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Research Paper

Fast charging techniques for electrical vehicles using AC-DC

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***Abstract*— The AC-DC quick charging method for electric vehicles (EVs) aims to increase power delivery and efficiency at charging stations. A shared rectification system, often a 12-pulse rectifier, is a critical component that improves power quality and decreases harmonics, making it ideal for high-power charging applications. This technique optimizes the overall stability and performance of the power network when paired with a DC side filter. An improved version of the Constant Current, Constant Voltage (CC-CV) approach reduces charging times while maintaining battery health, whereas the original CC-CV technique ensures safe battery charging. The experimental results demonstrate the possibility for faster and safer charging and validate the efficacy of the enhanced CC-CV approach. The system's scalability and integration of renewable energy sources further help sustainability goals. This technique not only increases consumer satisfaction, but it also fosters the development of effective, conveniently accessible EV charging infrastructure for the future.**

Keywords: Fast Charging, Electric Vehicle, Boost Converter, Charging Methods.

I. INTRODUCTION

THE introduction of electric cars (EVs) gain popularity throughout the world, the requirement for efficient and accessible charging infrastructure has grown to enable their broad adoption. The creation of rapid charging technologies that can swiftly recharge an EV's battery while guaranteeing efficiency, safety, and little downtime for drivers is one of the most urgent problems. A strong AC-DC fast charging infrastructure that enables quicker charging speeds than traditional charging techniques is being investigated as a solution to this problem. Long charging periods and range anxiety are two major obstacles to EV adoption that must be addressed by this advancement in charging technology.

The AC-DC rapid charging technology works by converting alternating current (AC) from the grid into direct current (DC), which may be utilized to charge an EV battery. Three charging levels are defined by the widely used SAE J1772 standard in North America: DC fast charging (up to 100 kW), AC Level 1 (up to 1.9 kW), and AC Level 2 (up to 19.2 kW). When compared to AC chargers, DC fast charging methods like CHAdeMO and CCS (Combined Charging System) enable noticeably quicker charging. Vehicles may reach an 80% charge in less than 30 minutes with DC fast chargers, which makes them ideal for long-distance driving and minimizes charging downtime.

The development of high-power ultrafast chargers has marked a significant advancement in DC rapid charging. With charging speeds ranging from 125 to 300 kW, these systems aim to drastically reduce charging time. According to experts and industry executives, these ultrafast charges will be essential to making EVs as feasible to drive as traditional gasoline-powered vehicles. To achieve this kind of high-speed charging, fast charging stations are designed to hold many chargers that can deliver high power to EV batteries simultaneously.

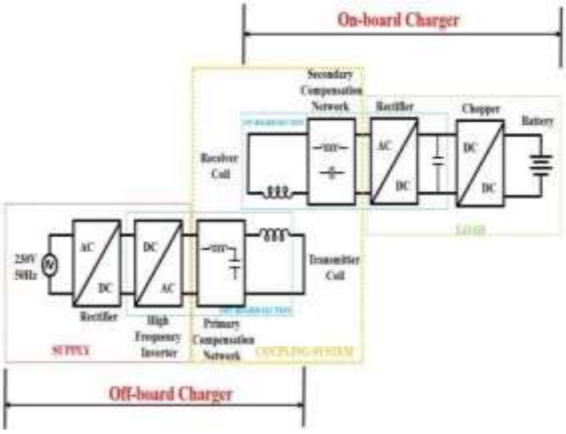

Fig.1. Basic Block Diagram of AC-DC for EV

The usage of a shared rectification system, which transforms alternating current from the grid into direct current, is crucial to the design of DC fast charging stations. Conventional charging stations are more complicated and expensive since each charger needs its own rectifier and inverter. A centralized rectification step, on the other hand, streamlines the design by using a single rectifier to power several chargers. By eliminating the need for several rectifiers and inverters, this architecture improves system efficiency while lowering costs and complexity. It also makes it simple to integrate renewable energy sources and energy storage devices, such batteries, which may help control power demand, stabilize the grid, and improve the sustainability of charging stations.

