VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JnanaSangama, Belagavi – 590018

A Mini Project Report on

" WIRELESS CHARGING FOR ELECTRIC VEHICLES WHILE DRIVING "

Submitted in partial fulfilment of the requirement for the award of degree of

BACHELOR OF ENGINEERING
IN
ELECTRONICS AND COMMUNICATION ENGINEERING

Submitted by

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DEPT OF ELECTRONICS &COMMUNICATIONENGINEERING

RAJARAJESWARI COLLEGE OF ENGINEERING

[Accredited by NBA & NAAC, Affiliated to VTU, Belagavi, Approved by AICTE,New Delhi]

#14, Ramohalli Cross, Mysore Road, Kumbalagodu, Bengaluru-74

2023-2024

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CERTIFICATE

This is to certified that the project work entitled **" WIRELESS CHARGING FOR ELECTRIC VEHICLES WHILE DRIVING "** is a bonafide work carried out by **HARSHA M [1RR21EC025], J N MOHIT [1RR21EC029], KUSHIPRIYA Y H [1RR21EC036], NIKITHA S [1RR21EC054]** in partial fulfilment for the award of **Bachelor of Engineering in Electronics and Communication Engineering** of the **Visvesvaraya Technological University**, **Belagavi** during the year 2023-2024. It is certified that all corrections & suggestions indicated for internal assessment have been incorporated in the report & deposited in the departmental library. The project report has been approved as it satisfies the academic requirements.

Signature of the Guide	Signature of the HOD	Signature of the Principal
Dr. Deepika J	**Dr. L. Rangaiah**	**Dr. R. Balakrishna**

DECLARATION

We, HARSHA M (1R R21EC025), J N MOHIT (1RR21EC029), KUSHIPRIYA Y H (1RR21EC036), NIKITHA S (1RR21EC054) students of 6th semester B.E in Electronics and Communication Engineering, **RajaRajeswari College of Engineering, Bengaluru** hereby declare that the project work entitled **"WIRELESS CHARGING FOR ELECTRIC VEHICLES WHILE DRIVING"** submitted to the **Visvesvaraya Technological University** during the academic year 2023-24, is a record of an original work done by us, under the guidance of Dr. DEEPIKA J, Associate Professor, Electronics & Communication Engineering, RajaRajeswari College of Engineering, Bengaluru. This project work is submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Engineering in Electronics & Communication Engineering. The results embodied in this have not been submitted to any other University or Institute for the award of any degree.

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ABSTRACT

This Project explores the benefits, technical aspects, and challenges of wireless charging for Electric vehicles. By integrating this technology into existing road networks, the system aims to address the limitations of traditional stationary charging stations, such as range anxiety and charging infrastructure availability. The proposed system, including increased driving range, reduced carbon emissions, and improved convenience for electric vehicle users. The wireless moving vehicle charging system presents a promising solution to promote the widespread adoption of electric vehicles and advance sustainable transportation initiatives. This Project aims to provide a comprehensive overview of wireless charging for EVs, highlighting its promise and potential to shape the future of transportation. Our goal is to provide a comprehensive understanding of wireless charging technology and its potential to transform the EV charging landscape, enabling widespread adoption of sustainable transportation solutions.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Motors made the world's first electric vehicle during 1996. But, with the initiation of Chevrolet and Nissan, manufacturers of EV have started a magnificent journey through the technology, and the acceptance of users for it causes no harm to the environment. Also, stepping into EV is considered as to take a significant step towards protecting the environment, enhancing transportation durability and diminishing fuel dependency. With this great advantage, many automobile manufacturers have started to make immense investments to bring improvement of the electric vehicles.

The world is witnessing a significant shift towards sustainable transportation, with Electric Vehicles (EVs) at the forefront of this revolution. The traditional plug-in charging method can be a barrier to widespread adoption, due to concerns around convenience, safety, and accessibility. Wireless charging technology has emerged as a solution to these challenges, offering a seamless and efficient charging experience for EVs. By leveraging electromagnetic fields to transfer energy between a transmitter and receiver.

