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Design and Implementation of Wireless Electric Vehicle Charging Stations and Basic Coil Design for Power Transfer

Sowmyashree N[1], Akhilesh[2], Chaitanya Y[2], Raghavendra Desai[2]
Assistant Professor, SJCE, JSS Science and Technology University, Mysore, India[1]
Students, SJCE, JSS Science and Technology University, Mysore, India[2]

Abstract: *Several factors contribute to the rising popularity of electric vehicles (EVs). This is advantageous for battling climate change and lowering air pollution. Additionally, compared to conventional petrol vehicles, electric vehicles are far more energy efficient, which may help drivers save money over time on fuel expenses. The rise in the number of electric vehicles now on the road, charging station is an essential component of infrastructure. Long-distance travel is now more practical and accessible, which enables EV owners to recharge their batteries swiftly and effectively in their cars. This paper gives a brief review about different types of electric vehicle charging stations, levels and different coil designs for wireless power transfer and also prototype of wireless EV charging to show the effectiveness of the proposed system. Simulation result of the same is obtained*

Keywords: Electric Vehicles

I. INTRODUCTION

Due to the global energy crisis, rising carbon emissions, and climate change, throughout the world, the automotive industry has seen a fundamental transformation in the way that ICE is shifted to EVs. Because oil is the main fuel used in ICE , which is a major contributor to the global environmental calamity, EVs are the best option. [1]. Therefore, electric vehicles are gaining more attention as a viable alternative to fossil fuel-powered automobiles, and they do so by utilising one-board energy storage devices. The general public's acceptance of electric vehicles is influenced by a variety of factors, including technological sophistication and perceived hazards. One of the main problems with electric vehicles is the design and installation of proper charging stations [2]. Three categories of EVs—battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs)—have been established[3]. PEV batteries are charged in charging stations that are situated in parking lots while they are in a static condition [4]. The electric vehicle charging system has recently evolved from plug-in to plug-less or wireless solutions. Wireless charging eliminates the inconvenience and hassle of plug-in systems [5]. The Wireless Power Transfer (WPT) will undoubtedly be incorporated into autonomous electric vehicles (EVs) to recharge their batteries, and as a result, it will probably take the place of the Plug-in charger after a transitional period. [6]. The field of wireless communication is familiar with a number of wireless power solutions. Understanding various methods may help you consider how you might employ them in a given field [7]. Wireless charging can be beneficial because it eliminates the need for bulky cables and connectors, making charging more convenient and easier to use. It also reduces wear and tear on charging ports and cables, which can be a significant issue with frequent use. Electric vehicle (EV) wireless charging (WC) technology may improve EV infrastructure, charging security, and convenience. The user of a wirelessly charged electric vehicle (EV) merely has to park the car and leave it there while it charges.

WC infrastructure is intrinsically safe from weather, vandalism, and electricity risks because it can be buried or constructed into the ground, completely sealed, and devoid of any outputs. EV charging stations that are strategically positioned might enable faster charging and permit more frequent charging. Infrastructure that enables EV users to "park and charge" their vehicles practically anywhere might lead to battery size reductions and lightweight EV designs. [8]. Wireless charging is especially useful for electric vehicles that have limited ground clearance, making it difficult to connect them to a traditional charging station. Wireless charging can be performed through different methods, such as magnetic induction, magnetic resonance, or radio frequency. Each technique has its benefits and drawbacks. Such as charging speed, cost, and efficiency. However, most wireless charging systems use magnetic induction technology, which is the most widely adopted and reliable method.

