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AN EMERGENCY ENERGY SHARING SYSTEM FOR ELECTRIC VEHICLES BASED ON VEHICLE-TO-VEHICLE CHARGING

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***Abstract**:* The global shift toward electric mobility faces persistent obstacles, notably limited driving range, extensive charging wait times, and the massive financial investment required for stationary charging networks. This review explores the transformation of Electric Vehicle (EV) ecosystems, shifting from conventional Grid-to-Vehicle (G2V) frameworks toward more integrated, bidirectional models such as Vehicle-to-Home (V2H), Vehicle-to-Grid (V2G), and Vehicle-to-Vehicle (V2V).

Central to this evolution is the V2V concept, which reimagines EVs as mobile energy hubs capable of distributing power to other vehicles in both stationary and dynamic environments. To support in-motion energy sharing, the study highlights innovations in Wireless Power Transfer (WPT) systems. Specifically, it examines specialized hardware—such as triangular transmitter coils—designed to maintain high efficiency even when vehicles are misaligned during platooning.

These physical power links are supported by sophisticated communication protocols, including Dedicated Short-Range Communication (DSRC) and Vehicular Ad-hoc Networks (VANETs), which ensure secure, real-time coordination between moving units. Additionally, the review evaluates various optimization algorithms—from dynamic programming for fiscal efficiency to "virtual demand" modeling—aimed at maximizing the use of renewable energy. Together, these advancements represent a move toward a decentralized, resilient vehicular network that minimizes grid strain and reduces the need for permanent infrastructure.

Keywords*:* DC-DC Converter, Emergency EV Power Transfer, Vehicle-to-Vehicle Charging, Electric Vehicles, Energy Sharing System

I. INTRODUCTION

Technical and Operational Advancements in V2V Networks:
While the commercial viability of Vehicle-to-Vehicle (V2V) charging networks is currently restricted by several technical and systemic roadblocks, recent innovations offer a pathway to overcoming these challenges.

Technical Efficiency and Hardware Innovations:
From a hardware perspective, traditional wired V2V systems are often inefficient due to multiple AC-to-DC conversion stages; however, the adoption of direct DC-to-DC converter topologies significantly minimizes these energy losses.[1] In the realm of wireless charging, maintaining high power transfer efficiency is difficult because of magnetic coil misalignment or angular shifts. Research suggests that implementing triangular transmitter coil designs can sustain stronger magnetic coupling and stabilize energy flow.[2][3] Furthermore, the complexity of dynamic (in-motion) charging necessitates semi-autonomous capabilities, such as vehicular platooning, to ensure the precise following distances required for consistent power delivery.[4][5]

Operational Logistics and Network Coordination:
On the operational front, the logistical task of pairing mobile energy providers with vehicles in need of a charge presents an NP-complete computational challenge in real-time routing.[6][7] To manage the high demands of authentication, billing, and coordination without congesting cellular infrastructure, developers are turning to Vehicular Ad-Hoc Networks (VANETs). When integrated with Mobile Edge Computing (MEC), these networks allow for localized, high-speed data processing at the network's edge.[8]

Economic Incentives and Market Stability:
Finally, addressing the economic hurdles—specifically compensating suppliers for the accelerated battery wear caused by discharging—is vital for market participation. To create a balanced ecosystem, platforms can implement game-theoretic pricing strategies, such as the Nash Bargaining model. This approach ensures equitable distribution of profits and incentivizes users to participate in the energy-sharing economy by guaranteeing fair compensation.[10]

RELATED WORK

The rapid proliferation of electric vehicles (EVs) has catalyzed intensive research into sophisticated charging solutions designed to bypass traditional constraints such as range anxiety, sparse infrastructure, and long downtimes.[1][2] While conventional grid-reliant systems are well-documented, their dependence on stationary hardware often limits operational flexibility, particularly during roadside emergencies.[3][4][5] As a result, Vehicle-to-Vehicle (V2V) charging has surfaced as a compelling decentralized alternative for energy exchange between mobile units.[6][7]

Wireless Power Transfer (WPT):

