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DESIGN OF DC-DC V2V CHARGING SYSTEM FOR ELECTRIC VEHICLES

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Abstract*: Electric Vehicle-to-Vehicle (V2V) energy transfer offers a promising approach to extend the range of electric vehicles and enhance charging flexibility without relying on external infrastructure. This project proposes a direct DC-to-DC energy transfer system that enables one electric vehicle (donor) to safely and efficiently charge another vehicle (recipient). The system employs a high-voltage, isolated bidirectional DC-DC converter to regulate the power flow between the two battery packs. The converter provides precise voltage and current control, ensuring compatibility between batteries with different voltage levels and state of-charge conditions. Key design considerations include galvanic isolation for safety, soft-start and inrush current limiting mechanisms, and real-time monitoring of voltage, current, and battery parameters via an embedded microcontroller. A laboratory-scale prototype was developed and tested to validate the proposed concept. Experimental results demonstrate stable DC charging performance, effective protection against overcurrent and overvoltage conditions, and efficient energy transfer with minimal losses. This work highlights the potential of direct DC-DC V2V charging as a practical solution for roadside assistance, peer-to-peer energy sharing, and decentralized charging infrastructure in future electric mobility ecosystems.

Keywords: Bidirectional DC-DC Converter, Electric vehicles, Vehicle -to-vehicle charging, Internet of Things

I. INTRODUCTION

With the rising need for green transport in the world, there has been an increasing adoption of Electric Vehicles (EVs), which are more environmentally friendly and efficient in comparison to gasoline-powered transport. EVs can decrease carbon emissions and pollutants in the atmosphere. Nevertheless, despite the various benefits accrued from the use of EVs, there are still crucial factors that have limited the extensive use of EVs in the world. One of these factors is the lack of charging points for EVs in remote locations, highways, and other developing countries. Long charging durations, lack of charging points, and unpredictable battery drain rates are some of the factors that have led to the crucial challenge of "range anxiety," which has limited drivers from embarking on long journeys on EVs. In addition, EVs have the challenge of relying on the power grid in standard charging systems that can be inconsistent in cases of power outages or natural calamities.

Vehicle-to-Vehicle (V2V) charging system: V2V charging system is a novel, feasible solution that aims to address the aforementioned challenges by facilitating the direct transfer of energy from one electric vehicle to another. In this regard, the V2V charging system helps in transferring power from the donor electric vehicle that possesses surplus battery charge to the receiving electric vehicle that suffers due to low battery charge. This novel solution that promotes peer-to-peer battery assistance does not require the immediate assistance of charging stations, allowing owners of electric vehicles to help each other in real-time. This solution is implemented using components such as DC-DC buck boost converters, battery management systems, current/voltage sensors, as well as microcontrollers that handle the sophisticated control of the system. These components help in efficiently, stably, and safely charging the electric vehicles. This system always keeps track of the electrical parameters of the vehicles, such as the battery voltage, charging current, temperature, as well as the SOC of the battery. This system includes the development of safety features such as overcharge, over-discharge, thermal runoff, reversal polarity, as well as current short circuits.

Additionally, to improve functionality, the latest V2V charging technology utilizes Internet of Things (IoT), allowing the transmission of data in real-time. This modern technology enables real-time charging status, transferred amount of energy, efficiency, battery status, as well as safety notices. It also enables the car to make decisions automatically. For instance, the car stops the charging process when the set SOC is attained. Apart from offering benefits to the individual, the V2V charging process helps in achieving various aims, such as the balance of the load of the electric grids, emergency backup of the supply of energy, as well as the dissemination of power. This enhances a responsive and flexible energy environment as the car enables the capacity to function as a mobile battery. In conclusion, the Vehicle-to-Vehicle charging system is an innovative technique that improves the accessibility of energy, reliability, reduces dependency, and helps the world shift to intelligent electric mobility

II. OBJECTIVE

The aim of this project is to develop an efficient DC-DC based vehicle-to-vehicle energy transfer system for V2V based power sharing between electric vehicles, making it possible to share power without requiring any charging infrastructure." There is an emphasis on stable voltage regulation, high power conversion efficiency, and real-time monitoring of the process parameters like battery voltage, current, temperature, and SOC. Additionally, intelligent protection schemes have been integrated into the system to protect the battery from damage due to overcharging, deep discharge, short circuit, and thermal-related issues. This technology is expected to improve the charging flexibility, overcome the range anxiety, and play an important part in the energy sharing process for a sustainable electric mobility service.

