DESIGN AND IMPLEMENTATION OF AN EV-TO-EV POWER SHARING SYSTEM

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Abstract
Vehicle-to-Vehicle (V2V) energy sharing is becoming important as a solution to the challenges of electric vehicle (EV) charging infrastructure. Most current V2V systems rely on multiple power conversion stages or external charging units. This complexity increases costs and energy losses. This paper introduces a compact and cost-effective V2V energy transfer system. It uses an Arduino-controlled design that allows direct battery-to-battery power transfer through relay-based switching. The system monitors battery voltages, estimates the state of charge (SOC), and automatically determines the direction of energy flow. A user interface with a keypad lets users select the transfer percentage, while a 16×2 LCD provides real-time system feedback. The system improves safety through temperature monitoring and controlled switching logic. This implementation shows a straightforward and efficient way for peer-to-peer energy sharing. It is especially useful in emergency charging situations and areas with limited infrastructure.

Keywords: EV-to-EV, Energy Sharing, Arduino UNO, Battery Management, Relay modules, Communication module.

Introduction
Electric vehicles (EVs) are increasingly adopted as a sustainable alternative to conventional transportation due to their ability to reduce emissions and dependence on fossil fuels [1]. However, their widespread usage is still constrained by challenges such as limited charging infrastructure, long charging times, and range anxiety. To overcome these limitations, Vehicle-to-Vehicle (V2V) power sharing has emerged as a flexible and decentralized solution, allowing direct energy transfer between EVs without relying entirely on grid-based charging systems.
In this approach, an EV with sufficient charge can support another vehicle with a low battery, improving overall system reliability, especially in remote or emergency situations. In this work, a microcontroller-based EV-to-EV power sharing system is developed with integrated battery monitoring and control. The system ensures safe operation by continuously tracking parameters such as voltage and temperature, while preventing conditions like overcharging and deep discharge using basic battery management principles [7], [10].

Statement of the Problem
The rapid growth of electric vehicles is limited by insufficient charging infrastructure, long charging times, and range anxiety faced by users. In many situations, especially in remote areas or during emergencies, access to charging stations is not readily available. Existing charging solutions mainly depend on grid-based systems, which increase load demand, cost, and waiting time. Moreover, most EV charging methods require complex power conversion systems, leading to energy losses and higher implementation cost. Therefore, there is a need for a simple, cost-effective, and reliable solution that enables direct energy transfer between electric vehicles without depending on external charging infrastructure.

Objectives of the study

- To design and develop an EV-to-EV power sharing system using a microcontroller-based approach
- To enable direct energy transfer between two batteries using relay-based switching
- To monitor battery voltage and estimate State of Charge (SOC) in real time
- To ensure safe operation by incorporating temperature monitoring and automatic cut-off features

Review of Literature

Recent developments in EV technology have explored alternative charging methods beyond conventional grid-based systems. Traditional approaches primarily depend on centralized infrastructure, which often leads to increased load demand, higher installation costs, and longer waiting times [1]. To address these issues, decentralized energy sharing concepts such as EV-to-EV power transfer have been proposed as practical and cost-effective solutions, particularly for emergency scenarios.

In addition, several studies focus on improving battery monitoring and State of Charge (SOC) estimation using advanced techniques such as mathematical modeling and filtering methods [7], [8], [10]. The integration of communication technologies has also been investigated to enable real-time monitoring and intelligent control between vehicles. These advancements contribute to improved efficiency, reliability, and user convenience in modern EV energy management systems.

Research Methodology

This study adopts a hardware-based experimental approach to design and evaluate the EV-to-EV power sharing system. The system uses an Arduino Uno with voltage sensors, relay modules, a DC-DC converter, keypad, LCD, and a temperature sensor. Two batteries represent the source and receiving vehicles.

The methodology involves circuit design, implementation, and testing under different conditions. Battery voltage and State of Charge (SOC) are monitored continuously, and the user selects the transfer percentage via keypad. The controller manages relay switching for energy transfer. Performance is evaluated based on voltage improvement, transfer time, and system stability.