II. TYPES OF CHARGING STATIONS

2.1 Residential Charging Station

Building an effective charging station to meet their necessary electricity consumption seems vital given the growing number of EVs. Charging electric vehicles (EVs) at home with renewable energy sources is one approach. The best option out of all the sources that are accessible is a PV system [9]. Residential EV charging refers to the process of charging an electric vehicle (EV) at home using a home charging station or a standard electrical outlet. The vast majority of EV owners choose to charge their vehicles at home. because it is convenient, cost-effective, and allows for greater control over the charging process. To charge an EV at home, you will need to have a charging station installed in your garage or driveway. Home charging stations come in two primary categories: Level 1 and Level 2. A Level 1 charger can be plugged into a standard 120-volt electrical outlet and provides a charging rate of 2 to Range of five miles per hour of charging. An EV may be charged at a pace of up to 25 miles of range per hour using a Level 2 charger, which needs a dedicated 240-volt circuit. To install a home charging station, you will need to work with an electrician to ensure that your electrical system can handle the load and that the station is installed correctly. You may also need to obtain permits from your local government and follow building codes and regulations. In addition to home charging, EV owners can also use public charging stations or workplace charging to charge their vehicles.

2.2 Parking/Wireless Charging Station

While parking time at a public charging station and network eases stress, charging a car takes time [1]. The wireless charging system does not require any type of cable or other conductive material between the EVCS and the EV to charge the EV.

Induction charging is achieved using induction pads. The electric car will be parked above the charging station's transmitting RF pad, and the EV's receiving RF pad will pick up the gearbox at the bottom of the car.. From the transmitting RF pad to the receiving RF pad, the battery management system, and finally the battery, electricity is transported inductively. [10].

Dynamic wireless charging: Electric vehicles no longer have a range limitation, and a new idea of dynamic wireless charging is developed to make them autonomous. Dynamic charging is a very efficient and quick method. When a car equipped with charging coils is on the road, it charges. It should not stop in order to charge [11]. This technology uses a series of charging pads or coils embedded in the roadway that transmit power to the vehicle's receiving coil located in the undercarriage.

Wireless charging is preferable to wired charging due to its ease of use, safety and dependability, a lack of sparks and electric shocks, a lack of dust and contact loss, a lack of mechanical wear and associated maintenance concerns, and the capacity to withstand adverse weather conditions like rain and snow. [24].

2.3 Public Charging Station

EV owners can charge their vehicles at public EV charging stations when they are away from home. These stations can be located in a variety of places, including hotels, parking lots, public parks, and shopping malls. Level 2 or DC fast chargers, which can deliver quicker charging rates than Level 1 chargers, are frequently seen in public charging stations.

Public EV charging stations typically fall into one of two categories: Level 2 or DC fast chargers. Depending on the vehicle and the charger's capacity, level 2 chargers may charge an EV up to 25 miles of range each hour, whereas DC fast chargers can charge an EV up to 150 miles of range in 30 minutes.

To use a public electric car charging station, electric car owners must have a compatible charging cable and an account with the charging network that runs the station. Some charging stations charge a fee, while others may offer free charging to customers or visitors. Payment methods can be credit card payments, mobile payments, or membership fees. It is essential to remember that public charging stations can be congested and EV owners must wait for a charging slot to become available. Electric vehicle owners should plan ahead and consider downloading mobile apps or checking online maps to find charging stations and check their availability.

2.4 Battery Swapping System

A battery swapping system is a type of electric vehicle (EV) charging infrastructure that allows drivers to swap out their depleted battery packs for fully charged ones, rather than waiting for their battery to charge at a charging station. This is accomplished in just a few minutes by removing the vehicle's exhausted battery and swapping it out for one that is fully charged.

Battery swapping can be a more convenient option for EV drivers who are in a hurry and do not want to wait for their vehicle to charge. Additionally, it can help alleviate range anxiety, as drivers can simply swap out their battery when it is a low rather than worrying about finding a charging station.

III. EV CHARGING SYSTEM

According to the method of energy transmission, EV charging systems may be divided into three categories: conductive charging systems, inductive charging systems and capacitive charging system.

3.1 Conductive Charging

A conductive charger has to be physically connected to the electric power supply and the EV. It can be created straight from a low- to high-frequency AC converter with power factor correction (PFC) or from an AC-DC rectifier and DC-DC converters. Onboard and off board conductive chargers are the two different sorts [11]. The most common configuration is an off-board frontend rectifier with power factor correction (PFC) and a fullbridge inverter that powers the primary coil. A passive or active rectifier is coupled to the on-board secondary coil [12].

