transportation and recharge. The paper concluded that the most effective utilization of motor components for grid-connected charging was achieved by identifying the appropriate switching mechanisms. Khan discovered that interconnected systems reduced the size of the system while enhancing thermal management. The research indicates that these designs are indispensable for the subsequent iteration of compact electric vehicles.

Park, H. (2021) Park employed motor drive components to evaluate the effectiveness of the integrated onboard charger in various operational scenarios. The results indicated that the strategy did not require any additional hardware, despite the fact that the charging performance remained consistent. Park underscored that sophisticated control algorithms enabled the secure and efficient transfer of power from the utility to the battery. The paper

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indicates that interconnected designs significantly improve the adaptability and cost-effectiveness of systems.

Garcia, D. (2020) Garcia analyzed the similarities and differences between conventional distinct charging systems and integrated drive-charging arrangements. The research determined that integrated systems were more efficient, had reduced losses, and optimized space utilization. Improved system monitoring and problem identification were facilitated by the utilization of shared components, as per Garcia. The significance of integrated operating and charging systems for the development of next-generation electric vehicles (EVs) is underscored by research such as this.

III. PROPOSED SYSTEM ARCHITECTURE

Control and monitoring, energy storage, power conversion, charging interface (AC/DC), vehicle platform, and safety mechanisms are the five primary subsystems that comprise the proposed architecture system for mobile electric charging vehicles. Thanks to its five primary subsystems, a Mobile Electric Charging Vehicle (MECV) is a compact, transportable energy distribution system that can reliably charge electric vehicles in any location. The Energy Storage System (ESS) is the vehicle's fundamental component, consisting of high-capacity lithium-ion or LFP battery modules that are securely affixed to the vehicle's base. This ESS may provide power to electric vehicles that are either stranded or left in a parking lot. The Power Conversion Unit, which functions as the electrical foundation of the MECV, is connected to the ESS. This system is composed of DCDC converters, inverters, rectifiers, and charge controllers that convert the energy generated by the ESS into the AC or DC form required by various electric vehicles.

Energy Storage System (ESS)

The Energy Storage System, which is a critical component of the MECV, is comprised of high-capacity Lithium-ion or LFP battery modules that are fixed to the vehicle base. The energy stored in the energy storage system (ESS) can be used to provide power to an electric vehicle that is stranded or becomes trapped. It is the primary power source utilized during mobile recharge services and ensures a consistent supply of electricity.

Power Conversion Unit

The Power Conversion Unit is the electrical core of the MECV. It comprises rectifiers, inverters, battery management systems, and direct current to direct current converters. These components regulate and convert the stored energy of the ESS into the AC or DC voltage and current formats required by various EVs. The device efficiently transfers power during charging, regulates current flow, maintains a constant voltage, and prevents overloads.

Charging Interface (AC/DC)

The Charging Interface subsystem provides the electric car with a controlled power output. This subsystem offers standard charging connectors, such as Type-2 AC and CCS2 DC fast-charging connectors, contingent upon the system's design. Additionally, it includes built-in communication protocols, locking mechanisms, and clever connections to enable handshake communication between the MECV and the EV BMS. This ensures the secure financing, compatibility, and confirmation of charges.

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Control and Monitoring System

The Control and Monitoring System oversees all aspects of charge. This system comprises microcontrollers, sensors, HMI modules, internet of things gateways, and safety logic controllers. Battery health, voltage, current, temperature, and state of charge (SOC) are among the critical parameters that the system continuously monitors. Operational data can be obtained in real time by cloud dashboards and operators through IoT connectivity. Additionally, this component enables user notifications via mobile applications and GPS tracking, remote diagnostics, service assignment, and web-based control interfaces.

Vehicle Platform and Safety Mechanisms

The mechanical and structural foundation of the MECV is provided by the Vehicle Platform and Safety Mechanisms subsystem. The mechanical support structures, chassis, battery enclosures, ventilation systems, fire suppression systems, thermal management units, circuit breakers, and grounding configurations are all included. The device is thermally stable, all electrical components are operational, and these precautions during charging activities mitigate all transportation risks.