In these systems, using a 12-pulse rectifier has become a typical way to improve power quality. By lowering harmonics and ensuring cleaner AC current from the grid, this kind of rectifier raises the charging station's overall stability and efficiency. To further improve system performance and lessen variations in power supply to the EVs, a DC-side filter is usually utilized in tandem with the rectifier. These cutting-edge technologies aid in reducing power quality problems including total harmonic distortion (THD), which can impair the charging station's and the car's battery's performance.

An other unique method in DC fast charging systems is the use of energy storage on the bus. Fast charging stations can improve load management and balance the grid's power consumption by integrating energy storage. This connection facilitates the station's involvement in demand response initiatives, lowers energy expenses, and helps control peak demand. To provide dependable service at ultrafast charging stations, energy storage can also assist in preserving a steady power supply during times of heavy charging demand.

1.1 Objectives of the paper

The objectives of AC-DC fast charging systems focus on delivering high-speed charging by efficiently converting alternating current (AC) to direct current (DC). These systems aim to significantly reduce charging time for electric vehicles, portable devices, and other battery-powered equipment. They ensure compatibility with various devices, promote energy efficiency, and support the development of a sustainable, eco-friendly infrastructure. Additionally, AC-DC fast charging systems prioritize safety features to prevent overheating and electrical hazards while optimizing power delivery. By improving overall charging performance, these systems help reduce downtime, contribute to user convenience, and support the growing demand for rapid charging solutions in the modern technological landscape.

II. METHODOLOGY

Constant Voltage

A crucial step in the charging process for constant voltage (CV). Maintaining the charging voltage at the highest permitted for a particular battery type is essential for safe and efficient charging using this method. Here are some more things to think about when charging a CV. Even if constant voltage charging is good at safeguarding batteries, reducing lengthier charge times is critical to improving the user experience and attracting more people to buy electric vehicles. We might be able to better balance battery charging efficiency and safety by investigating state-of-the-art charging methods and algorithms. Since this study aims to directly address these issues, improving the CC-CV approach is very crucial. [19] [20].

Constant Current

The charging technique known as constant current (CC). While it allows the battery to charge at a consistent pace until it reaches a specified voltage, there are certain downsides, including heat generation and battery longevity. Here are some things to think about. A battery may be rapidly charged to almost full capacity using constant current charging; but, to extend battery life and guarantee safety, careful control of current and temperature is necessary. The charging process may be optimized by switching to CV charging and balancing the benefits of CC charging with suitable heat control techniques. Your emphasis on enhancing the charging algorithm to resolve these problems is extremely pertinent to the development of electric car battery technology.

Constant Current – Constant Voltage (CC-CV)

The essential concepts of Constant Current-Constant Voltage (CC-CV) charging are widely understood. Although this technique is frequently used to charge batteries, it has drawbacks, especially when rapid charging is involved. Let's examine the subtleties of CC-CV charging, its drawbacks, and how adjustments can improve its constant current phase and constant voltage phase performance. The CC-CV charging technique has been a solid standard for battery charging; nonetheless, its limits in fast-charging applications need constant improvement. Multiple current phases and adaptive charging techniques can significantly improve the CC-CV process's speed and efficiency, making it more appropriate for high-demand situations like charging electric vehicles. In order to advance charging technology and better the user experience overall, it is imperative that you investigate these improvements.

Pulse Charging

The essence of pulse charging successfully. This technique addresses typical issues like polarization and heating while optimizing performance by using the dynamics of charging. Here's a closer look at the major features of pulse charging and its advantages: pulsed current delivery, rest periods, and adaptive operation. The charging procedure offers a practical way to enhance charging durations and battery health while taking variables like polarization, temperature, and changing impedance into account. Your emphasis on these elements draws attention to the continuous development of charging techniques, which is essential for the advancement of battery-dependent applications such as electric car technology.