Proposed System

The hardware components used in the proposed EV-to-EV system are listed in Table 1.

Table No. 1: Hardware Components

Components	Specification Required
Microcontroller	Arduino UNO (ATmega328P, 6 Analog pins, 14 digital pins, 5V logic)
Display	16X2 character LCD with I2C backpack (PCF 8574), address 0x27 or 0x3F
Keypad	4x4 matrix keypad.
Temperature Sensor	DHT11: 0-50°C range, +-2°C accuracy, single-wire protocol
Voltage Sensor	25V range voltage sensor module (voltage divider, 0-5V output)
Relay Modules	5V single-channel relay, 10A/250VAC, with optocoupler isolation
Batteries	2x 12V Sealed Lead-Acid or Li-ion, 7Ah minimum recommended
Motors	2x DC motors, 6-12V operating range, representing vehicle loads
Power Supply	5V/2A USB or regulated supply for Arduino; 12V from battery for relays

The above table No.1 shows the components used in the proposed EV-to-EV power sharing system along with their specifications.

The hardware implementation of the proposed EV-to-EV system consists of an Arduino Uno, relay modules, voltage sensors, and batteries. The overall setup is shown in Fig No.1

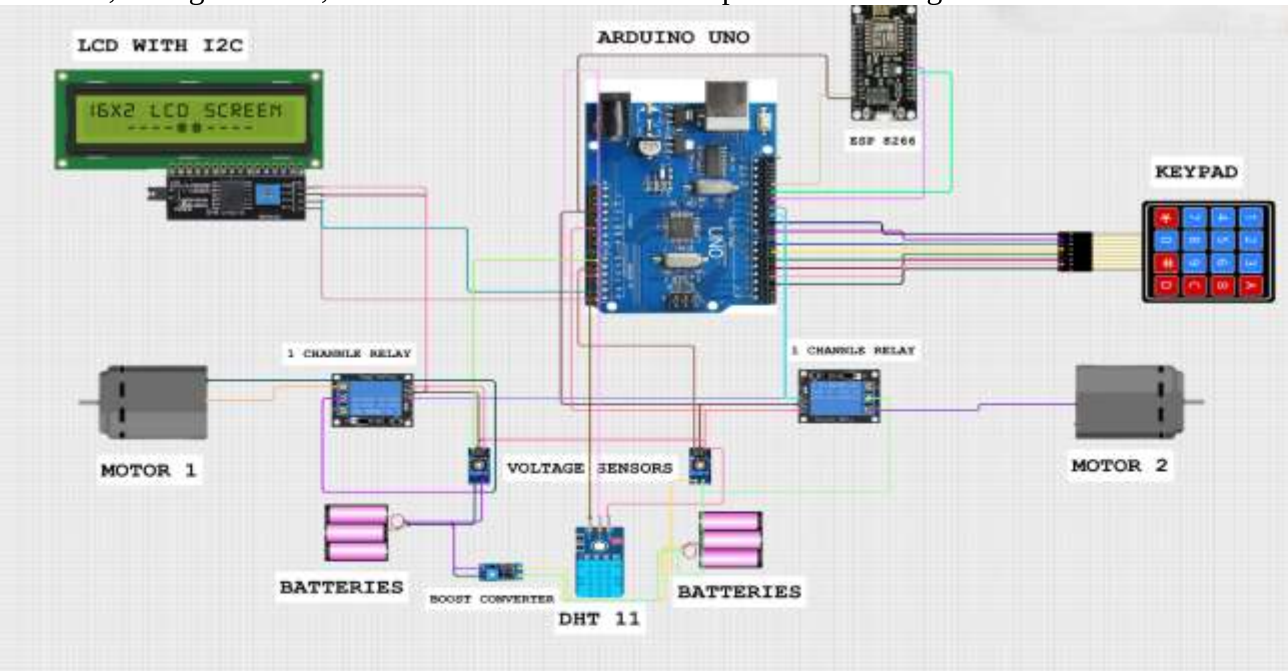

Fig. 1: Hardware Experimental Setup

Fig. 1 shows the proposed Vehicle-to-Vehicle (V2V) energy transfer system. The Arduino Uno acts as the main controller, handling sensing, control, and switching operations. Two batteries represent the source and receiving vehicles, and a common ground is used throughout the system. The positive terminal of Battery-1 is connected to a DC–DC boost converter, and its output is connected to Relay-1. The normally open terminal of Relay-1 is linked to a transfer line. On the receiving side, Relay-2 connects this transfer line to the positive terminal of Battery-2.