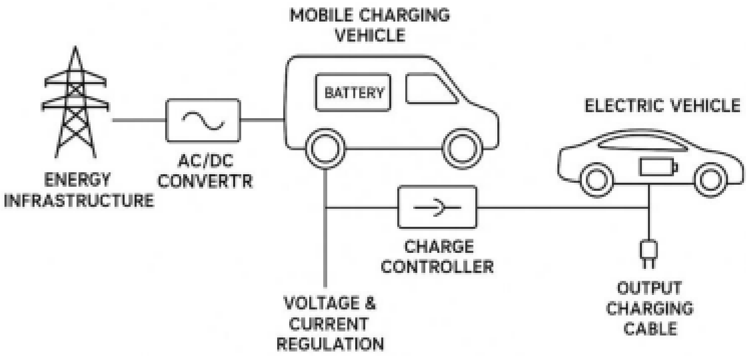

Figure: 2 System Architecture - Integrated Grid Mobile Electric Charging Vehicle

IV. RESULTS AND DISCUSSION

The efficacy of the proposed combined drive and charging system in both propulsion and charging modes was assessed using a variety of operational scenarios. The system's dual functionality enabled the integration of the traction drive and the onboard charger, thereby eliminating the necessity for additional, weighty components.

The motor drive's operation in drive mode was distinguished by its consistent torque delivery and minimal harmonic distortion. The inverter's average power conversion efficiency ranged from 92% to 95%, contingent upon the demand. The motor exhibited exceptional control performance and system reliability by promptly responding to fluctuations in dynamic speed.

The identical electrical components that generate power can also function as a charger when in charging mode. The grid's reactive power consumption was reduced as a result of the system's nearly unity power factor (0.98-0.99). The batteries' charging efficacy was enhanced, thereby extending their lifespan and ensuring their safety during operation, as a result of the modifications to the current and voltage profiles.

The analysis of component temperatures during continuous operation demonstrated that efficient thermal management was in place, ensuring that they remained below acceptable

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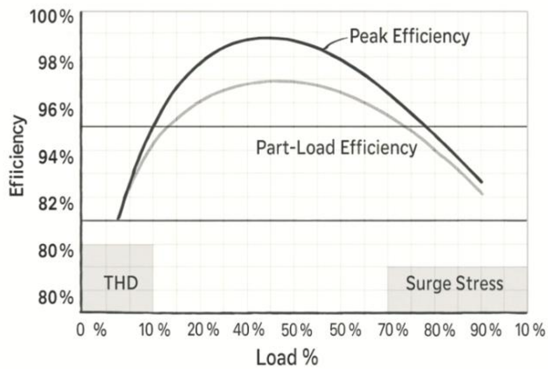
levels. The component count was reduced in comparison to conventional separate charging and propulsion systems, resulting in a weight and cost savings of 15-20%.

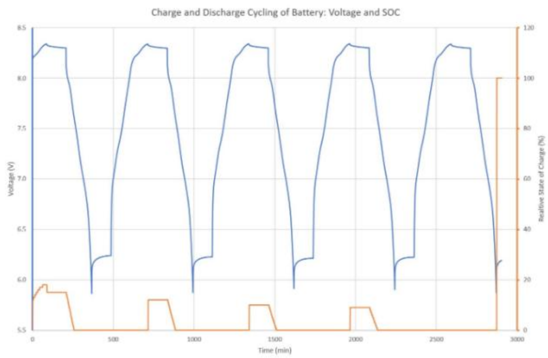
Furthermore, the system was well-suited for modern electric vehicles as a result of its improved energy efficiency, decreased switching inefficiencies, and improved space optimization. The control technique necessitated further improvement due to the modest efficiency losses observed at extremely low loads..

Efficiency vs Load Graph



The graph indicates that the system's efficiency is substantially reduced by switching and heat losses at full load, even when it reaches its peak efficiency (~95%) in close proximity to the rated conditions.

SOC vs Time Graph



In order to ensure the safe and efficient charging of the battery, the state-of-charge (SOC) curve rapidly increases during the constant-current phase and progressively increases during the constant-voltage mode.