Wireless charging enables EVs to recharge without the need for cables or plugs. This technology has the potential to revolutionize the EV industry, enhancing user experience, reducing range anxiety, and paving the way for a more sustainable transportation future.

The current development in this sector by the automobile companies and the research institutes show that within the next ten to twenty years charge while driving (CWD) infrastructure can be stationed for widespread use. That is why many companies have been looking at ways to not only extend the range of EVs by wireless charging but also to make the charging process seamlessly automatic

1.2 MOTIVATION OF THE PROJECT

The motivation for developing wireless charging for electric vehicles (EVs) in motion is Wireless charging on the move can significantly extend the driving range of EVs, reducing the need for large .

Seamless and less dependent on user action. Vehicles can charge while in use, reducing downtime spent at charging stations and increasing overall efficiency. It Reduces the demand on stationary charging infrastructure, potentially lowering the need for widespread, high-capacity charging stations. Supports the transition to renewable energy by integrating charging into everyday infrastructure, making the use of EVs more practical and widespread. Reduces the long-term costs associated with EV maintenance and battery replacements, as well as potential savings from lower energy costs. Promotes technological advancement and positions early adopters as leaders in the growing market for electric mobility solutions.

1.3 PROBLEM STATEMENT

The adoption of electric vehicles (EVs) is rising rapidly due to their environmental benefits and technological advancements. However, one significant challenge facing the widespread adoption of EVs is the limitation of battery range and the need for frequent recharging. While stationary wireless charging technologies have been developed, they typically require the vehicle to be stationary, which can be inconvenient and time-consuming.Developing an efficient and practical wireless charging system for electric vehicles while they are in motion remains a complex and unsolved problem. The main issues include maintaining a consistent and reliable power transfer as the vehicle moves, ensuring safety, and minimizing energy loss. Current stationary wireless charging systems use inductive coupling to transfer energy from a ground-basedcharging pad to a vehicle-mounted receiver. However, adapting this technology for dynamic, moving vehicles introduces new technical challenges.

1.4 OBJECTIVES OF THE PROJECT

- Maintaining precise alignment between the vehicle's charging receiver and the charging infrastructure as the vehicle moves.
- Adapting the power transfer system to handle variations in vehicle speed, load, and battery state-of-charge.
- Modifying existing road infrastructure to incorporate wireless charging lanes or embedded charging systems.
- Addressing potential electromagnetic interference with other devices

CHAPTER 2

LITERATURE SURVEY

2.1 OVERVIEW OF LITERATURE SURVEY

Literature survey is very important to get a knowledge on desired topic. By using the information provided in the several literatures give credit to other researchers to prevent duplication. By surveying the several literatures, we can identify in constancies like gaps in research, conflicts in previous studies, open question left from other research. We referred some of the scholars to know some of the information about the project. The scholars which we have referred is listed below.

2.2 BASE PAPERS:

[1] A new wireless charging system for electric vehicles using two receiver coils –
Naoui Mohamed , Mohammed Alqarni , Basem Alamri , Ziad M. Ali.

Usually, electric vehicle systems are based on various modules that should ensure the high power and stability of the vehicle on the track. The majority of these components are linked to the charging mechanism. In this regard, dynamic wireless power transfer is a practical method to solve electric vehicle range anxiety and reduce the cost of onboard batteries. Wireless recharging has long been common with pure electric vehicles and is designed to allow charging even when the vehicle is in motion. However, it is difficult to analyze this method since its operating philosophy is complex, particularly with the existence of several variables and parameters. Also, the state of the vehicle, whether it is in motion or not, defines several parameters such as the vehicle speed as well as the sizes and dimensions of the coil receivers. This paper presents a novel method to improve the performance of the dynamic wireless recharge system. In the proposed system, receiver coils have been added to maximize charging power by offering a dynamic mathematical model that can describe and measure source-to- vehicle power transmission even though it is in motion. In the proposed mathematical model, all physical parameters describing the model were presented and discussed. The results showed the effectiveness of the proposed model. Also, the experimental tests confirmed the validity of the simulation results obtained by providing two coil receivers under the vehicle.

