ELECTRICAL VEHICLE-TO-VEHICLE POWER SHARING SYSTEM BASED ON STATE OF CHARGE

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Abstract
Electric vehicle-to-vehicle (V2V) charging empowers energy sharing among (EVs), especially in zones with constrained charging framework. In any case, existing approaches suffer from expanded cost, space necessities, and in inefficient power conversion. This work proposes a coordinate battery-to-battery V2V charging strategy utilizing onboard Type-2 charger ports, eliminating redundant conversion stages and improving effectiveness. A State of Charge (SOC)-based control procedure is executed to regulate power flow direction and ensure secure operation. The framework is validated through MATLAB/Simulink simulation illustrating steady operation, improved effectiveness, and reliable energy transfer, making it a viable arrangement for proficient and feasible EV energy sharing.

Keywords: Electric Vehicles (EV), Vehicle-to-Vehicle (V2V), State of Charge (SOC), Bidirectional DC-DC Converter, PWM Control, MATLAB/Simulink, Onboard Charger

Introduction

Electric Vehicle-to-Vehicle (V2V) charging has emerged as a promising solution to enhance the flexibility and reliability of energy sharing among electric vehicle (EVs). With the expanding adoption of EVs, the restrictions of ordinary charging framework, such as restricted accessibility and long charging times, have gotten to be more apparent. These challenges are especially critical during long-distance travel and in remote zones where charging facilities are scarce.

Existing V2V charging procedures, although effective, regularly depend on off board power interfaces or numerous energy conversion stages, which result in expanded framework complexity, extra weight, higher cost, and diminished proficiency. The presence of significant energy losses, thereby constraining the viable feasibility of such frameworks for large-scale implementation.

To overcome these confinements, this work proposes a coordinate battery-to-battery V2V charging approach utilizing the existing onboard Type 2 charging ports of electric vehicles. By eliminating unnecessary conversion stages, the proposed method significantly moves forward energy exchange effectiveness whereas diminishing framework complexity and cost. Moreover, the approach leverages bidirectional power flow capacity to empower adaptable energy transfer between EVs.

Statement of the Problem

Proficient energy utilization remains a major challenge in electric vehicle frameworks, especially when batteries work at diverse State of Charge (SOC) levels, driving to lopsidedness in energy utilization. Ordinary charging strategies fundamentally depend on outside framework and do not better coordinate vitally sharing between energy sources. In expansion, numerous existing approaches need adaptable control mechanisms for bidirectional power flow under shifting working conditions. There is too restricted center on simplified simulation models that can successfully illustrate controlled energy exchange and framework behavior. Subsequently, there is a require for a dependable simulation-based approach to analyze SOC -driven power flow, ensure steady operation, and progress in general energy management without the complexity of equipment execution.

Objectives of the study

- To develop a simulation model for bidirectional energy transfer between two batteries.
- To implement SOC-based control logic for determining the direction of power flow
- To analyze system behavior under different SOC and voltage condition
- To simulate step-up and step-down operation using a DC-DC converter
- To ensure stable and controlled power transfer in the simulation environment
- To evaluate system performance in terms of efficiency and response
- To demonstrate safe operation by stopping transfer at predefined SOC limits

Review of Literature

Various investigators have worked on making strides energy management in electric vehicle systems. Anuja et al. (2004) utilized MATLAB/Simulink to ponder bidirectional charging, showing up how simulation can be profitable to understand system behavior. Iyer et al. (2021) and Reddy et al. (2022) clarified how bidirectional converters plan and how SOC can be utilized to control the heading of power flow. Khan et al. (2021) additionally included solar PV with EV charging, though Verma et al. (2021) examined battery management and SOC estimation. Apart from this, considers by Vinay et al. (2023), Manjunatha (2021), Pasha et al. (2023), and Keseev (2020) fundamentally deal with particular EV components and design perspectives. Indeed, in spite of the truth that these works allow awesome understanding around EV systems, most of them center on network affiliation or hardware models. There is still a cleft in basic simulation-based models that clearly show up how energy can be shared between batteries utilizing SOC control in a secure and controlled way.

Research Methodology

The methodology of this work is basically based on simulation to consider how energy can be exchanged between two batteries. The demonstrate is created in MATLAB/Simulink, where two batteries with distinctive SOC levels are considered. Based on this distinction, a basic SOC-based control logic is utilized to choose the direction of power flow. A bidirectional DC-DC converter is included in the demonstrate so that it can work in both step-up and step-down models depending on the condition. During the simulation, imperative parameters like voltage, current and SOC are persistently watched to understand how the framework carries on. Diverse cases are tried by changing the SOC levels to see how the power exchange takes place. The framework is also outlined to halt automatically once the required SOC level is achieved or if restrain is crossed, so that secure operation is kept up.

