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Contact-Free Power Transfer Methods for Electrical Vehicles

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Abstract -Globally, Electric vehicle (EV) charging via static wireless charging is becoming more and more common. An EV, however, is limited in how far it can go between charges. To extend its range, more batteries will be required. Dynamic Contact-free charging is a feature that EVs have to greatly increase their driving range and do away with large batteries. This dilemma is being avoided by certain modern EVs. However, plug-in charging and static WPT will eventually be obsolete thanks to dynamic WPT. Allowing an EV's total runtime to be infinite. An EV may be charged while being driven, eliminating the need to pause or consider charging it again. Two types of coils—the receiver coil and the transmitter coil—are required for Contact-free charging. While passing across the transmitter coil via mutual induction, the receiver coil will gather power from it. For Contact-free power transfer (WPT), however, the difference in distance between two neighbouring coils has an impact. For dynamic charging, a charging channel is also included. The transfer of power is then calculated using mutual inductance while the EV is driven in a charging lane. The load may be used to calculate how far an EV can go with this additional power.

Keywords: Contact-free power transfer, Electric vehicle, Dynamic charging, Static Charging, Efficiency, charging lane.

1.INTRODUCTION

As a need for electric vehicles keeps going up, there is an increasing required for efficient and convenient energizing solutions. One intriguing way to overcome the difficulties with conventional EV charging is using Contact-free charging technology. This technology transfers energy to vehicle's battery from a charging station without requiring an actual plug-in link, offering a seamless and effortless recharging experience. Contact-free charging increases public interest in electric mobility by doing away with the need for plugs and cords.

Beyond ease use, Contact-free power transfer signifies a fundamental change in the way we engage with our cars and the cities in which they are driven[1]. Compared to traditional charging techniques, it offers a number of benefits, including as automatic charging, less component wear and tear, and the possibility of extended system lifespans with less maintenance. Additionally, Contact-free charging simplifies the charging procedure, improves the overall experience for EV owners, and reduces the amount of physical infrastructure required at charging stations. These advantages encourage the wider adoption of electric vehicles by addressing issues with user-friendliness and accessibility of charging stations.

This state-of-the-art technology transfers energy between a receiver point mounted underneath car and a charger pad on the ground[2]. Electricity flows smoothly without direct physical touch thanks to the concepts of electromagnetic induction and resonant coupling. Among the several types of Contact-free charging techniques are plug-less charging, dynamic Contact-free charging, magnetic resonance Contact-free charging, resonant inductive charging, and inductive charging. Contact-free charging sticks out as a progressive and eco-friendly option for the future of electric mobility as the automotive sector continues to strive for sustainability[3].

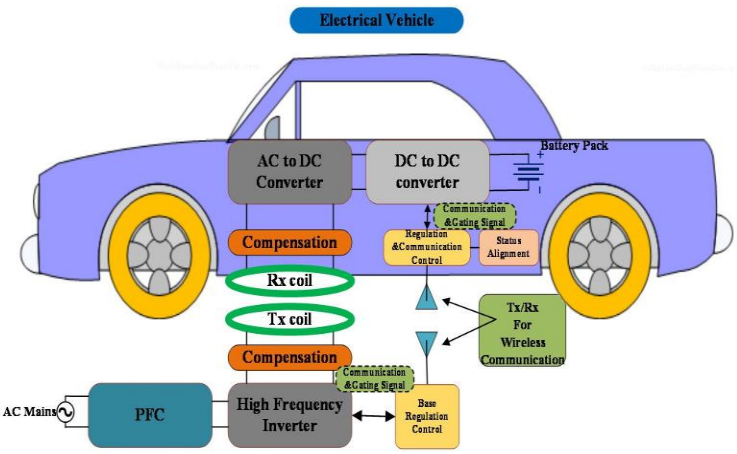

Fig.1 Contact-free power transfer for Ev

Wireless charging solutions for electric vehicles (EVs) can be categorized into three main types: Charging systems can be fixed, semi-dynamic, or dynamic. Stationary systems function similarly to typical plug-in chargers, allowing users to park their vehicles and charge them easily. These setups involve an onboard a receiving pad, as well as an external charging pad embedded in the ground, eliminating the need for physical connections. Semi/quasi-dynamic systems are suitable for locations such as In dynamic surroundings, bus stops, taxi stands, and traffic signals provide short, intermittent charging chances. Dynamic wireless power transfer (DWPT) technologies allow EVs to charge while driving, dramatically increasing driving range and eliminating 'range anxiety.' According to sources, DWPT has the potential to reduce battery capacity requirements by

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up to 20%, lowering the initial investment in a new EV.. Consequently, wireless power transfer holds great promise for EVs and could contribute to their increased adoption.