[2] Wireless Charging of Electric Vehicle While Driving

- Norbahiah Misran , (Senior Member, IEEE), and Mohammad Tariqul Islam .

Static wireless charging is becoming popular all over the world to charge the electric vehicle (EV). But an EV cannot go too far with a full charge. It will need more batteries to increase its range. Dynamic wireless charging is introduced to EVs to capitally increase their driving range and get rid of heavy batteries. Some modern EVs are getting off this situation. But with Dynamic WPT the need of plug-in charge and static WPT will be removed gradually and the total run of an EV can be limitless. If we charge an EV while it is driven, we do not need to stop or think for charging it again. Eventually, in the future the batteries can be also removed from EVs by applying this method in everywhere. Wireless charging needs two kinds of coils named the transmitter coil and the receiver coil. The receiver coil will collect power from the transmitter coil while going over it in the means of mutual induction. But the variation of distance between two adjacent coils affects the wireless power transfer (WPT). To see the variation in WPT, a system of two Archimedean coils of copper is designed and simulated for vertical and horizontal misalignment in Ansys Maxwell simulation software. The transfer power for 150 mm air gap is 3.74 kW and transfer efficiency are gained up to 92.4%. The charging time is around 1 hour and 39 minutes to fully charge its battery from 0 state for a 150mm air gap for an EV with 6.1 kW power may take. Also, a charging lane is designed for dynamic charging. Then the power transfer is calculated from mutual inductance when the EV is driven on a charging lane. From the load power, it can be calculated how further an EV can go with this extra power.

[3] Simultaneous Wireless Power and Data Transfer for Electric Vehicle Charging –
Michela Diana , Mojtaba Khalilian , Paul antonie.

Wireless charging of Electric Vehicles (EVs) has become an important research topic in recent years. During the wireless charging process, wireless data exchange must take place between the EV and the charging station. Battery status, current and voltage of the charger or the EV identification may be required on the primary side in order for the system to operate properly. This data exchange can be carried out through commercial wireless communication solutions such as Bluetooth, or Zig Bee. However, these technologies introduce cyber security problems, high and variable transmission delays and possible connection losses during communication. To address these issues, numerous solutions have been proposed based on wireless data transmission through the wireless power transfer circuit. This paper gives a comprehensive review of the different issues that need to be considered for simultaneous wireless power and data transmission (SWPDT) for wireless EV charging applications. This context represents a challenge for SWPDT due to the power levels and the high probability of operating with notable misalignments or even with the EV on move. Specifically, a classification of SWPDT systems is described, and six different criteria to consider when designing a SWPDT system are analysed for EVs. The suitability of different system configurations is evaluated according to three representative use cases: (i) providing maximum efficiency, (ii) synchronisation for bidirectional wireless chargers and (iii) dynamic charging. We have also analysed the feasibility of using the Open Charge Point Protocol (OCPP) together with ISO 15118, which is the most popular communication protocol used in EV charging infrastructures.

[4] A Coil Detection System for Dynamic Wireless Charging of Electric Vehicle

- Devendra Patil, John Miller, Babak Fahimi, T. Balsara, Veda Galigerkere

Application of wireless power transfer while EV is in motion can significantly reduce the battery storage capacity. A major challenge in implementation of dynamic wireless power transfer (DWPT) is automatic detection of EV to avoid loss in efficiency and alleviate any safety concerns. This paper proposes a novel coil detection method for segmented DWPT. Detection of the EV ahead of its arrival will initiate energizing of the transmitter buried inside the road to enable just-in-time transfer of power. At low speeds, communication can be a reliable method to power up the transmitter coil. However, at high speeds on highways, communication latency time for the detection of an EV is long and hence impractical. This paper proposes a low cost and low power EV detection system based on a novel orthogonal coil arrangement to detect EVs traveling at high speeds. The proposed detection system was tested on a laboratory scale prototype for verification purpose. For high speed verification, simulation in PLECS was conducted to test the functionality of the proposed system.