Negative Pulse Charging

This novel technology improves battery charging efficiency while also addressing some of the fundamental problems connected with existing charging techniques. A closer look of negative pulse charging, its workings, and its benefits—such as energy recapture, stress reduction, and intermittent discharges—is provided here. One major development in battery charging techniques is negative pulse charging. This method increases battery longevity in addition to efficiency and charging speed by introducing controlled discharges during the charging process. Your focus on the benefits of this approach draws attention to its possible influence on battery technology going forward, especially in the expanding market for electric vehicles and other high-demand energy applications.

III. MODELING AND ANALYSIS OF CHARGING SYSTEM

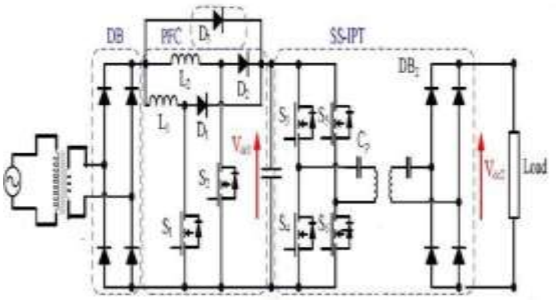

Fig.2. Circuit Diagram of Charger Circuit for EV

Rectifier and Interleaved Boost Converter

In general, all AC/DC converters include a transformer after the input filtering, which then flows to a rectifier to create rectified DC. Multi-stage conversion topologies are employed by the AC-DC converters [5]. Even silicon controlled rectifiers (SCR) and triodes for alternating current (TRIAC) are utilized as rectifiers, but diode bridge rectifiers only carry current in one direction. The higher end of the transformer secondary winding is positive in relation to the lower end during the positive half cycle of the input voltage. Diodes D1 and D3 are therefore forward biased during the first half cycle, and current passes through the load resistance. The diodes D2 and D4 are reverse biased during this negative half of each input cycle, preventing current from flow, as indicated in Fig. 3. During the second half cycle of the input voltage, the lower end of the transformer secondary winding is positive in comparison to the upper end. As a result, current enters the load resistance through arm CB and diodes D2 and D4 become forward biased.

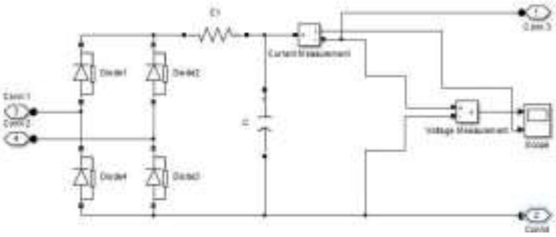

Fig.3. Rectifier at the primary side

Interleaving is the process of connecting N boost converters in parallel at the same switching frequency but with a phase shift of 360/n. The advantages of an interleaved boost converter include a high ripple frequency, a lower peak current value, and low input and output voltage ripple content [6]. High dependability and efficiency result from this. The size and losses of the magnetic components can be decreased since the suggested converter runs at a high frequency. This article examines a two-phase interleaved boost converter that displaces pulses to MOSFET switches by 180 degrees. In contrast to a traditional boost converter, this divides the current flow into two pathways, resulting in lower conduction (I2R) losses and higher overall efficiency. The ripple frequency is doubled since the two phases are joined at the output capacitor, making ripple voltage reduction more simpler. Similarly, when the input capacitors are spaced apart, the ripple requirements decrease. In order to satisfy the harmonic standards, the input current's total harmonic distortion (THD) is lowered [7 & 8]. Fig. 4 displays the interleaved boost converter circuit schematic.