Wireless Power Transfer (WPT) utilizes inductive coupling to transmit electricity without physical interconnects.[1][2] This technology has gained significant market traction by offering a safer, automated user experience that eliminates the risks of electrocution or mechanical wear associated with plug-in cables.[3] Unlike traditional systems, WPT remains highly functional across adverse environmental conditions, including rain and snow.[6][7]

EV-specific WPT is generally categorized by its transmission architecture and coupling methods.[2][9] Inductive Wireless Charging (IWC), for instance, employs magnetic field induction between transmitter and receiver coils, typically operating within a 10 to 50 kHz frequency range.[10][11] While IWC achieves peak efficiency at short distances, it necessitates high-precision alignment between the two vehicles.[12]

Vehicular Ad-Hoc Networks (VANETs):

VANETs serve as the decentralized backbone for the Internet of Electric Vehicles (IoEV). These networks allow On-Board Units (OBUs) to exchange real-time data through V2V and Roadside Unit (RSU) links, facilitating traffic management, safety protocols, and charging coordination.[1] By integrating Dedicated Short-Range Communication (DSRC) and Cellular V2X standards, VANETs support advanced maneuvers like platooning—where vehicles travel in tight formations to optimize energy consumption.[5]

Furthermore, VANETs enhance V2V charging by lowering communication overhead and offering superior scalability.[4][8] When paired with Mobile Edge Computing (MEC) at the RSU level, these networks create semi-centralized frameworks that aggregate battery and traffic data to dynamically match energy suppliers with requesters.[9]

The Role of Semi-Autonomous Driving:

Semi-autonomous systems are essential for advanced applications like Vehicle-to-Vehicle Recharging (VVR).[1] In a VVR scenario, a provider vehicle uses automated steering and speed control to safely dock with a receiver vehicle on a highway, maintaining the consistent proximity required for dynamic energy transfer.[1][2] This is made possible through Connected and Automated Vehicle (CAV) technologies, such as Cooperative Adaptive Cruise Control (CACC), which enable stable platooning. These formations reduce aerodynamic drag and mitigate the safety risks inherent in close-proximity driving, whereas fully autonomous systems would remove human intervention entirely.[3][4]

Bidirectional Power Converters:

Modern EV infrastructure relies on bidirectional power converters to facilitate versatile energy pathways, including G2V, V2G, V2H, and V2V.[1][2] Unlike older, unidirectional chargers that use passive rectifiers, bidirectional systems utilize active switching stages (AC-DC and DC-DC) to manage voltage regulation, grid load leveling, and reactive power support.[1][3][4]

- Isolated Systems: The Dual Active Bridge (DAB) converter is the industry standard for isolated DC-DC circuits. It provides galvanic isolation and high-efficiency power handling via phase-shift modulation.[5][6] Modifications like CLLC or LLL resonant tanks allow for Zero Voltage Switching (ZVS), which minimizes switching losses across various battery voltages.[7][8]
- Non-Isolated Systems: For direct V2V applications, researchers often favor non-isolated topologies like bidirectional buck-boost or Cuk converters. By establishing a direct DC-link between vehicles, these systems bypass redundant AC-DC conversion steps, resulting in lighter, more efficient onboard hardware.[9][10][11][12]