III. PROPOSED SYSTEM

The proposed system is an intelligent, DC-to-DC-based V2V charging platform, which has been designed to realize direct and controlled energy transfer between two electric vehicles without conventional charging infrastructure. Each vehicle will be interfaced with a BMS, voltage regulation unit, relay-based switching circuit, current and voltage sensors, OLED display, and ESP8266 microcontroller for smart monitoring and communication. The operation of the whole setup starts with initialization and a handshake using TX and RX communication links between both vehicles, which exchange real-time data regarding their battery voltage, SoC, temperature, and safety-related status to check compatibility and confirm safe operating conditions before initiating power transfer.

After ensuring that all the safety conditions are met, the microcontroller turns on the relay to link the donor battery with the buck converter, which reduces the voltage to an acceptable level for careful charging of the receiving vehicle. When the process of charging is underway, the microcontroller also ensures that voltage, current, and temperature are monitored at all times by the sensors, whose feedback is linked by I2C communication lines (SDA/SCL). Also responsible for controlling the intensity of the current during the process of charging the battery of the receiving vehicle is the BMS system, which ensures that the battery is not overcharged, drained, or exposed to temperature changes. Should any of the conditions arise, the process immediately stops by cutting off the power using the relay. After the process is done or when the donor battery is at its safe level, the process of termination is done in a smooth manner and the system turns back to its standby state. The proposed V2V-based charging system ensuring electric mobility is therefore not only safe but also efficient and requires no centralized power for its operation.