3.2 Inductive Charging

The dynamic wireless EV charging system built on the RIPT protocol consists of two physically independent coils that exchange power via alternating magnetic fields without the use of wires. Through rectification, power factor correction, and high frequency inversion circuits, the primary coil, which is positioned on the ground, is linked to the mains grid. Together, these produce high-frequency magnetic fields that are coupled to the secondary coil installed at the base of the electric vehicle (EV). This enables an automobile to wirelessly access the grid for electricity.[10].

This WPT is based on magnetic resonant inductive coupling as its central concept. The system's charging coils will firmly pair in a tuned environment if they are physically separated by an amount comparable to the coil size. As a result, the attractive coupling is able to efficiently transfer energy from the transmitter to the receiving coils during reverberation.

3.3 Capacitive Charging

The capacitive WPT type's power transmission uses direct electric fields, which eliminates the requirement for electromagnetic field shielding. The capacitive WPT type can work at higher frequencies since there are no magnetic ferrite cores, which allows for smaller and less costly devices[25]. Through capacitive coupling, which occurs when two metal plates with an insulator between them are brought close together, the energy is wirelessly transferred from the pad to the vehicle.

3.4. Types of Coil Designs

For various coil designs, the power transmission efficiency is explored Efficiency may be improved by carefully taking into account the air gap length, operating frequency, permissible coil designs, and coil characteristics. There are five different coil designs available: circular, rectangular, double-D, double-D quadrature (DDQ), and bipolar. The DDQ design is the most effective for maximising power transmission efficiency, however the structure is complicated because more wires are utilised in this configuration [13].

A) Circular Coil Design

A wireless power transfer system's coil, which transforms energy between its electric and magnetic forms, is a crucial component. Additionally, the poor productivity in the recruitment sector points to a decline in the effectiveness of the overall framework. [14] The curl cushion plan of IPT framework is troublesome and complex on the grounds that oneself and shared inductance of loop cushion are elements of many variables, for example, vertical distance between loop cushions, curl calculation, number of turns, loop cushion misalignment, ferromagnetic material thus on[15]. Due to its compact design, a planar circular coil shape is chosen for the majority of WPT applications [16]. The wire thickness (t), inner diameter (din), outer diameter (dout), number of turns (N), and space between turns (s) are the parameters that define the geometry of the coil. Circular coils work well in stationary wireless charging systems where multi-objective optimisation techniques may be used to maximise coil performance. When compared to alternative single-coil designs, the circular pad exhibits the strongest magnetic coupling and magnetic field for any number of turns [18][19].

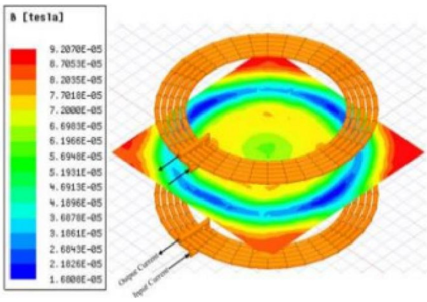

Fig 1: Circular Circular Coil Design [16]

B) Rectangular Coil Design

Another fundamental coil design for wireless charging is the rectangular pad (RP). It is reasonable in unique charging because of its expense adequacy. In addition, RP is popular due to its power transfer capability and reasonable material costs[21] For high longitudinal misalignment tolerance and efficient space utilisation on the vehicle, the most common dynamic wireless power transmission architecture is rectangular, as shown in Figure[16]. In terms of cost-effectiveness, rectangular coils are preferred over circular and hexagonal patterns [15]. Moreover, rectangular pads transmit the most power possible across a small area with the material allowance that is offered. The coupling coefficient doesn't vary much as the distance between coils grows. However, the rectangular-rectangular coil's centre displays the lowest power, while the coil's bottom nearly lost half of its leakage flux.