Proposed System

The proposed framework is modelled and examined utilizing MATLAB/Simulink, and its execution is assessed under diverse working conditions. The results illustrate that the framework accomplishes productive, reliable, and controlled energy transfer, making it a viable solution for future EV energy sharing applications.

In conventional electric vehicles, onboard Type 1 and Type 2 chargers comprise of a AC-DC converter (active Rectifier) followed by a DC-DC converter that performs constant current-constant voltage (CCCV) charging. Whereas these converters are essentially designed for grid-based charging, they can also be adapted for Vehicle-to-Vehicle (V2V) energy transfer.

A common V2V approach involves interfacing two Type 1 and Type 2 chargers, where the provider EV converts its battery DC power into AC, which is then converted back into DC by the receiving EV. Although functional, this strategy endures from numerous power transformation stages, resulting in higher energy losses and decreased efficiency.

Another possible method is to coordinate DC-link association between two EVs using mechanical switches. However, this approach is troublesome to execute in practice due to the lack of direct access to internal DC-links in commercial EV systems.

To address these restrictions, the proposed framework utilizes onboard Type 2 chargers to empower effective V2V energy exchange. The Type-2 charging ports of two EVs are directly connected and the active rectifier stages are repurposed as an interface between the two batteries . This altogether diminishes unnecessary power conversion stages, subsequently progressing overall effectiveness.

The key contribution of this work is the implementation of a State of Charge (SOC) based control technique. Unlike regular systems that depend only on voltage or current control, the proposed system intelligently manages power transfer based on the battery SOC levels of both vehicles.

The framework persistently monitors the SOC of the receiving EV and compares it with a predefined threshold. Energy transfer is permitted when the SOC is underneath the threshold, ensuring controlled and secure charging. Once the desired SOC level is reached, the framework automatically stops power transfer, preventing overcharging and progressing battery life.

In expansion to SOC-based decision-making, the framework includes a mode choice mechanism that determines buck or boost operation depending on the voltage levels of the two batteries. This empowers productive bidirectional energy transfer regardless of voltage differences.

During operation, selective switches of the active rectifiers are turned ON to create a coordinate association between the DC-links of both EVs. These switches remain active throughout the charging process, forming a bidirectional buck-boost converter. Complementary PWM signals are utilized to control the switching devices, ensuring secure operation and avoiding shoot-through conditions.

By combining decreased conversion stages with SOC-based intelligent control, the proposed framework achieves efficient, reliable, automated energy sharing between electric vehicles. This makes it especially appropriate for real-world applications such as emergency charging and decentralized energy management.

Operation Under Break Even with Battery Voltage Condition (SOC-Based Control)

In practical scenarios, both electric vehicles may have comparable or equal battery voltage levels. In such cases, conventional voltage-based control methods fail to determine the direction of power flow, making energy transfer difficult to manage. To address this limitation, the proposed framework employs a State of Charge (SOC)-based control strategy. Even when the battery voltages of both EVs are equal. The framework compares their SOC values to recognize the provider and receiver. This empowers viable energy exchange independent of voltage differences.

To facilitate power flow under equal voltage conditions, the bidirectional DC-DC converters are worked in a controlled way, where one converter functions in boost mode and the other in buck mode with closed-loop control. The switching is controlled utilizing PWM signals to make a controlled voltage distinction across the inductive connect, permitting current to flow from the higher SOC battery to the lower SOC battery. The energy transfer continues until the receiving EV reaches the predefined SOC threshold. One this threshold is accomplished, the control logic automatically stops the charging process, ensuring secure operation and preventing overcharging.

This SOC-based approach provide a significant advantage over framework systems, as it empowers intelligent and dependable energy sharing indeed when battery voltages are identical.

V2V: Equal Battery Voltage Condition (V(bat1)=V(bat2))

In this situation, both electric vehicles have equal battery voltages, which makes conventional voltage-based power exchange ineffectual. To empower energy sharing beneath this condition, the proposed framework utilizes a State of Charge (SOC)-based control technique, which plays a key part in deciding both the direction and term of power transfer. Instead of depending on voltage contrasts, the framework ceaselessly compares the SOC levels of two EVs, where the vehicle with higher SOC acts as the supplier and the one with lower SOC acts as the receiver. This guarantees shrewdly and solid energy sharing when the battery voltages are identical.