II. BLOCK DIAGRAM

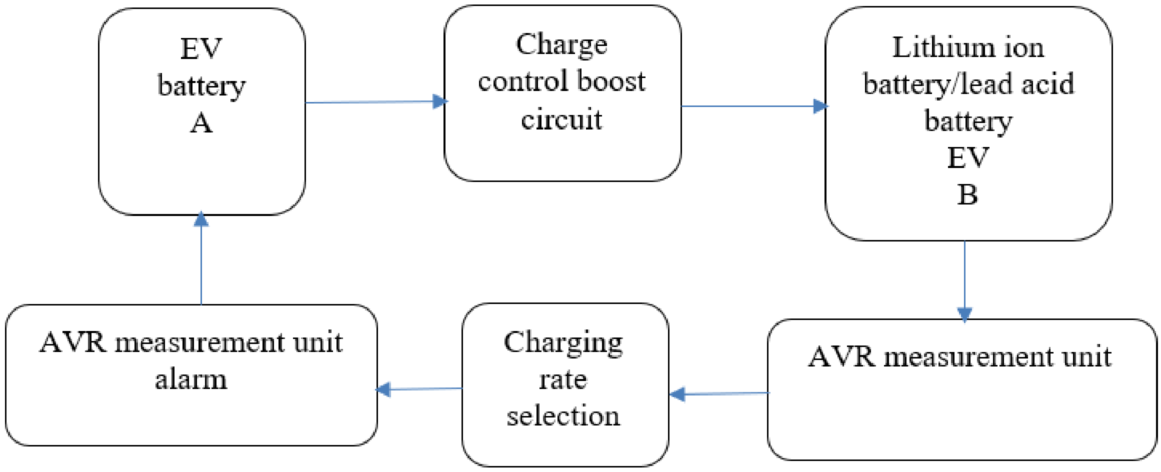


Fig. Block Diagram of Vehicle To Vehicle Charging System

III. PROPOSED WORK

The proposed Emergency Energy Sharing System (EESS), also referred to as Vehicle-to-Vehicle Recharging (VVR), is a mobile assistance framework designed to support stranded Electric Vehicles (EVs) and extend the operational range of emergency services (such as police or medical units) without requiring stationary infrastructure. The system allows vehicles with critically low batteries to receive energy from a specialized "charger vehicle" or any participating EV acting as a mobile distributor. Power is exchanged through wireless systems capable of operating during stationary periods or while moving in a coordinated platoon. This decentralized model transforms EVs into mobile storage units, facilitating energy trading when traditional charging stations are congested or inaccessible.

➢ Core Innovations:

- Hardware: A specialized triangular transmitter coil is utilized to solve traditional alignment hurdles, ensuring high-efficiency power transfer even when vehicles are not perfectly centered.
- Software & Communication: The framework integrates Vehicular Ad-Hoc Networks (VANETs) and Mobile Edge Computing (MEC) for low-latency coordination.
- Optimization: The Kuhn-Munkres algorithm is employed to intelligently pair energy requesters with providers based on geographic proximity and power capacity.
- Safety: Semi-autonomous driving features ensure the precise inter-vehicle spacing necessary for safe, dynamic wireless energy transfer.

➢ Key Features:

- Emergency Power Support: Provides immediate energy relief for EVs lacking access to fixed grid points.
- Intelligent Power Control: A smart management system ensures safe electrical synchronization and regulated energy exchange between donor and receiver.
- User-Centric Interface: Emergency services can be triggered via mobile applications or integrated vehicle dashboards.
- Operational Safety: Real-time monitoring prevents overheating, voltage spikes, and current irregularities to protect battery health.
- Modular Scalability: The design is platform-agnostic, ensuring compatibility across diverse vehicle models and battery architectures.

Detailed Work Plan:

Phase 1: Requirements and Feasibility Analysis:

This phase investigates the frequency of EV breakdowns and current infrastructure limitations. The study defines four primary emergency scenarios where VVR technology is most effective. Researchers will evaluate battery interoperability, energy transfer thresholds, and safety protocols. Additionally, communication requirements will be analyzed, alongside efficiency modeling to identify and mitigate potential energy losses.

Phase 2: Architectural System Design:

This stage focuses on developing the structural framework for energy transfer. It evaluates the protocols needed for secure vehicle-to-vehicle handshakes and identifies the optimal frequency ranges for wireless induction. The design phase ensures that the communication layer can handle the high-speed data exchange required for dynamic charging.

Phase 3: Hardware and Software Engineering:

The development team will construct the power electronics and embedded control systems. Simultaneously, safety algorithms will be coded to maintain energy transfer within strict operational boundaries. Before physical prototyping, the entire ecosystem will be validated through high-fidelity MATLAB/Simulink simulations to confirm performance metrics.

