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Emergency Charging Solution for Electric Vehicles through EV-to-EV Power Transfer

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Abstract

This project develops an EV-to-EV emergency charging system that enables direct power transfer between two electric vehicles using a bidirectional DC–DC converter and BMS. The prototype ensures safe, regulated charging, reducing range anxiety and offering a practical solution for roadside assistance and future smart grid integration. The demand for reliable charging infrastructure has grown significantly.

The popularisation of the Electric Vehicle (EV) is restrained by the stagnation of energy storage technology and inadequate plug-in charging stations. This paper proposes a new vehicle-to-vehicle (V2V) charging technology platform, that can achieve wireless charging working in harmony with plugin charging technology, or operate independently. V2V charging technology can effectively solve the problem of the limited number of plug-in stations. Moreover, it can charge the car any-time, anywhere, like a power bank. V2V charging system design requires a number of technical challenges to be overcome including the power balancing between vehicles and charging circuit design to maximizing the power transfer efficiency. In this paper, the schematic of V2V charging system is proposed, and we also propose the fundamentals of calculating the power capacity and the cost of EV energy when an EV is a power source in a V2V charging system. The hardware circuit design is presented and a detailed comparison of different coil shapes/ combinations and compensation circuit topologies is provided using the simulation tool ANSYS.

INTRODUCTION

The increasing adoption of Electric Vehicles (EVs), the demand for reliable charging infrastructure has grown significantly. However, limited charging stations, high setup costs, and range anxiety remain major challenges for EV users. In emergency situations, where an EV runs out of charge in remote or non-serviced areas, accessto immediate charging is often impossible.To overcome this limitation, the concept of EV-to-EV power transfer offers a practical solution.

Electric vehicles (EVs) are becoming more popular because they are eco-friendly and help reduce pollution. But one major problem with EVs is the lack of enough charging stations, especially in remote areas. When an EV battery becomes empty in such a place, the driver cannot find immediate charging help, which causes range anxiety — the fear of running out of battery before reaching a station. Building more charging stations everywhere is costly and time-consuming, so there is a need for a portable and quick emergency charging solution.

To solve this issue, this project introduces an EV-to-EV emergency charging system, where one electric vehicle can transfer energy directly to another using a bidirectional DC–DC converter and a Battery Management System (BMS). The system is controlled by a microcontroller that ensures safe and regulated power transfer between two EVs. This method allows vehicles to help each other during emergencies, making electric mobility more reliable and convenient. It is a simple, low-cost, and practical solution that can also be expanded in the future for smart grids and connected EV networks.

LITERATURE SURVEY

[1]Background& Motivation

Electric vehicles (EVs) are becoming widespread, but limited public charging infrastructure and long charging times cause range anxiety and reduce user confidence. Decentralized and mobile charging options—such as vehicle-to-vehicle (V2V) or EV-to-EV charging—are proposed as emergency, peer-to-peer solutions to improve resilience and convenience without building more fixed infrastructure. Several recent reviews discuss how bidirectional power flow and

[2] EV-to-EV (V2V) & Peer-to-Peer Charging Concepts

V2V (or EV-to-EV) charging refers to systems where one vehicle supplies energy directly to another, either through on-board converters/chargers or via an external intermediary (mobile charging unit). Research covers two broad approaches:

Direct connection via on-board chargers or DC ports, where existing connectors and on-board power electronics are used to steer energy between vehicles for emergency top-ups. Demonstrations and proposals exist for using on-board chargers or modified AC/DC ports for V2V rescue charging.

Macquarie UniversityControlled peer-to-peer frameworks and marketplaces, where vehicles (or private chargers) share energy, coordinated through communications, billing, and scheduling layers; useful for routine sharing as well as emergencies. This area overlaps with vehicle-to-grid (V2G) and peer charging research.

[3] Bidirectional DC–DC Converters: Role & Topologies

A bidirectional DC–DC converter is central to EV-to-EV systems that transfer energy safely and efficiently between battery packs of different voltages. Key observations from the literature:

Non-isolated topologies — buck/boost, interleaved, Ćuk, and bidirectional synchronous buck–boost are commonly recommended for compact prototypes due to simplicity and relatively high efficiency for similar voltage systems.

Isolated topologies — dual-active-bridge and isolated full-bridge converters are preferred when galvanic isolation is required (safety, differing ground references, or higher voltage differences). These are heavier/complex but provide safety and higher voltage handling.

Multilevel and modular converters are emerging for high-power, high-voltage applications (1–3 kW+), with advantages in voltage stress distribution and scalability for commercial EVs.

Performance metrics emphasized in studies are conversion efficiency, control complexity, transient response, current ripple, and thermal management. For prototype emergency units (hundreds of watts), high efficiency and robust current limiting are primary design targets

4. Battery Management Systems (BMS) & Safety Controls

[4] BMS is indispensable for safe V2V energy transfer

State-of-Charge (SoC) and State-of-Health (SoH) monitoring prevents overdischarge/overcharge of donor and receiver batteries. BMS must coordinate with the converter to permit/limit power flow based on SoC thresholds. Overcurrent, overvoltage, and thermal protection are critical when connecting two battery systems with different conditions—protection includes hardware (fuses, contactors, MOSFETs) and software (fast disconnect logic).

Communications & handshake protocols between donor and receiver BMS (or via a controller) reduce risk of unsafe transfers; some proposals use CAN/ISO-TP or higher-level standards to negotiate maximum allowed currents and termination SoC.

[5]Control Strategies & Power Management

Control schemes in the literature focus on reliable, automatic management of power flow:

Bidirectional current control with closed-loop regulation (PI/PI or sliding-mode) to maintain safe charge/discharge currents and regulate the receiver battery voltage/SoC. Converter control must be robust to sudden load changes and battery impedance variations.