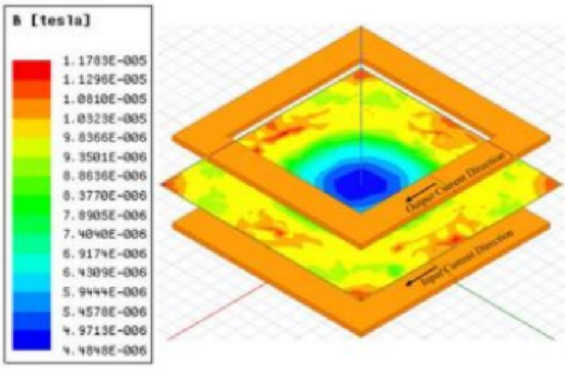

Fig 2: Rectangular rectangular coil design [16]

C) Coreless Double-D Coil (DDC)

Double-D coil (DDC), in addition to circular and rectangular pads, is one of the most well-liked designs for wireless EV charging. This is because of a superior presentation and it interoperability with various optional geographies[21]Figure exhibits the DDC with ferrite bars and shows the standard shape of a coreless double-D coil (DDC). For a clearer understanding, the DDC geometry is like two equal rectangular [15].

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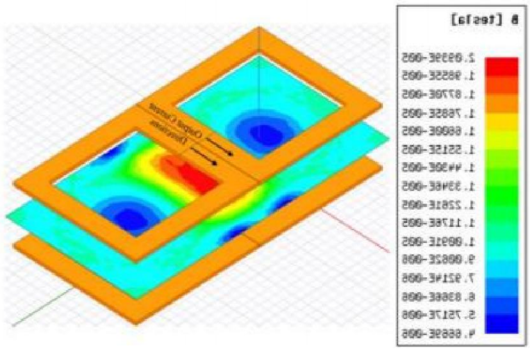

Fig 3: DD DD coil design [16]

D) Double-D Quadrature – Double-D Quadrature Coil Designs (DDQ-DDQ)

The quadrature coil is added to the DD design to create DDQ, allowing for the coupling of both horizontal and vertical flux [21]. The DDQ pad has double the flux height of a circular coil because it combines two windings. DDQ has preferable execution over DD with various optional geographies and is usually utilized in auxiliary. The DDQ cushion has a stronger resistance to misalignment, but as there are more loops, there is an increased cost and need for space. The proficiency is the most impressive among all loop designs, and the connection is the highest according to the reenactment results[16]. For instance, the transmitting and receiving coils of the DDP-DDQP system, which are five times bigger than those of the traditional CP-CP system[22], can be used to expand the charging zone.

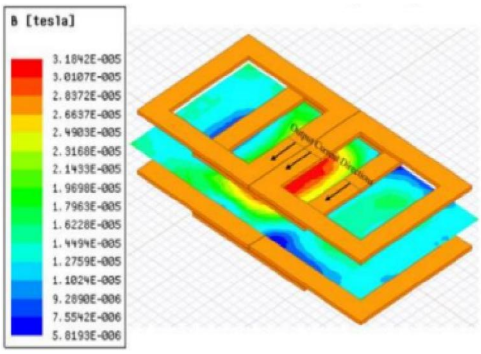

Fig 4:DDQ-DDQ coil design [16]

IV. SYSTEM MODELLING

Wireless EV charging simulation entails modelling and analysing of the wireless charging process for electric vehicles (EVs).