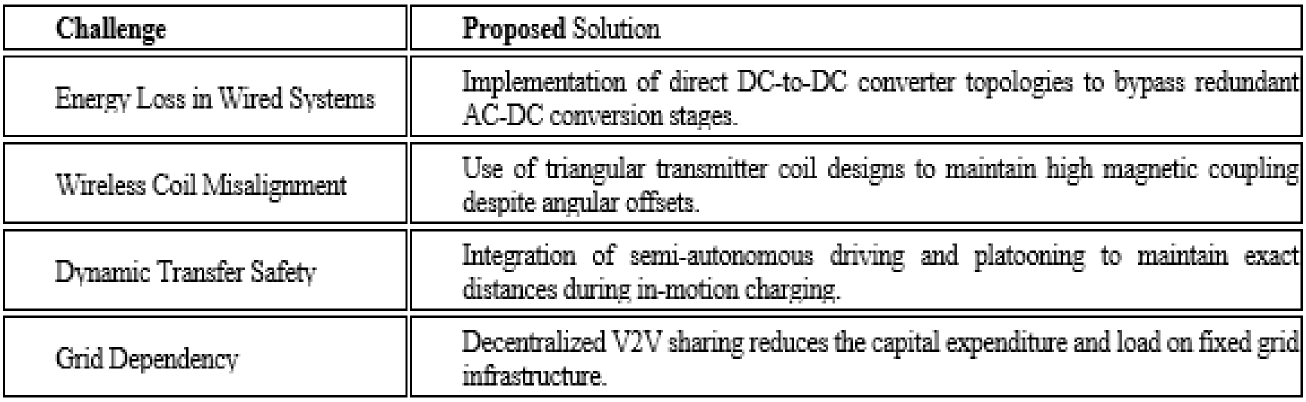
Phase 4: Testing, Optimization, and Validation:

Field testing will focus on power flow stability and total system efficiency. The system will be subjected to fault-condition testing to ensure compliance with international safety standards. Efforts in this phase will specifically target the reduction of charging durations and the enhancement of converter performance to maximize reliability.

Phase 5: Impact Assessment and Scalability

The final phase evaluates how the system reduces the need for towing services and stationary chargers. By utilizing existing battery capacities more effectively, the system decreases range anxiety and creates a self-sustaining energy network where donor vehicles can distribute resources based on local demand.