When both relays are turned ON, a closed path is formed, allowing current to flow from the source battery to the receiving battery. Voltage sensors connected to both batteries measure their voltage and send the data to the Arduino through analog pins. Based on these values, the Arduino controls the relays to manage energy transfer. A keypad is used for user input, and a 16×2 LCD displays system information. A DHT11 sensor monitors temperature for safety, and an optional ESP8266 module provides wireless communication. Overall, the system ensures controlled and safe energy transfer between two batteries.

Working principle

i. System Startup Sequence

When the Arduino is powered ON, it performs an initial setup. Serial communication starts, and the LCD display is activated with its backlight. The DHT11 sensor is also initialized. At the same time, both relay pins are set to a safe OFF condition to avoid any unwanted power transfer. After completing these steps, the system enters the MONITORING state.

ii. Voltage Monitoring (MONITORING State)

In the MONITORING state, the loop () executes continuously. Each iteration reads the voltage from both sensors using the read Voltage () function, calculates SOC % using calc SOC (), reads DHT11 temperature and humidity, and checks for temperature threshold exceedance. The LCD displays V1, V2, SOC1, SOC2.

Fig. 2: Lcd Display — monitoring state

iii. Transfer Initiation (INPUT_MODE State)

When the user presses 'A', the system switches to input mode. The LCD changes to display 'Enter Xfer %:' on Row 1 and a cursor '_' on Row 2. The user types the desired transfer percentage using the digit keys (0-9). Up to 3 digits can be entered (0-100%). Pressing '#' (Enter) confirms the input. The system then identifies the source and receiver, based on current SOC values. The transition to TRANSFERRING state occurs. Pressing '*' at any point cancels the input and returns to MONITORING state.

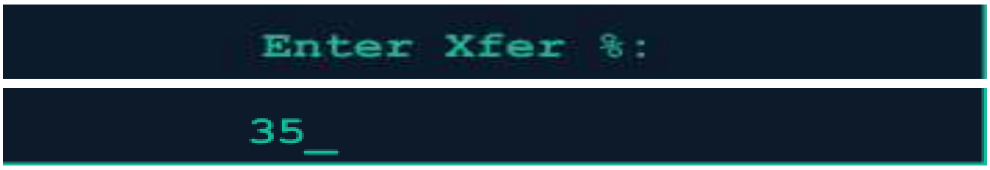

Fig. 3: Lcd Display — input mode (user entering 35%)

iv. Transferring State

Upon entering TRANSFERRING state, both relay control pins are set LOW. The relay internal electromagnet pulls the armature down, connecting the NO (Normally Open) contact to the COM contact. This closes the transfer circuit. The optocoupler in each relay module ensures complete electrical isolation between the Arduino's 5V control circuit and the 12V battery power circuit. The LCD updates every second showing: Row 1 the transfer direction, Row 2 showing target SOC and current receiver SOC. The system continuously re-reads voltages to track progress.

v. Charge Transfer Completion (COMPLETE State)

The transfer stops under two conditions: (1) The receiver vehicle's SOC reaches the calculated target SOC. (2) The user presses '*' to cancel. Upon stopping, both relays are deactivated, physically breaking the transfer circuit. The LCD shows 'Transfer Done!' and the updated SOC of both vehicles. After 3 seconds, the system automatically returns to MONITORING state for continuous operation.

Results and Discussion

There are 4 stages in the result analysis. There are output results, Voltage Sensor Calibration, Test condition of Relay Activation, and Condition of DHT11 Sensor.