[5] Wireless Charging of Electric Vehicle

- Dr. S. S. Kadlag1 , Choure Mayuri Arunrao , Gaikwad Kaveri Kailas , Kolkar Ankita Aniruddha , Pawar Smita

As the configuration used for the Mobile Ad hoc Networks (MANET) does not have a fixed infrastructure as well, the mechanism varies for each MANET. The path is tested for the warm hole attack, as the node is detected the data packet sent in between the source and destination selects the path from the multi-paths available and the packet delivery is improved. The packet delivery ratio (PDR) is calculated for the proposed mechanism, and the results have improved the PDR by 71.25%, throughput by 74.09 kbps, and the E-to-E delay is decreased by 57.92ms for the network of 125 nodes.

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CHAPTER 3

WIRELESS CHARGING TECHNOLOGY

Wireless charging technology, also known as inductive charging, allows for the transfer of electrical energy from a power source to a device without the need for physical connectors or cables. This technology is widely used in various applications, from charging consumer electronics like smartphones and electric toothbrushes to more advanced uses such as charging electric vehicles (EVs) and medical implants. Utilizing electromagnetic fields, it simplifies the charging process by eliminating cables and plugs, offering convenience and reducing wear on connectors. The most common method, where a transmitter coil generates an alternating magnetic field that induces a current in a receiver coil, which then charges the device. Enhances efficiency over greater distances and allows for some misalignment by tuning both coils to resonate at the same frequency. Uses electric fields between conductive plates to transfer energy, though less common than inductive methods. Widely used for smartphones, smart watches, and other small devices.

Emerging applications include stationary charging pads and dynamic systems that charge EVs while in motion. Enables charging of implants and medical equipment without invasive procedures. Eliminates the need for physical connectors, Reduces wear on charging ports, Minimizes risks associated with exposed connectors. Typically less efficient than wired connections, with potential energy loss. Requires precise alignment between transmitter and receiver. Infrastructure for dynamic and large-scale applications can be expensive.

Ongoing research aims to enhance performance and reduce energy loss. Efforts to establish unified standards for compatibility across devices. Combining wireless charging with green energy sources to promote sustainability. Wireless charging technology continues to advance, offering new opportunities and applications while addressing existing challenges to enhance convenience and efficiency.

3.1 THE BASIC

3.1.1 Inductive Coupling

Basic Principle: Uses electromagnetic fields to transfer energy between two coils: a transmitter coil (in the charging station) and a receiver coil (in the device).

Operation: Alternating current (AC) flows through the transmitter coil, creating a magnetic field. This magnetic field induces an alternating current in the receiver coil, which is then converted to direct current (DC) to charge the device's battery.

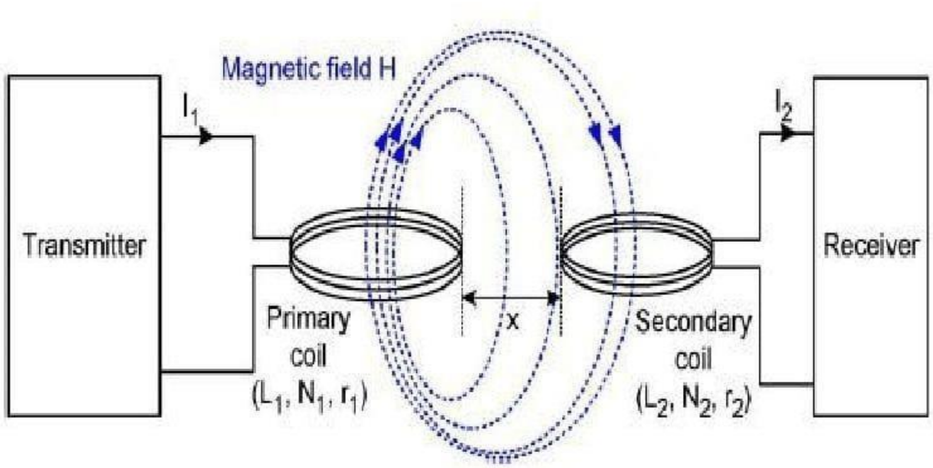

Fig: 3.1 inductive coupling

3.1.2Resonant Inductive Coupling

Advanced Principle: Similar to inductive coupling but uses resonant circuits to improve efficiency over larger distances and varying alignments.