2.Problem Statement

It might be expensive to install Contact-free charging infrastructure for both private users and corporations. This covers the related technology rather than the costs of producing and setting up the charging pads[4]. Determining who should pay for these expenses and figuring out how to make this technology available to a variety of consumerism the difficult parts. The need for efficient power transfer regardless of coil misalignment, controlling the effects of high-frequency electromagnetic fields on human health and communication systems, and lowering the high upfront costs of infrastructure development are some of the major obstacles that still need to be addressed despite advancements in Contact-free charging technology for electric vehicles (EVs).

3. Literature Review

In "Electric vehicle Contact-free charging techniques," The goal of this literature study is to present a thorough analysis of Contact-free charging techniques for electric cars. It explores the many technologies, technical factors, benefits, and difficulties related to Contact-free charging. It also looks at the regulatory environment, the state of deployment at the moment, and new developments in this quickly changing industry[5].

By doing away with the need for bulky batteries, dynamic WPT can greatly extend EVs' driving range while lowering weight and increasing vehicle efficiency. This is a noteworthy development that may lead to more useful and environmentally friendly electric vehicles. Electric vehicle charging Contact-freely while operating a motor vehicle.

This creative method, which takes the shape of a Multiplexing LCC Module (MLM), removes the need for extra inductors by enabling unenergized transmitters to operate as a component[6].

EV Autonomy Assessment: The study makes it possible to assess an EV's autonomy while driving on a Contact-free charging road by using the mathematical models that were covered. Customers and industry participants may find this information useful in comprehending the advantages and real-world applications of Contact-free charging infrastructure. "A Thorough Examination of Contact-free Charging Systems for Electrical Cars."

3. METHODOLOGY

high frequency (Hf) AC by a DC-AC inverter and an AC-DC converter. S-S compensation design is used by both the transmitter and receiver coils to deliver the best possible transfer of power to the receiving end. Typically, the transmitting pad is positioned below the surface of the road, while the receiving pad is positioned beneath the vehicle. The receiver pad is usually placed lower from the EV's frame to receive more magnetic flux. The high-frequency AC is converted to DC via an AC/DC converter and then sent to the battery bank[9]. The battery management system (BMS) communications and power controller are used to ensure consistent operation and avoiAC power from the grid at Low-frequency is converted to d any safety issues. The entire grid-to-vehicle (G2V) charging procedure. Since the transmitter and receiver coils are in theory, the most important parts of the overall system, they are the main focus of this work. The overall efficiency can be increased by changing the properties of these two coils.

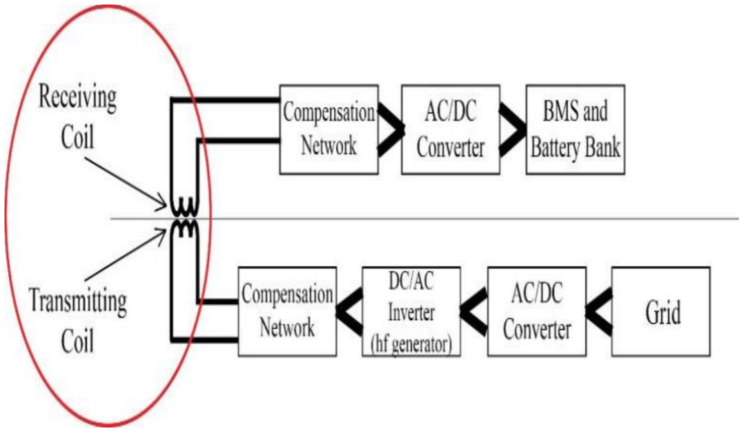

Fig 2: Block diagram of grid to vehicle Contact-free charging system

4. Contact-free Charging Types

4.1 Inductive Contact-free Charging

An innovative method of charging electric vehicles (EVs) is inductive Contact-free charging, which uses electromagnetic induction to transfer power to the EV's battery from a ground-based charging pad. This technology eliminates the need for physical wires by using two primary coils, one in the car's underbelly and the other one in the charging pad. An AC flowing through the coil of the charging pad creates a magnetic field. The electrical vehicles coil then generates an electric current as a result of this field, effectively charging the battery. For EV owners, inductive Contact-free charging streamlines the charging process by offering a practical, frictionless, and effective substitute for conventional cable systems. In the automotive sector, this simplified and approachable method is becoming more popular and making a contributing significantly to the further use of electric vehicles[7].

The electrical vehicle has a receiver coil underneath it. When the car lines up with the charging pad, energy is sent to the battery through a current that flows through the receiver coil due to the magnetic field the pad creates. The technology stands out due to its contactless, cable-free functioning, which streamlines charging and improves user convenience.