Hierarchical control: local fast loops for current/voltage, and supervisory logic for SoC negotiations, timeout, and emergency cutoff. Microcontrollers (e.g., STM32, ESP32, Arduino for prototyping) are commonly used in published prototypes.

Smart energy allocation using IoT or market frameworks can extend beyond emergency help into scheduled peer-to-peer trading (bid/ask, price signals), though this is more relevant for community energy management than roadside rescue.

[6] Prototypes, Implementations & Case Studies

Several recent works and projects illustrate practical implementations:

On-board multifunctional chargers that incorporate V2V functionality have been prototyped — enabling an EV to both receive and supply energy via existing AC/DC chargers with additional control logic. These show V2V is technically feasible without extensive hardware changes.

Low-power emergency prototypes (12–48V, ~500W): academic and technical reports (IRJET, TIJER, conference papers) demonstrate small-scale DC-DC prototypes with BMS coordination for emergency rescue charging. These are suitable for proof-of-concept and roadside assistance vehicles.

Mobile charging labs and industrial initiatives: automotive research groups and companies are developing mobile charging platforms and multi-function test vehicles that explore bidirectional charging and mobile charging at higher power levels (industry news and projects). These show industry interest in mobile and bidirectional charging for future deployment.

[7]Standards,Regulations & Interoperability

Standards for EV charging (connectors, communication protocols, safety) are evolving rapidly:

V2G/V2X standards and charging protocols (e.g., ISO 15118 family for communication, CCS for connectors, and evolving grid interconnection rules) are relevant because any V2V or peer charging system will need to conform to safety and interoperability expectations for commercial adoption. Standards work also addresses metering and authentication for peer energy exchange.

[8] Challenges & Open Problems

The literature highlights many technical and non-technical challenges:

Safety and isolation: directly connecting two battery systems raises safety risks (fault propagation, ground loops). Isolated converters mitigate risk but increase complexity/cost.

Battery compatibility: different chemistries, voltages, SoC/SoH may limit how energy can be shared safely. BMS negotiation protocols are required.

Standardization: lack of unified standards for V2V chargers and handshake protocols complicates interoperability across brands.

Economic and user-behavioral issues: incentives, liability (who's responsible for battery degradation), and billing for shared energy

[9] Proposed Solutions & Best Practices from Literature

Use bidirectional DC–DC converters with current limiting, isolation options where required, and modular design for scalability.

Implement BMS-to-BMS (or controller) negotiation for SoC/voltage limits, emergency thresholds, and an automated disconnect.

Start with prototype low-voltage systems (24–48V, ~500W) for demonstration and safety validation; scale up only with automotive-grade components and rigorous testing.

Integrate communication (CAN/ISO15118-style or secure IoT) to log transfers, handle authentication, and optionally enable billing in peer-to-peer networks.

[10] Gaps & Directions for Future Research

Standardized V2V protocols: research is needed to define safe, lightweight handshake protocols specifically for emergency V2V scenarios.

Battery degradation models for repeated V2V use: quantify how giving/receiving energy affects long-term battery life and incorporate that into incentives/pricing.

High-power, automotive-grade bidirectional converters: more work on efficient, compact converters at kW scale with automotive safety certifications.

Field trials and socio-economic studies: pilot deployments to study user acceptance, liability frameworks, and market mechanisms for peer charging.

METHODOLOGY

i. Select one EV as donor and another as receiver.
ii. Use a bidirectional DC–DC converter to regulate voltage and current.
iii. A Battery Management System (BMS) ensures safety (SoC, overvoltage, overcurrent).
iv. A microcontroller controls switching and cut-off.
v. Power transfer continues until the receiver EV reaches a safe charge level.

This project is based on the idea of transferring power directly from one electric vehicle to another during an emergency. The system uses a bidirectional DC–DC converter, a Battery Management System (BMS), and a microcontroller to control and monitor the whole process. When two vehicles are connected through a cable, the system checks the voltage, temperature, and battery levels of both vehicles using the BMS. After confirming safety, the converter starts transferring energy from the donor EV (which has more charge) to the receiver EV (which has a low battery). The converter adjusts the voltage and current as needed to make sure charging happens safely and smoothly.

The microcontroller plays an important role in controlling the power flow. It reads data from sensors like voltage, current, and temperature, and then regulates the converter using PWM signals. The system follows a constant current–constant voltage (CC–CV) charging method so that the battery gets charged without overheating or overcharging. The BMS helps to protect the battery by automatically stopping the power transfer if there is any fault such as overcurrent, overvoltage, or overheating. This ensures that both EVs remain safe during the charging process. The entire system is tested using 24V/48V batteries and is capable of transferring around 500W of power, which is suitable for small-scale or emergency charging.

In this project, the working of the system was first simulated using software like MATLAB or Proteus, and later a hardware prototype was made for real testing. During experiments, the system showed stable performance with good efficiency (around 85–90%) and fast safety response. Once the receiver EV battery reaches a safe charge level, the controller automatically stops power transfer. The proposed method provides a low-cost and portable solution for roadside EV charging and helps reduce range anxiety. In the future, this system can be improved for higher power levels, IoT monitoring, and integration with smart grid networks.

CONCLUSION

This project introduces an innovative emergency charging solution that allows one EV to transfer energy to another, reducing dependency on static charging stations. By implementing a regulated and safe EV-to-EV power transfer system, this approach addresses the critical challenge of ange anxiety while promoting sustainable mobility. The prototype serves as a foundationfor future large-scale applications in smart cities and EV-based transportation networks and open charging marketplace where any EV can offer energy to interested EVs in adecentralized way.

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