Operation: Both the transmitter and receiver coils are tuned to the same resonant frequency, enhancing energy transfer efficiency and allowing for greater distances between the coils compared to standard inductive coupling.

3.13Capacitive Coupling

Basic Principle: Uses electric fields between conductive plates to transfer energy.

Operation: Alternating voltage creates an electric field between plates in the charging station and the device, which induces a current in the receiver plates.

3.11.1 Magnetic Resonance

Advanced Principle: Uses resonant magnetic fields for more flexible power transfer.

Operation: The system employs resonant circuits that allow for energy transfer over greater distances and misalignments compared to inductive coupling. This method is less common but offers advantages for dynamic applications like EV charging on the move.

3.1.4 Types of Wireless Charging Technologies

3.1.5 Contact-Based Wireless Charging

Features: Requires close proximity or slight contact between the transmitter and receiver coils.

Applications: Common in smartphones, tablets, and other small consumer electronics.

3.1.6 Non-Contact Wireless Charging

Features: Can operate over short distances without physical contact between the coils.

Applications: Emerging applications include electric vehicles, where systems can be designed to charge the vehicle while it is parked or even in motion.

3.1.7 electric Vehicles (EVs)

Stationary Charging: Allows for charging EVs when parked, typically via a charging pad embedded in the ground.

Dynamic Charging: An emerging technology that aims to charge EVs while they are in motion through embedded charging lanes or pads.

CHAPTER 4

Wireless battery charging for Electric Vehicles

The wireless solution represents an ever-growing method of battery charging in several applications. The lack of wires is desirable whenever the power cable is inconvenient or even impossible to use. Wireless battery charging can be employed in different applications, ranging from the ultra-low power levels of the wireless sensors to the ultra-high power levels of the Railway Applications and passing through the following examples: electrical toothbrush, mobile phone, laptop, television, electric bicycle, electric car, electric bus.

4.1 Wireless charging for low-power applications

The wireless battery charging for low-power devices ranges from ultra-low power applications such as wireless sensors or implantable devices, to consumer electronic devices, such as smartphones or notebooks. The ultra-low power devices range from µW tomW power levels, whereas the power levels of the consumer electronic devices range fromsome W (e.g. mobile phones) to tens of W (e.g. laptops).

4.1.1 Wireless Sensor Networks and biomedical applications

In Wireless Sensor Networks (WSN) the use of wires for the power supplying is generally impossible, since the wireless sensors are inherently hard to reach from the human beings, like in meteorological data collecting or military applications. In similar applications, the wireless solution represents the best option for both communications and power supplying.

The following method of wireless battery charging for nodes of a WSN is proposed:
a wireless charging vehicle (WCV) travels along a planned path inside the network and recharges the sensors, through an inductive power transfer link. In a power transfer inductive link is proposed to supply the batteries of the WSN nodes. The distance between the inductive coils is in the range (1÷10) mm.
The use of the environmental energy harvesting in order to supply the sensors can be considered as a form of wireless battery charging: the batteries and the super capacitors of sensor nodes are respectively supplied by radio-frequency waves and solar power. Wireless power transfer is also convenient in biomedical applications for the supply of implantable devices. In several examples of wireless battery charging systems for implanted devices are proposed and investigated.