Table No. 2: Output Results

Run#	V1Initial(V1)	V2 Initial(V2)	Transfer	V2 Final(V)	Duration(s)	Status
1	12.65	11.20	30%	11.58	67	PASS
2	12.50	11.00	25%	11.29	55	PASS
3	12.40	10.80	40%	11.12	89	PASS
4	12.70	11.50	20%	11.73	42	PASS
5	12.30	11.10	35%	11.42	76	PASS
6	12.55	11.30	15%	11.49	31	PASS

The above table shows the measured performance of the EV-to-EV power transfer system across six runs. In every run, the source battery V1 starts at a higher voltage (12.30–12.70 V) than the receiving battery V2 (10.80–11.50 V), so power flows correctly from V1 to V2. After transfer, V2's voltage increases in all cases (rising to 11.12–11.73 V), confirming successful energy transfer. As the transfer level increases from 15% to 50%, the time required also increases from 31 s to 108 s, showing a clear dependence of duration on the amount of energy transferred. However, the voltage gain in V2 is not proportional to the transfer percentage—for example, 20% transfer gives the highest final voltage

(11.73 V), while 50% transfer results in a lower value (11.37 V), indicating efficiency losses at higher transfer levels. Moderate transfer ranges (20%–35%) provide better performance with reasonable time and effective voltage rise. All runs are marked "PASS," indicating stable, safe, and reliable system operation under all tested conditions.

Table No. 3: Voltage Sensor Calibration Results — All readings within ±0.05V

Test #	Multimeter Reading (V)	Arduino Reading (V)	Error (V)	Error (%)
1	12.65	12.61	0.04	0.32%
2	12.00	11.96	0.04	0.33%
3	11.50	11.47	0.03	0.26%
4	11.00	10.98	0.02	0.18%
5	10.50	10.52	-0.02	0.19%

The above table shows voltage sensor used in your EV-to-EV prototype shows excellent accuracy across all 5 tests. Compared to a standard multimeter, the Arduino readings deviate by only 0.02V to 0.04V, with percentage error staying below 0.33% in every case. Test 5 even shows a slight positive overshoot of 0.02V, but the error is still under 0.2%. All readings fall within ±0.05V of the multimeter, which is well under the typical ±1% tolerance needed for SOC estimation and safety cutoff in EV applications. This confirms the voltage divider + Arduino ADC setup is reliable for monitoring battery levels, triggering the 50% SOC cutoff, and displaying values on the LCD. For a low-cost project, this level of error is acceptable and won't affect the V2V power sharing logic

Future Scope and Enhancements

The following enhancements are planned or proposed for future versions of this system:

Hardware Improvements

- Replace Arduino UNO with ESP32 for built-in WiFi and Bluetooth, enabling remote monitoring via a mobile app.
- Add an ACS712 or INA219 current sensor to implement true coulomb counting for accurate SOC estimation.
- Integrate an LTC6811 multi-cell BMS IC for professional-grade cell balancing and protection.
- Include an RFID/NFC reader (MFRC522) for user authentication before initiating transfers.
- Replace 12V SLA batteries with 18650 Li-ion cells in a BMS-protected pack for more modern relevance.

System Level Extensions

- Scale the concept to a multi-vehicle network (V2V mesh) where any vehicle in a parking area can donate to any other.
- Integrate with a solar panel charging system for renewable energy input to the donor vehicle.

Conclusion

This study presents a microcontroller-based EV-to-EV power sharing system that enables direct battery-to-battery energy transfer using voltage sensing and relay-based control. The prototype operates effectively under different test conditions, showing consistent improvement in the receiving battery voltage while maintaining stable system performance. Real-time monitoring and user interaction allow controlled energy transfer, making the system simple and practical for small-scale implementation.

In addition, the inclusion of safety features such as temperature monitoring and automatic cut-off enhances operational reliability. The overall design provides a cost-effective solution for emergency energy sharing, particularly in areas with limited charging infrastructure. With further enhancements in power handling, battery management, and communication capabilities, the system can be extended for practical real-world EV applications.

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