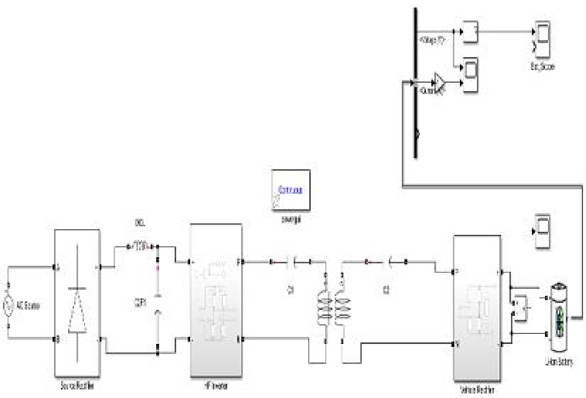

Fig 5: Circuit which depicts Wireless EV charging configuration

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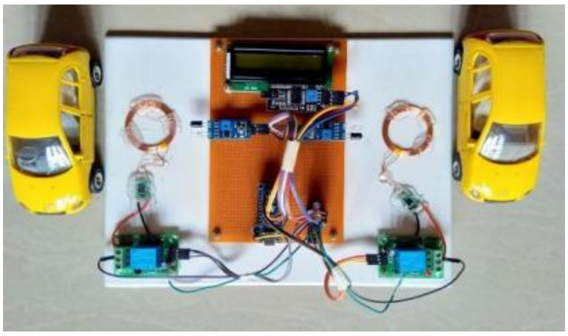
Fig 6: Output voltage of the rectifier

The simulation shows that the wireless charging system is capable of rectifying 230V AC to 5V DC. This Indicates that the wireless charging system is capable of transferring power over a istance of 2-10mm.

4.1 Experimental Setup



Electromagnetic induction is a mechanism that wireless charging stations utilise to transfer power from the charging station to a device without the usage of wires. When an electric current passes through a coil of wire within the charging station, an electromagnetic field is created. When an object with a suitable receiver coil is placed within an electromagnetic field, the energy is picked up by the coil and transformed back into electrical power to recharge the battery. Here, the proposed system provides a method for the ideal alignment for wireless charging an electric vehicle. A Wireless EV model with line follower functionality was prepared. The two coils, often known as the transmitting and receiving coils, are the primary coil and secondary coil. Under the road is the primary coil, and the underside of the car is the secondary coil. This variant uses infrared sensors to find the vehicle and then sends a signal to an Arduino nano. In this scenario, the Arduino acts as the brain and sends the command to the relay control to turn ON and OFF. The IR sensor sends a correction signal to the Arduino if the automobile deviates from the path's range. The relay is then instructed to switch off using Arduino. Relay turns on when a vehicle enters the range of an IR sensor, at which point the car is charged via electromagnetic induction. A possible method to improve the charging experience for EV owners combines the REES52 IR infrared obstacle avoidance sensor, LCD display, Arduino Nano, singlechannel relay, and PCBA coil transmitter module. The wireless transmission of electrical power from a transmitter coil to a receiver coil is made possible by a coil transmitter module, also referred to as a wireless power transmitter or wireless charging module. It functions according to the electromagnetic induction principle, where a shifting magnetic field causes an electric current to be induced in a nearby coil. A transmitter coil, a power management circuit, and a control circuit normally make up a coil transmitter module. When an alternating current (AC) is transmitted through the transmitter coil, it creates an alternating magnetic field. The power transfer medium is this magnetic field. While the control circuit oversees the module's general operation and safety features, the power management circuit makes sure that power conversion is efficient and controls the output voltage and current. The power generating stage and the power transfer stage are the two main phases that make up a coil transmitter module's operation. The transmitter coil, which creates an oscillating magnetic field, is coupled to an AC power supply during the power generating stage. The receiver coil, which is frequently built into a different device or module, is placed close to the transmitter coil during the power transfer stage. Through electromagnetic induction, the changing magnetic field causes the receiver coil to produce an alternating current. The device is then charged or its components are powered using this rectified current.

V. CONCLUSION

This paper gives an extensive investigation of various EV charging systems and types of coil designs, featuring their qualities, benefits, and impediments. AC and DC charging systems, as well as wireless charging technologies, were all examined in the study. Additionally growing in popularity are wireless charging stations, which offer a practical and effective charging option. For wireless EV charging stations, there are several sorts of coil designs, each having pros and cons. With one coil on the ground and another in the undercarriage of the vehicle, the static charging pad arrangement is the most basic and popular. This design is appropriate for low-power charging and is simple to install and maintain. On the other side, dynamic charging pad designs employ numerous coils to provide a magnetic field that travels with the car. This offers an easy and effective charging option for electric buses and trucks by enabling continuous charging even while the vehicle is moving. However, installing and maintaining this architecture is more difficult and expensive.

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