4.2 Capacitive Contact-free Charging

Another cutting-edge technique for sending electrical energy to EVs Contact-freely is capacitive Contact-free charging. Instead of relying on electromagnetic fields as inductive charging does uses an electric field created between pairs of capacitive plates refers , capacitive charging. The charging setup includes a pad with capacitive plates embedded in the ground and a similar set of plates integrated within the EV.

When the EV is placed on top of the charging pad, a capacitive connection is made between the ground plates of the EV and those on the pad. By creating an electric field, this coupling makes energy transmission easier and charges the EV's battery. Compared to certain inductive systems, capacitive Contact-free charging may have the advantage of more alignment flexibility between the car and the charging.

The Aspect	Inductive Charging	Capacitive charging	Dynamic Charging
Charging Speed	Fast	Low	changeable
Distance Tolerance (cm)	1-2cm	0.5-1cm	0 – 10cm
User Experience	Standard	Basic	changeable
Efficiency (%)	71.5-81.5%	60.5-70.5%	changeable
Power Output (Watts)	4-15W	2-10W	changeable
Cost	Moderate	Low	changeable
Safety Features	Standard	Basic	Advanced

Table 1: Numerical Comparisons Between types of Contact-free charging

4.3 Dynamic Contact-free charging

Dynamic Contact-free charging is a new technology that allows electric vehicles (EVs) to be charged while they are moving. Unlike traditional charging, dynamic Contact-free charging systems place coils in the road surface while the EV is equipped with a receiver underneath. As the vehicle travels over these coils, an electromagnetic field is produced, which causes current to flow through the receiver and continuously charge the battery. This innovation may help reduce range anxiety by enabling continuous charging while traveling and reducing the need for frequent stops for charging. Even though this technology is still in its infancy, it holds the potential to be transformative electric mobility by making EVs easier and more practical for everyday use. A magnetic field produced by an alternating current flowing through embedded coils in the road allows energy to be Contact-freely sent to a receiver inside the car. In an effort to increase the sustainability and efficiency of EV travel, dynamic Contact-free charging is still in the experimental and testing stages, with pilot projects underway in cities across the globe.

6.Protection Strategies

These safeguards help ensure the security, durability, and efficiency of Contact-free charging techniques for EVs, boosting trust in the broad use of this game-changing technology. As Contact-free charging technology develops, ongoing research and development attempts to further improve and hone these safeguards.

Over voltage Protection: Over voltage protection is used to shield the EV's electrical components from damage. In order to reduce the dangers of voltage surges or spikes during the Contact-free charging process, this defence mechanism is essential.

Alignment and Positioning Controls:For effective charging, the EV must be positioned and aligned precisely over the charging pad. In order to guarantee correct alignment, systems may have sensors and controllers that halt charging if misalignment is found access and safeguard user data, implement secure authentication and permission procedures for EV charging.

Over current Protection: Use Excess current prevention devices to prevent excessive current flow when charging, which can lead to electrical issues and fires.

Automated Alignment: Use automatic alignment devices to ensure proper placement and alignment between the automobile receiver and the Contact-free charging station in order to prevent potential misalignment issues.

Authentication and Authorization: To stop unwanted access and safeguard user data, implement secure authentication and permission procedures for EV charging.

7.Coil Design

Fequency, Power, and voltage considerations dictate the topology, compensation,and magnetic coil shape in the design and optimization of magnetic linked systems, which are complicated processes. The process for a system that is magnetically connected. Coil geometry must be chosen based on the application. The mutual inductance, self-inductance, and design tolerance are all determined by coil shape. Finite Element Analysis (FEA) can be used to confirm the coil design parameters for maximum efficiency. Whe nthe designing the randomly shaped coils, the mathematical computations the parameters get increasingly complex.

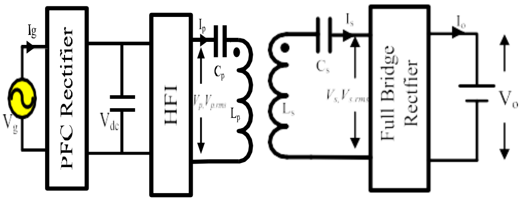

Fig 3: Diagram of the MATLAB simulation model for s-s compensation.

Finite element analysis (FEA) can be used to confirm the coil design parameters for maximum efficiency. When designing the randomly shaped coils, the mathematical calculations of the parameters get increasingly complex. Finite element analysis can be used to get around these restrictions.