To encourage control stream, the DC-DC converters are controlled such that one works in boost mode and another in buck mode, both beneath current-controlled operation. This facilitated control makes a little fake voltage distinction over the converters, empowering current to flow between the batteries. In the forward boost mode, where EV1 has higher SOC and acts as the supplier, DC-DC converter-1 operates in boost mode while DC-DC convereter-2 operates in buck mode. During the ON state of switch Sb1, the inductor L1 stores energy from EV1's battery whereas switch Sb2 allows inductor L2 on the inductor side to freewheel. The switches Sa1 and Sa2 operate complimentary to ensure proper switching. When the switches turn OFF, the stored energy in L1 is transferred to EV2's battery through intermediate connection path, including switches S1 and S1' and inductor L2. This controlled switching mechanism enables effective power transfer from EV1 to EV2 despite equal voltage levels.

In the turn around boost mode, when EV2 has higher SOC, the roles are turned around, and the control streams from EV2 to EV1. In this case, DC-DC convereter-2 works in boost mode while DC-DC converter-1 works in buck mode under closed-loop current control. The switching operation remains similar, but the direction of energy transfer is reversed. The energy transfer continues until the receiving EV reaches the predefined SOC threshold, after which the system automatically stops charging, ensuring secure operation and preventing overcharging.

Thus, the proposed system successfully enables efficient, controlled, and bidirectional V2V energy transfer based entirely on SOC, rather than voltage contrasts, making it profoundly appropriate for viable real-world applications.

Results and Discussion

The proposed framework is created and approved using a MATLAB/Simulink (2024a) simulation model that represents a peer-to-peer Electric Vehicle (EV) charging system. In this setup, one EV acts a power provider while the other functions as a receiver, enabling direct energy transfer between vehicles. This model is designed to address real-world situations such as emergency charging in remote or infrastructure-limited areas. Both EVs are displayed with 12V batteries, giving a practical adjust between energy capacity and framework achievability. The simulation coordinating a State of Charge (SOC)-based control technique, guaranteeing that power exchange occurs only when necessary and automatically stops once the wanted SOC level is reached, subsequently improving security and efficiency.

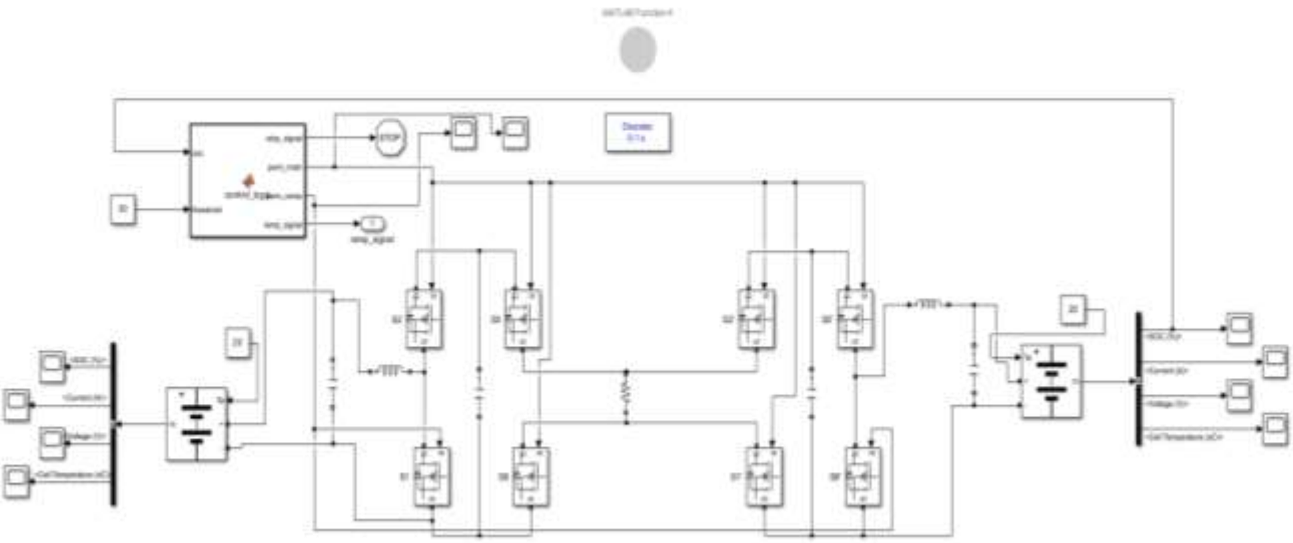

Fig No.1: MATLAB Simulink Model

Beyond specialized execution the proposed framework emphatically adjusts with different Sustainable Developmental Goals(SDGs) it underpins Reasonable and Clean Energy (SDG 7) by advancing productive framework too contributes to climate actions (SDG 13) by diminishing reliance fossil fuels advertisement bringing down carbon outflows through shrewd EV energy sharing.