4.1.2 Consumer electronic devices and household appliances

The following range of power levels is represented by the electronic consumer devices, such as mobile phones and notebooks. For these applications, the power level range from some W to tens of W. The wireless battery charging for mobile phones is fully commercialized and standardized. This wireless charging is based on the Inductive Power Transfer (IPT) between two coupled coils: one of them is placed inside a pad and connected to the electrical grid, the other one is placed inside the device and connected to the electric battery. By positioning the mobile device upon the pad, the charging operation automatically starts through magnetic induction. A standard has been created by Wireless Power Consortium (WPC) to build a common platform that helps the compatibility between wireless charging stations and mobile devices. More than 200 companies have joined WPC . One of the most attractive benefits brought by wireless battery charging for consumer electronics is the opportunity to simultaneously charge different devices on the same pad.

Fig 4.1 : Different device charging wireless

4.2Wireless charging for Electric Vehicles

If compared to the consumer electronic devices, the electric vehicles (EV) charging occurs at notably higher power levels, ranging from a few hundreds of W (as in the case of the E-bike) to several tens of kW (as in the case of the electric buses). The Wireless Electric Vehicle Charging (WEVC) is still far from a full commercialization and standardization.

Nevertheless, being implemented through Inductive Power Transfer (IPT) between two coupled coils, it provides benefits in terms of safety and comfort to all the users.

The EVs can be recharged or supplied by IPT exploiting mainly three alternative options static wireless charging, quasi-dynamic or dynamic wireless charging. The static IPT consists of the EV charging whenever the vehicle is stationary and nobody stays inside it, e.g. in the case of a parked car. In the quasi-dynamic IPT, the recharge occurs when the electric vehicle is stationary but someone is inside it, e.g. in the case of a cab at the traffic light intersections or a bus at the stop. The dynamic IPT consists in supplying the vehicle during its motion, e.g. in the case of a car running on a highway or of a moving train. An overview on research and applications about IPT-based wireless charging for some electric means of transportation will be given in the following.

4.1.3 IPT for E-bike

The Electric Bicycles (E-bikes) are light and compact vehicles, representing a potentially consistent category of transportation means in the current and future scenarios of a smart and green urban mobility. Due to the generally frequent necessity of using E- bikes during a day and therefore recharging them, the wireless solution may be considered the most appropriate way of E-bike charging. E-bike wireless charging is based on IPT. Academic researchers and commercial operators have proposed different solutions, as far as the position of the coupled coils is concerned. For all the proposed solutions, the E-bike is supposed to be parked in order to have the charging operation. On the academic side, an investigation about different coupling solutions is carried out, all of them consisting of a magnetic coupler made of a transmitter buried underground and a receiver installed inside the bicycle kickstand. Different cases of kickstand are investigated as well. The distance between transmitter and receiver of the magnetic coupler is 2 cm. the bicycle coil is placed on the side of the front basket and the grid connected coil is installed next to a wall, both in a vertical position, The wireless charging operation occurs at a 5 cm distance between the coils.