For instance, in the construction of a circular coil, the inner radius of the primary coil should be lower than secondary coil inner radius, and the outside diameter of both coils should be maintained at the same level. There are two forms of coil winding: tightly wound and loosely wound. Circular flat spiral coils that are tightly wound (the breadth between coils turns less) can increase coil-transfer efficiency to a certain amount. However, too many turns will result in increased losses because of parasitic resistance, which restricts transfer efficiency[10].

In contrast to tightly wrapped coils, loosely wound coils (the width between coils rotates more) can significantly increase the coil-system transfer efficiency. Numerous scientists and scholars have provided an equation for coils.

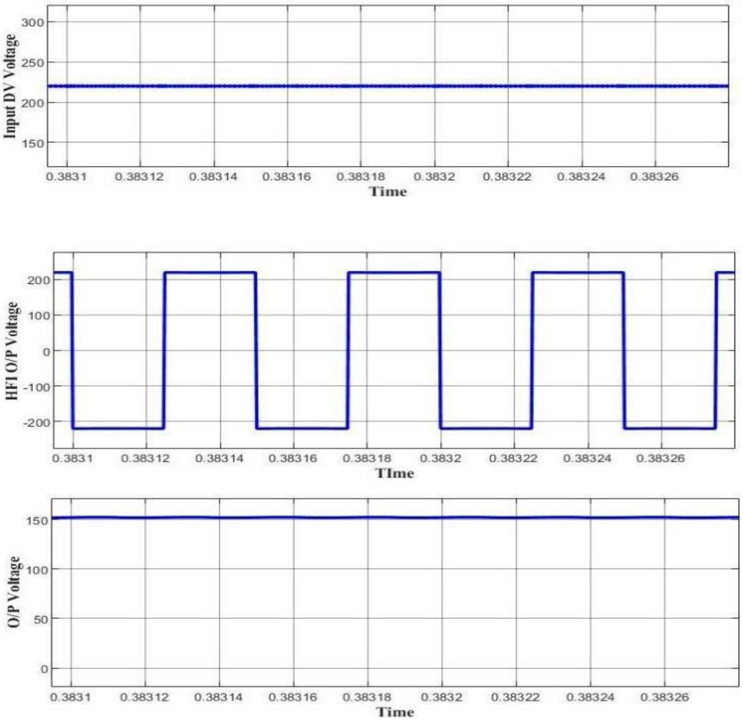

Fig 4: Waveforms of voltage from MATLAB simulation.

Parameters	Values
Power	3.6kW
Frequency	20kHz
V_o	168V
V_{prms}	220V
V_{srms}	152V
I_{prms}	16.4A
I_{srms}	24.9A
R_o	7.84Ω
L_p	24.12μH
L_s	552.80μH
C_p	114nF
C_s	262nF

Table 2 MATLAB simulation parameters.

Based on Wheeler's equation, the coil inductance for a circular coil is provided below. The circular coil design model.

$$L=N^2a^2/(8x+11y)$$

Therefore,

$$x = D_{out}/2 - D_{in}/2$$

$$y = D_{out}/4 - D_{in}/4$$

$$D_{out} = D_{in} + 2W + (T + W)(2W - 1)$$

where w is the wire's diameter, D is its outer diameter, and Din is its inner diameter, and T is the distance between turns.

The MATLAB software program was used to simulate the 3.6 kW WPT system test model with a resonance frequency of 20 kHz, taking into account the wire cross section of a circular coil area, in order to determine the SS compensation values. Simulated block diagram. We employed a direct current source for the HFI instead of using a PFC converter, in the voltage waveform simulation results for the different stages are shown. The bottom wave form displays the secondary side rectifier's output voltage, the top wave indicates the DC voltage input, while the middle wave shows the high frequency voltage. flux dispersion by FEA analysis.

The design and production process must take into account a few elements in order to create the best WPT system, as shown.

5. Conclusions:

Contact-free charging is revolutionizing the automobile sector by providing convenient substitutes such as capacitive and inductive technologies that expedite the charging procedure. By solving range concern and facilitating on-the-go replenishment, dynamic wireless charging has added practicality. The safety and dependability of these systems are guaranteed by strong protection mechanisms, such as defences against overvoltage and overcurrent. With the global adoption of environmentally friendly modes of transportation, wireless charging are crucial, and ongoing research aims to increase productivity and improve technology, moving us closer to a cleaner and more accessible future of electric mobility. Future developments in electric vehicles may be greatly impacted by wireless charging methods. A more useful and ecologically friendly transportation ecology that benefits EV users and the environment worldwide should be anticipated as the technology advances and becomes more widely available. The development and implementation of wireless charging infrastructure must continue to be a priority in our larger to create a future that is more electric and sustainable.

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