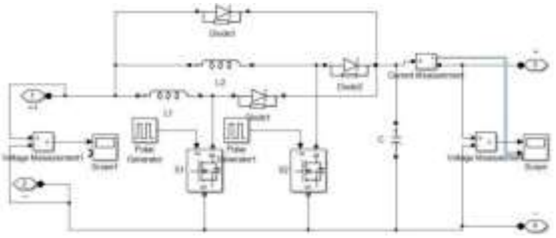

Fig.4. Simulink diagram of interleaved boost converter

PWM Voltage Source Inverter and Coil Design

The inverter serves an important function in converting fixed dc into variable ac [9]. The inverter can be powered by renewable energy sources or by a dc supply that is drawn from an ac source. Four semiconductor switches on each of the two arms of the single-phase inverter are linked by an anti-parallel diode. The reverse current passes through the anti-parallel diode when the switches are turned off. The switches (S1, S2, S3, and S4) are activated alternately so that no switch on the same leg can conduct, resulting in a'shoot through issue'. However, to prevent short circuiting, both switches were switched off for a certain time known as the blanking time [10]. The load is attached between the two arms. Figure 5 displays the proposed single-phase inverter's Simulink diagram. The power transfer in SS (series-series) compensation is determined by the bus voltages, frequency of operation, and mutual inductance between the two inductivepads. The frequency is kept constant and equal to the resonant frequency in order to minimize commutation losses. Additionally, the maximum power will be achieved at the highest mutual inductance and bus voltage [11]. One important factor is the alignment of two inductive coils. If two coils are near together, maximum coupling is achieved; if two coils are apart, the bus voltage decreases. Therefore, single-phase inverter features restrict the alignment characteristic of the inductive power transmission system. An iterative design method must be used to keep inductive coils aligned correctly (fig. 5).

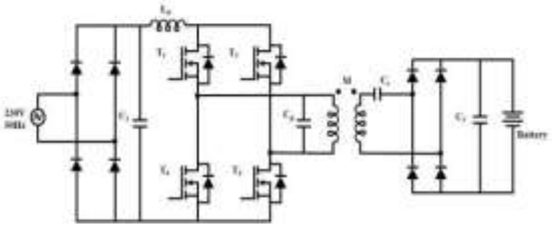

Fig.5. Basic Block diagram of High-frequency Converter with Compensation topology

IV. RESULTS AND DISCUSSION

In reality, this combined FEM-circuit simulation and circuit analysis are nearly identical. The FEM considers induced currents in the ferrites, which indicate Joule losses that are absent from the circuit analysis. That is the sole difference. These losses are negligible and don't significantly alter the behavior of the system in Figure 6.