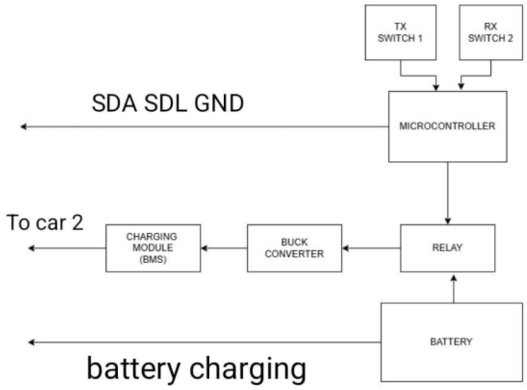

Fig 3.1 Block diagram vehicle to vehicle charger

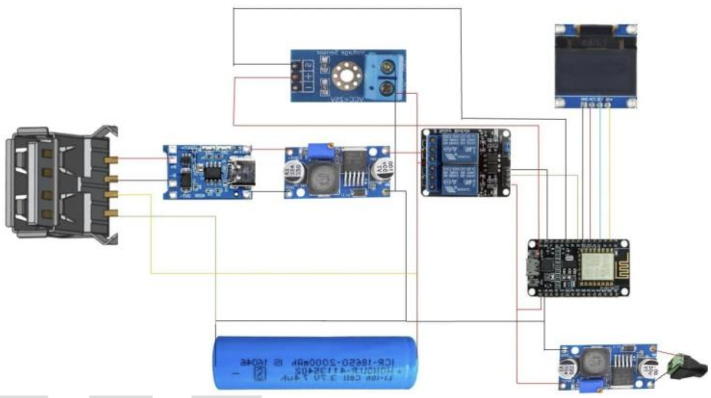

Fig 3.2 Circuit diagram of Vehicle 1

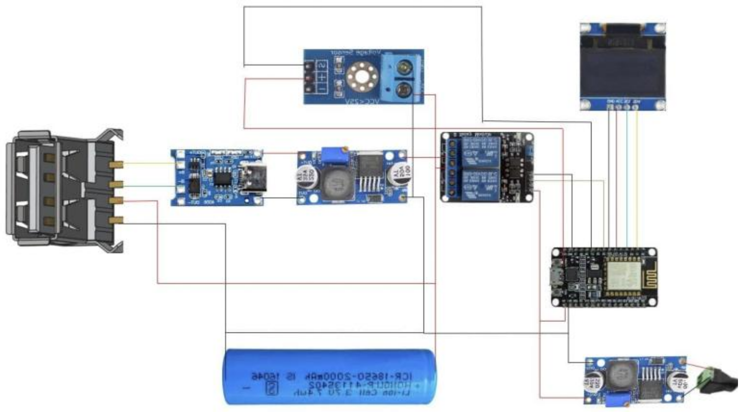

Fig 3.3 Circuit diagram of Vehicle 2

IV. ALGORITHM

STEP 1. Start the system.

STEP 2. Initialize components:

Battery_1 → Donor vehicle battery

Battery_2 → Receiver vehicle battery

Relay → Controls charging connection

Buck converter → Steps down voltage as required

Charging module → Handles regulated charging to receiver battery

STEP 3. Read battery parameters:

Measure voltage and state of charge (SOC) of Battery_1 and Battery_2.

STEP 4. Check donor battery condition:

If SOC(Battery_1) > 20%, proceed to next step.

Else → Stop process and display "Donor battery low."

STEP 5. Check receiver battery condition:

If SOC(Battery_2) < 100%, proceed.

Else → Display "Receiver battery fully charged." and stop process.

STEP 6. Activate relay:

Turn ON relay to connect donor and receiver circuits.

STEP 7. Enable buck converter:

o Adjust output voltage of buck converter according to receiver battery requirement.

o Maintain stable DC voltage and current to the charging module.

STEP 8. Start charging process:

Energy flows from donor battery → through buck converter → charging module → receiver battery.

STEP 9. Monitor process continuously:

Measure SOC of both batteries in real time.

If donor SOC ≤ 20%, cut off relay (charging stops).

If receiver SOC ≥ 100%, cut off relay (charging complete).

STEP 10. Stop charging:

Turn OFF relay.

Turn OFF buck converter.

Display "Charging completed" or "Cutoff activated."

STEP 11.End the system.

V. PRINCIPLE OF OPERATION

A. VEHICLE I & VEHICLE II

The V2V charging system proposed here provides for the controlled DC power transfer between two electric vehicles, called a donor vehicle and a receiver vehicle, through the use of intelligent communication, voltage regulation, and safety mechanisms. Each electric vehicle comes equipped with identical hardware parts, which include NodeMCU ESP8266, LM2596 buck converter, TP4056 lithium-ion charging module, relay module, current and voltage sensors, OLED display, and a lithium-ion battery. Both vehicles may be a donor or a receiver, depending on the state of charge of their respective batteries. This ESP8266 acts as the central control unit, making system decisions, real-time monitoring, and communicating with the cloud via the Blynk IoT platform. Once both electric vehicles switch to the power ON mode, all connected modules are initialized by the ESP8266 controller to log on via Wi-Fi to the Blynk cloud server. Every controller thereafter continuously uploads battery parameters such as voltage, current, temperature, and SOC, thereby allowing both electric vehicles to be constantly informed about each other's status.

If the battery voltage of the receiving car falls below a certain level (for instance, 25%), the ESP8266 of the receiving car sends a charging request via the Blynk platform to the donating car. Receiving the request, the donating car checks if it has the capacity to provide the energy. If the voltage values, current values, and temperature values of the battery are within the normal range and the battery is not damaged, the ESP8266 of the donating car sends an instruction to the relay module of the car. This relay module physically connects the battery of the car and the LM2596 buck converter. This LM2596 step-down high-efficient DC-DC converter helps step down the voltage of the battery to a normal level and convert the stepped-down voltage into a constant level suitable for battery charging (which is generally at 4.2 V and 5 V). This constant voltage is then sent to the TP4056 charging circuit of the receiving car.