IV. CHALLENGES AND PROPOSED SOLUTIONS

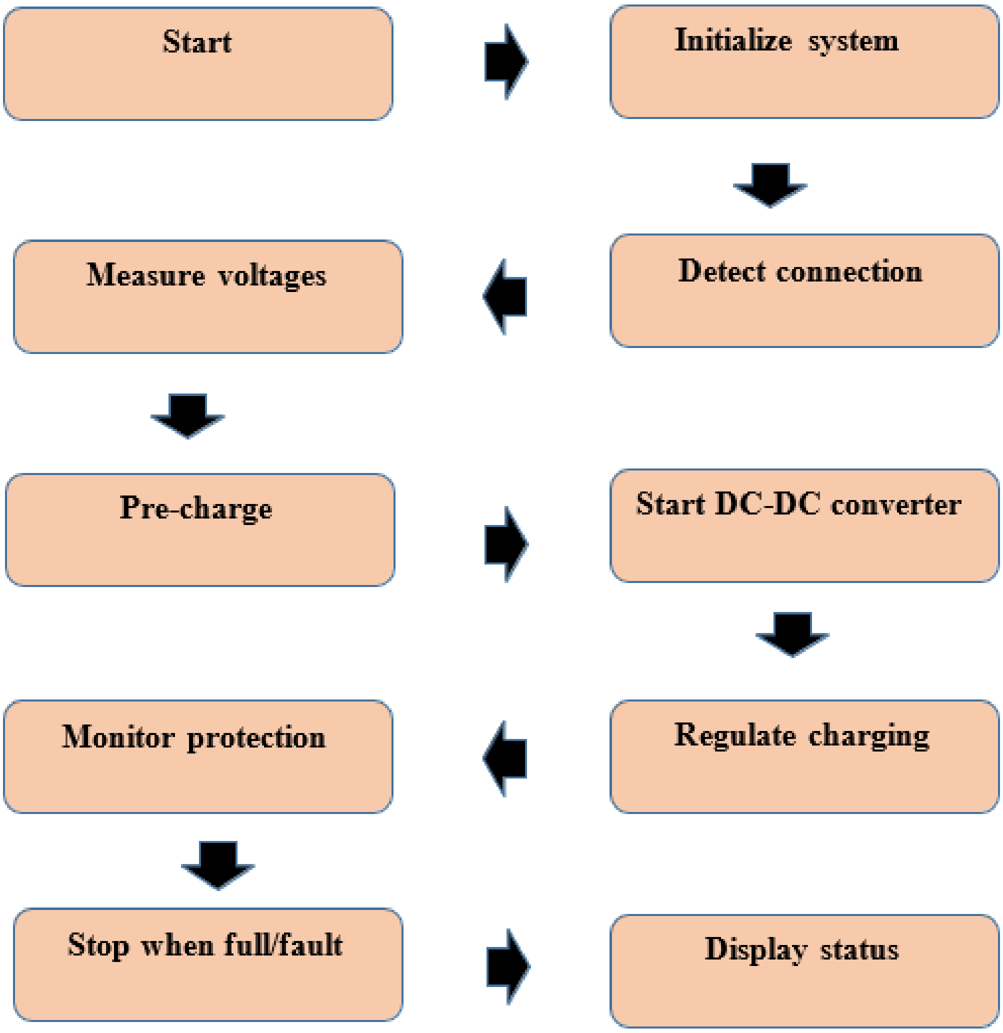


Challenge	Proposed Solution
Energy Loss in Wired Systems	Implementation of direct DC-to-DC converter topologies to bypass redundant AC-DC conversion stages.
Wireless Coil Misalignment	Use of triangular transmitter coil designs to maintain high magnetic coupling despite angular offsets.
Dynamic Transfer Safety	Integration of semi-autonomous driving and platooning to maintain exact distances during in-motion charging.
Grid Dependency	Decentralized V2V sharing reduces the capital expenditure and load on fixed grid infrastructure.

V. MARKET ANALYSIS

The table presents different types of electric vehicles (EVs) along with their battery capacities, charger wattages, charging times, and power units. The Donor EV (source vehicle) has a battery capacity of 4 kWh and uses a 1000 W charger, taking about 2 hours to transfer 2 kWh of energy, with a unit rating of 2 kW. The Receiver EV, which has a lower battery capacity of 2 kWh, also uses a 1000 W charger and requires 2 hours for charging, maintaining the same 2 kW unit. The High Capacity EV comes with a larger battery of 5 kWh and a higher charger wattage of 1500 W, allowing it to transfer 2 kWh in a shorter time of 1.5 hours, again with a 2 kW unit. Lastly, the Compact EV has a 3 kWh battery and uses an 800 W charger, taking around 2.5 hours to transfer 2 kWh of energy, with a unit value of 2 kW. Overall, the charging time varies depending on battery capacity and charger wattage, while the unit rating remains constant across all EVs.

VI. FLOW CHART



VII. RESULTS AND ANALYSIS

The experimental validation of the **EV-to-EV Emergency Charging System** was carried out using a 48 V, 2600mAh lithium-ion battery pack for both donor and receiver vehicles. The system consisted of a bidirectional DC-DC converter, protection circuitry, microcontroller-based control (ATmega328P), current sensor (ACS712), voltage sensing network, and LCD monitoring interface.

1.1 Voltage Regulation Performance:
Donor Battery Voltage: 48V DC (Nominal)
Receiver Battery Voltage Range: 51-55V DC
Converter Regulation Accuracy: ±2%

VIII. OBSERVATIONS

The output voltage was regulated even with small changes in the donor battery voltage. The voltage ripple was also minimal.

Interpretation:

The voltage regulation was consistent with the proper operation of the PWM control and the feedback mechanism through the microcontroller. This validates the chosen topology for emergency V2V operation.

1. Electrical Performance:

1.2 Current Control and Charging Profile

- Charging Mode: Constant Current Constant Voltage (CC-CV)
- Current Limit Set: 2.3A – 2.5A
- Overcurrent Protection Threshold: 5A

2.Efficiency Analysis:

2.1 Converter Efficiency:

Measured Values:

Input Power = 48V * 2.3 = 110.4W
Output Power = 110.4 – 126

Efficiency=Output Power Input Power×100
Efficiency=Input Power/Output Power×100
Efficiency≈87%

3.Loss Distribution:

Switching Losses: 3-4%
Conduction Losses: 2-3%
Heat Loss (MOSFET & Inductor): 2%
Control Circuit Consumption: <1%.