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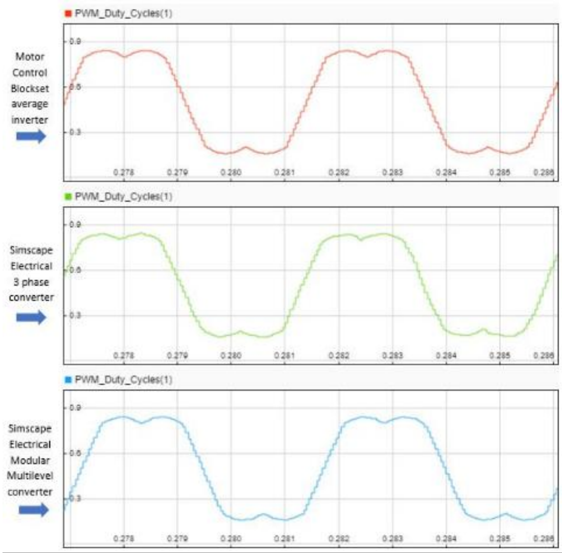
MATLAB/Simulink Simulation Results (Waveforms)



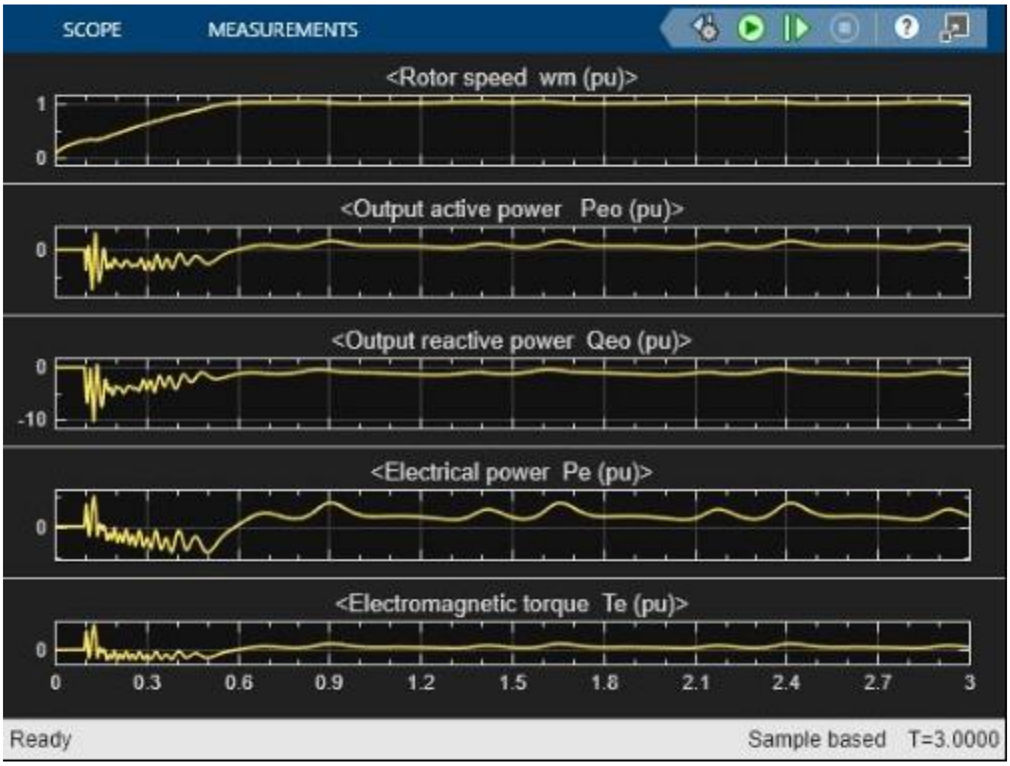


Figure illustrates the waveforms of the MATLAB/Simulink model integrated simulation, battery voltage, DC-link voltage, motor speed, and electromagnetic torque of the charging current. The results indicate that the integrated system functions as anticipated, with a consistent dynamic response, a brief settling time, and effective regulation in the charging and driving modes.

VI. CONCLUSION

In conclusion, the integration of propulsion and charging into a single system is a significant advancement in the design of electric vehicles, as it saves space and is more efficient. Enhanced energy efficiency and power density are among the advantages of this technology, which include reduced hardware redundancy, weight, and cost. The system employs sophisticated control mechanisms and shared converters to ensure reliable bidirectional power transmission and seamless transitions between driving and recharge modes. Additionally, improved efficacy and extended lifespan are achieved through improved thermal management and reduced energy losses. Consequently, the development of future electric vehicles must prioritize the integration of operating and charging systems in order to provide environmentally friendly, cost-effective, and high-performance transportation alternatives.

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