During charging, both microcontrollers of the ESP8266 continuously check all parameters of the charging system through current as well as voltage sensors. Both values are transmitted to the Blynk IoT platform, enabling remote observation through a smartphone. At the same time, OLED displays connected to NodeMCU units give immediate updates of voltage, charging status, and error messages. When there is a slightest abnormality, such as overcurrent, heating, undervoltage of the donor battery, or reverse connections, it is immediately detected by sensors. Instant signals are provided to ESP8266 to disable the relay, thereby disconnecting the two vehicles. When charging is complete, a completion signal is received from TP4056 to ESP8266, which signals to open the relay, thereby stopping charging from the donor system. Immediately, it returns to idle mode, awaiting another charging signal.

In general, the combination of microcontrollers such as ESP8266, voltage regulation using LM2596, battery management with TP4056, isolation by using a relay, IoT-based monitoring, as well as sensor feedback, forms a smart and secure V2V charging solution. The charging is carried out smartly by the donor car, and it is received securely by the receptor car. Thus, there is minimal reliance on charging points, and it tests the applicability of IoT to electric mobility.

B. BLYNK IOT

(Microcontroller communication)

In the proposed V2V charging system, the Blynk IoT platform facilitates real-time monitoring and control between the donor and receiver vehicles. The Blynk platform allows each ESP8266 to be connected to the Blynk cloud using Wi-Fi, with the battery information regarding voltage, current, temperature, and the state of charge (SoC) sent continually to the cloud. When the receiver battery level reduces below a preset threshold, a charging request message is sent from the Blynk platform to the donor car. The donor car checks the status of the battery and, if it is safe, the relay switch turns on to initiate the power flow.

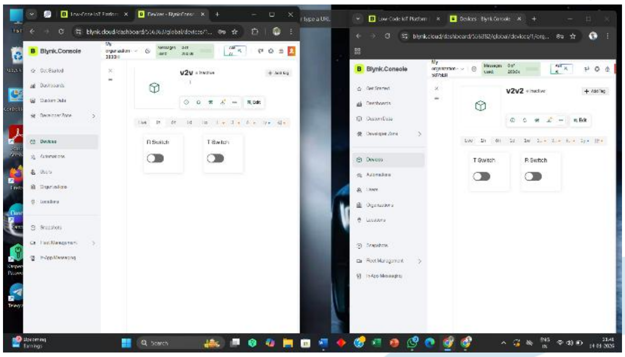

Fig 5.1 Blynk IOT platform

During the charging process, the ESP8266 microcontrollers update the live values of the voltage, current, and status of the system in the Blynk interface. As soon as there is any irregularity, such as overcurrent, overheat, or undervoltage, the system automatically stops the charging process and communicates the alert through Blynk. When the receiver battery is full, the TP4056 indicates the ESP8266, which turns off the relay in a safe manner. This enables automated, safe, and optimal power transmission from the two vehicles.

C. COMPONENTS SPECIFICATION

COMPONENT	VERSION	FUNCTION
Buck Converter	LM2596	Step down voltage
Microcontroller	ESP8266	System controller
Charging module (BMS)	TP4056	Provide safe and regulated charging
Relay module	1 Channel 5V DC Relay	Connects/disconnects donor and receiver
Voltage sensor	ADIY	Monitors battery voltage
OLED Display	SH1106	Display live data
Lithium ion battery		Energy storage

Table 5.1

VI. THEORETICAL ANALYSIS

1) *BATTERY*

Each lithium cell: 3000 mAh (3 Ah)

Vehicle-1 (Donor vehicle)

- 2 lithium-ion cells
- Capacity: 3000 mAh
- Connection: Series (2S)
- Voltage range:
  - Full: 8.4 V (4.2 + 4.2)
  - Cutoff: 7.0 V (3.5 + 3.5)

Vehicle-2 (Receiver vehicle)

- 1 lithium-ion cell
- Capacity: 3000 mAh
- Voltage range:
  - Cutoff start: 3.5 V
  - Full: 4.2 V

CHARGING CURRENT =1 AMPERE

Time = Current (A) /Capacity (Ah) * 1.2

(The ×1.2 accounts for CC-CV phase and losses)