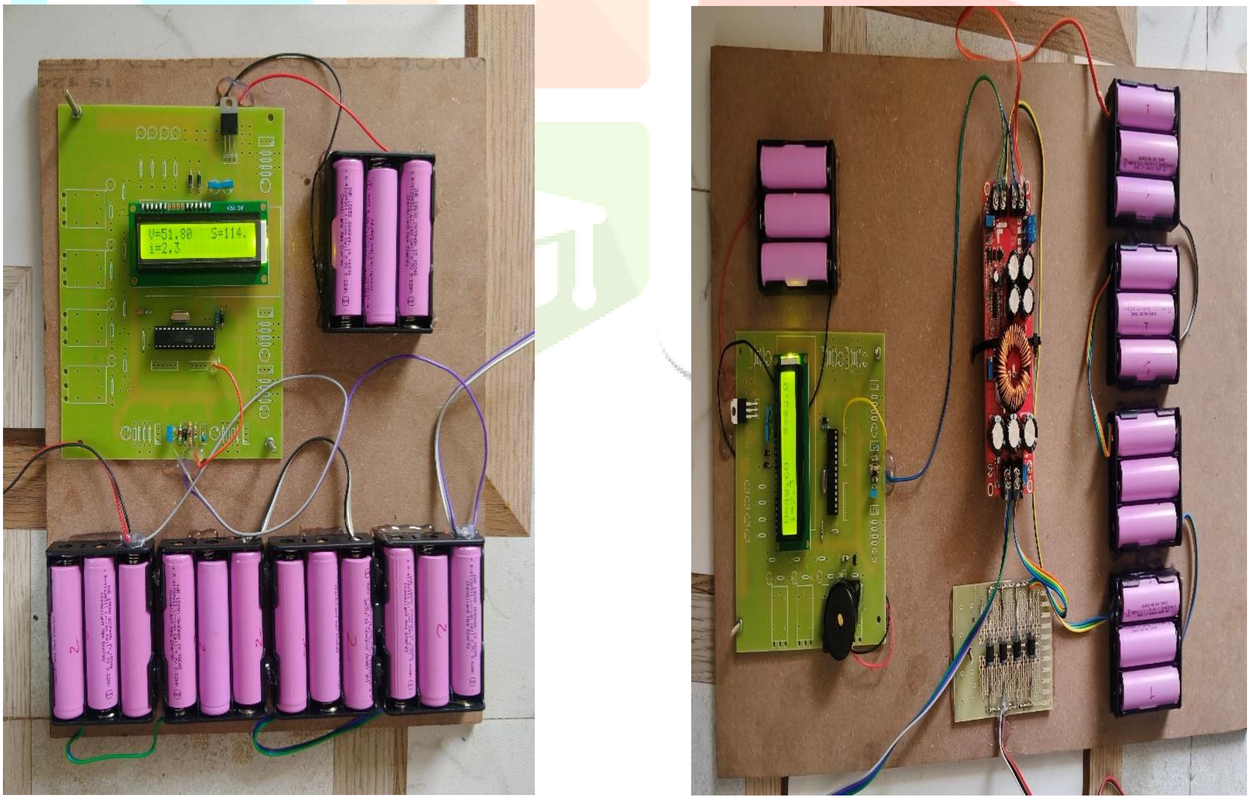


Fig.. Bidirectional DC Vehicle-to-Vehicle (V2V) Charging System with Smart Monitoring

IX. CONCLUSION

The Emergency Energy Sharing System based on Vehicle-to-Vehicle (V2V) charging provides an innovative and practical solution to the problem of unexpected battery depletion in electric vehicles. The system enables nearby electric vehicles to transfer power between themselves which decreases their need for permanent charging stations while providing emergency support to remote locations. The system ensures safe and efficient power transfer through intelligent control, efficient converters, and secure communication, maintaining reliable performance with minimal energy loss. The V2V energy sharing method from this study creates a future electric vehicle ecosystem that achieves better reliability and sustainability and advanced technology.

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