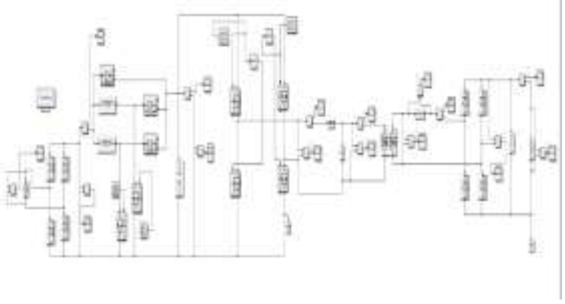

Fig. 6. Simulink Diagram

Fig.7. Rectifier Input Voltage

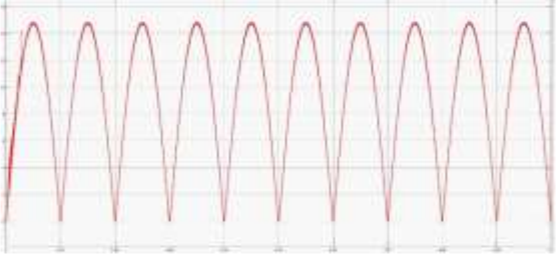

Fig.8. Rectifier Output Voltage

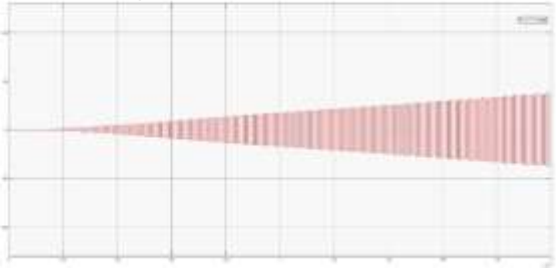

Fig.9. Inductive Coil Primary Side Voltage

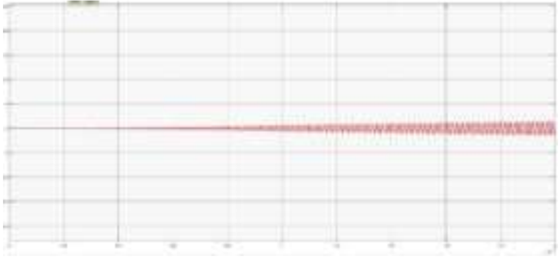

Fig.10. Inductive Coil Primary Side Current

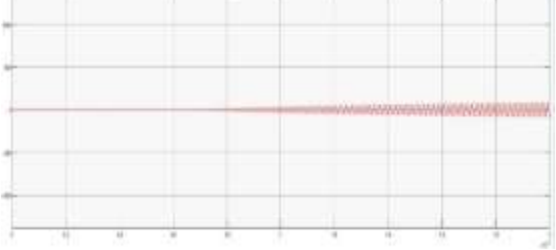

Fig.11. Inductive Coil Secondary Side Voltage

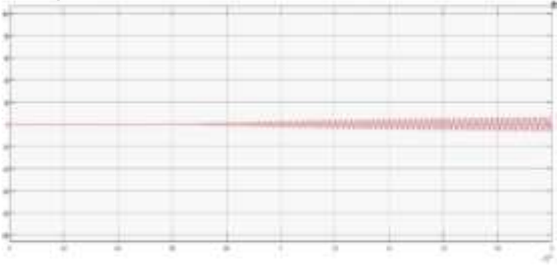

Fig.12. Inductive Coil Secondary Side Current

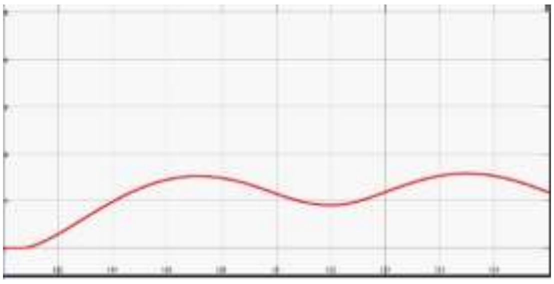

Fig.13. Rectifier Output Voltage Secondary Side

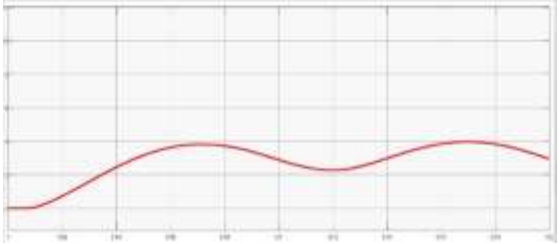

Fig.14. Rectifier Output Current Secondary Side

V. CONCLUSION

Finally, AC-DC rapid charging systems play an important role in improving the efficiency and speed of charging processes for electric cars and electronics. These systems enable quick power delivery by successfully converting alternating current to direct current, hence reducing user downtime. Together with energy efficiency and safety features, their connectivity with a wide range of devices promotes environmentally beneficial and sustainable technological improvements. AC-DC fast charging technologies will continue to advance as the need for dependable and speedy charging solutions increases. They will play a crucial role in the creation of contemporary infrastructure and provide users worldwide convenience and accessibility.

VI. FUTURE SCOPE

The AC-DC fast charging technique for electric cars (EVs) has tremendous future promise due to its ability to charge EVs quickly while guaranteeing grid efficiency. Faster charging options are essential to cutting down on charging time and enhancing the entire EV ownership experience as the use of EVs increases. While DC fast charging, which employs high voltage direct current, enables far quicker recharge times and is therefore perfect for public charging stations, AC charging is more accessible while being slower. Advanced power electronics, enhanced battery technology, and smart charging infrastructure will all help to increase charging efficiency. Future AC-DC rapid charging technology looks to play a significant role in facilitating the mainstream adoption of EVs as the trend toward more environmentally friendly modes of transportation continues to increase.

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