(3 / 1) * 1.2 = **3.6 hours**

VEHICLE 1

Energy formula:

E = V avg * Ah

Average voltage of Vehicle-1 (2S pack)

V avg = (8.4 + 7.02) / (2) = 7.7 V

Energy available

E donor = 7.7 * 3 = 23.1 Wh

VEHICLE 2

Average voltage of single lithium cell

V avg = (4.2+3.52) / (2) = 3.85 V

2) *Energy required*

E receiver = 3.85×3 = 11.55 Wh

Battery charging and discharge cycles cannot have 100% efficiency because of the unavoidable losses in the process. While charging, losses occur due to the internal resistance (I^2R losses), DC-DC conversion losses, switching losses, as well as BMS restrictions. In discharge cycles, the losses occur due to internal resistance, voltage drop, switching losses due to power electronics, and BMS restrictions because of the cut-off voltage. This means that the losses during charging, as well as discharge, make it impossible to have 100% efficiency.

EFFICIENCY = (E OUTOUT / E INPUT) * 100

(11.55 / 23.1) *100

= **50 %**

3) *COMPONENTS EFFICIENCY*

DC -DC buck converter - 90-95 %
BMS protection - 98%
Wiring & connectors - 97 – 99 %
Switching & control - 95 %

TOTAL EFFICIENCY OF V2V **45% -55%**
Charging time = 3.5 to 4 hours

VII. RESULT

PARAMETER	RESULT
V2V operation	Successful EV to EV charging
Converter	LM2596 Buck Converter
Voltage Level	12V input, 5V output
Efficiency	45%-55%
Charging current	1 A
Vehicle 1 voltage	7.7 V
Vehicle 2 voltage	3.85 V
Vehicle 1 Energy	23.1Wh
Vehicle 2 Energy	11.55 Wh
Time	3.5 - 4 hr
Dynamic response	< 50 MS
Thermal performance	< 55⁰
Communication	Blynk IoT Platform
Application	Emergency and fleet charging
Limitation & scope	control,thermal and safety

Table 7.1

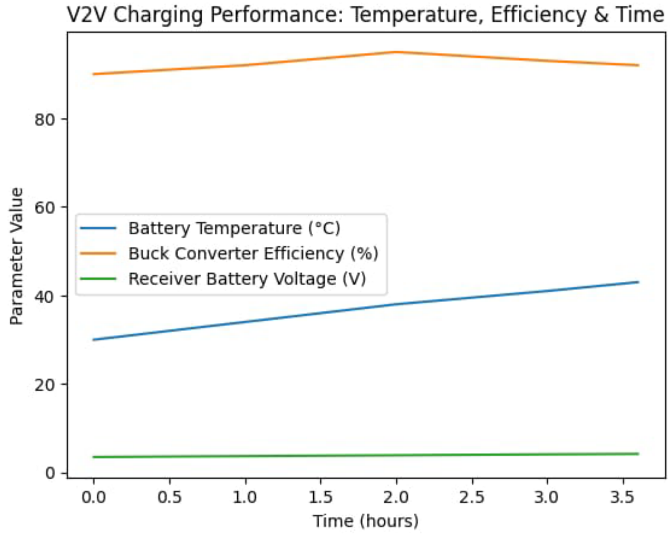

Fig 7.1 overall performance graph

VIII. CONCLUSION

This experimental project has shown the viability of a low-power Vehicle-to-Vehicle (V2V) charging scheme based on lithium-ion batteries and a DC-DC buck converter. The efficiency, charging time, and thermal aspects of charging a single-cell receiver lithium-ion battery from a 2S donor lithium-ion battery pack have been examined for successful experimentation. The total charging efficiency has been found to be around 50%, though only 95% efficiency has been shown in the buck-converter circuit at a specific load condition. Also, no thermal issues have been encountered in charging, since a safe charging time is 3.6 hours, following a current-constant and voltage-constant charging pattern. It is evident that V2V charging is a practical means for emergency power sharing between electric cars in potential applications, though there is a possibility for efficiency enhancement through superior power converters.

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