Additionally, the framework adjusts with Industry, Development and Foundation (SDG 9) by presenting progressed energy-sharing innovations that upgrade cutting edge transportation framework. It underpins Maintainable Cities and Communities (SDG 11) by empowering dependable and decentralized EV charging arrangements, which are basic for urban and rustic portability. The concept of V2V energy sharing moreover contributes to Capable Utilization and Generation (SDG 12) by optimizing utilization and minimizing wastage through shrewdly SOC-based control. Furthermore, by progressing availability to energy or farther zones, the framework by implication bolsters Diminished Disparities (SDG 10), guaranteeing that clean vitality arrangements are not constrained to well-developed locales alone.

The simulation comes about illustrate steady and proficient bidirectional energy exchange between EV's. The SOC-based control successfully decides the heading of control stream, avoids overcharging and guarantees secure operation beneath diverse conditions, counting equal voltage scenarios. Overall, the proposed framework offers a solid, cost-effective and economical arrangement for future EV vitality sharing with solid pertinence to worldwide maintainability goals.

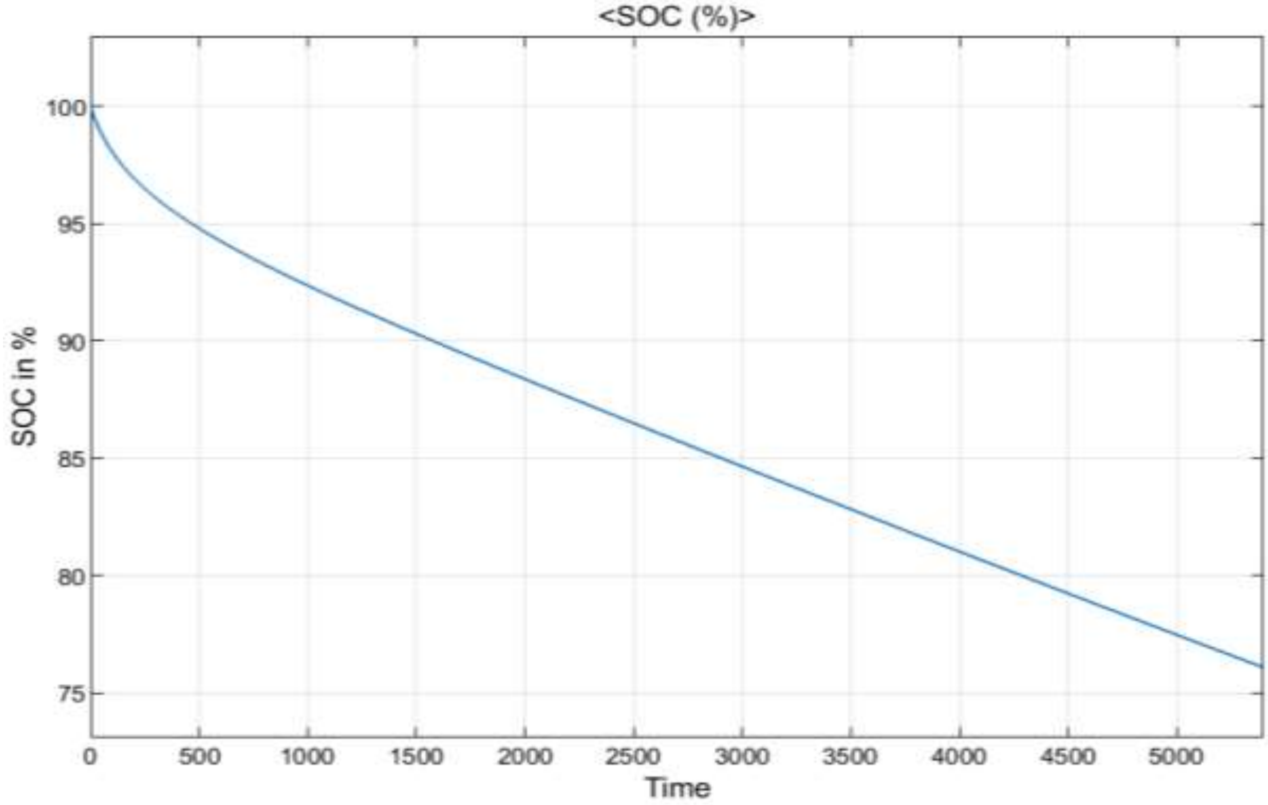

Fig No.2: SOC plot of Battery 1

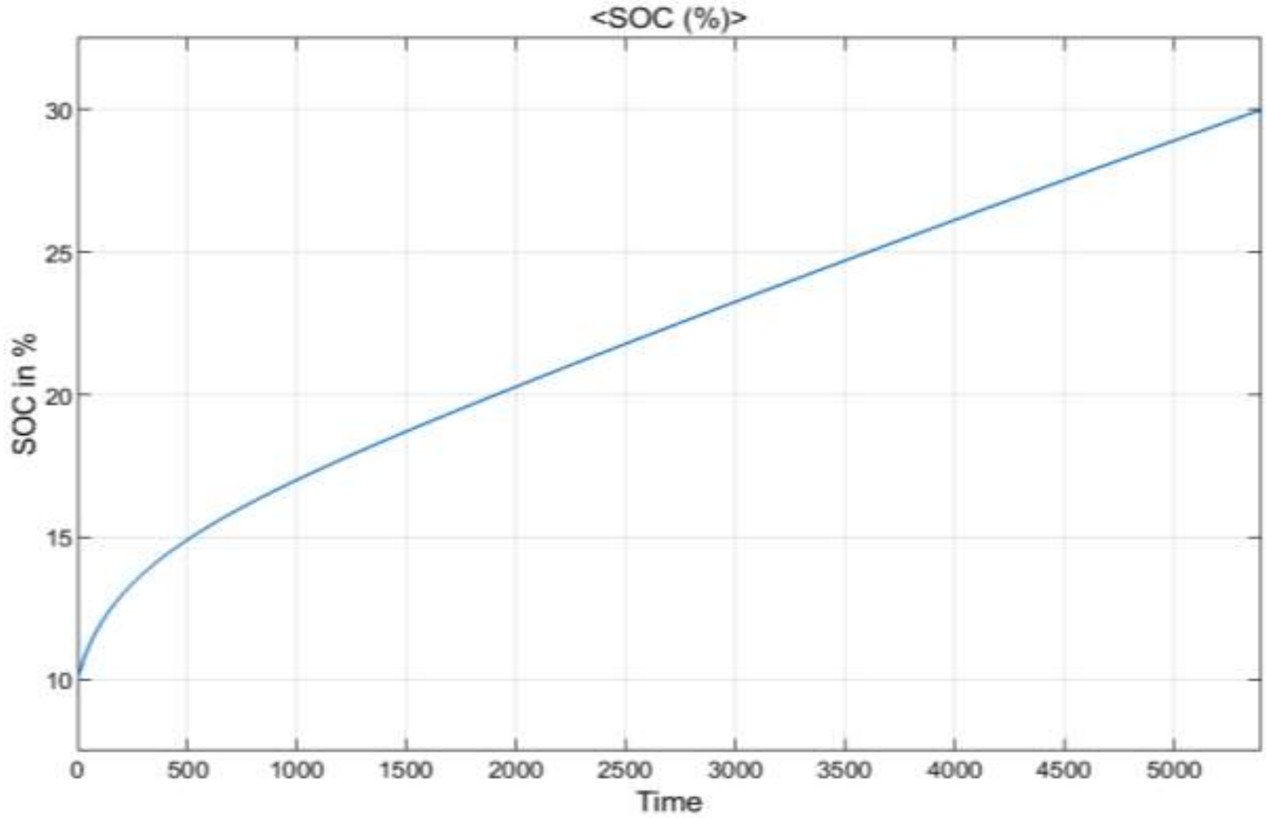

Fig No.3: SOC plot of Battery 2

Conclusion

This work proposes a contribute V2V charging framework that empowers productive energy exchange between electric vehicles utilizing onboard charger ports without extra equipment. The framework consolidates a State of Charge (SOC)-based control methodology to guarantee cleverly, secure and computerized control sharing. By eliminating excess change stages, the proposed strategy progresses general productivity and diminishes vitality misfortunes. The MATLAB simulation comes about approve steady bidirectional operation and compelling SOC-based control beneath distinctive conditions. Subsequently, the proposed approach gives a viable and cost-effective arrangements for further EV energy sharing applications.

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