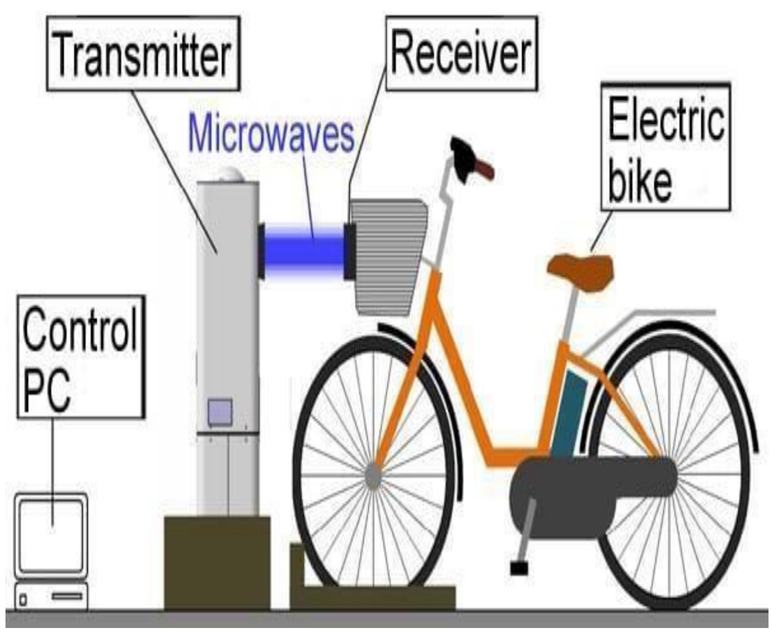

Fig 4.2: IPT for E-bike

4.1.4 IPT for electric car

Implemented through Inductive Power Transfer, the wireless charging for car drivers is convenient as far as safety and comfort are concerned: the user should not be worried about handling power cords, thus avoiding the electrocution risk, and could park the car in proper spaces, so that the charging operation can automatically start. The coils are generally placed in the following way: the one connected to the grid is placed on the ground and the other one, connected to the battery, is placed in the bottom of the vehicle chassis,

The minimum power level for electric car charging is generally 3 kW. Different examples of commercial wireless charging stations for electric cars can be provided, since the EV companies are increasingly interested to this innovative charging technology. Among the car manufacturers, Toyota, Nissan, General Motors and Ford are some of the companies showing interest in the inductive charging method. Among the companies producing wireless charging systems for EVs, Evatran and HaloIPT are leaders in providing and improving the inductive charging technology. Evatran has created the inducive charging system Plug less Power. HaloIPT, one of which images of the inductive charger, has been acquired by Qualcomm. The opportunity of a fast charging would make the IPT more attractive for EVs.

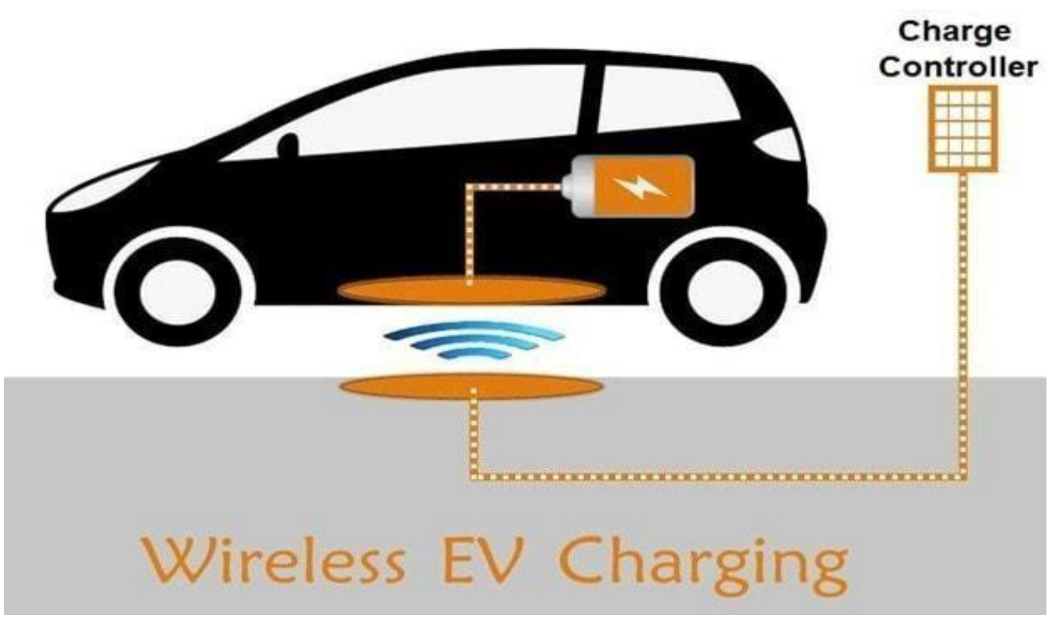

Fig 4.3: wireless EV charging

Furthermore, the scientific research is ever more focused on the investigation of different aspects related to the IPT for wireless electric car charging, which are reported in other scientific work that will be cited in the following of the thesis. In the realistic scenario of an ever-growing use of EVs, one the most interesting challenges is represented by the possibility of an "on-the-road" charging, meaning that the battery can be recharged while the car is used.

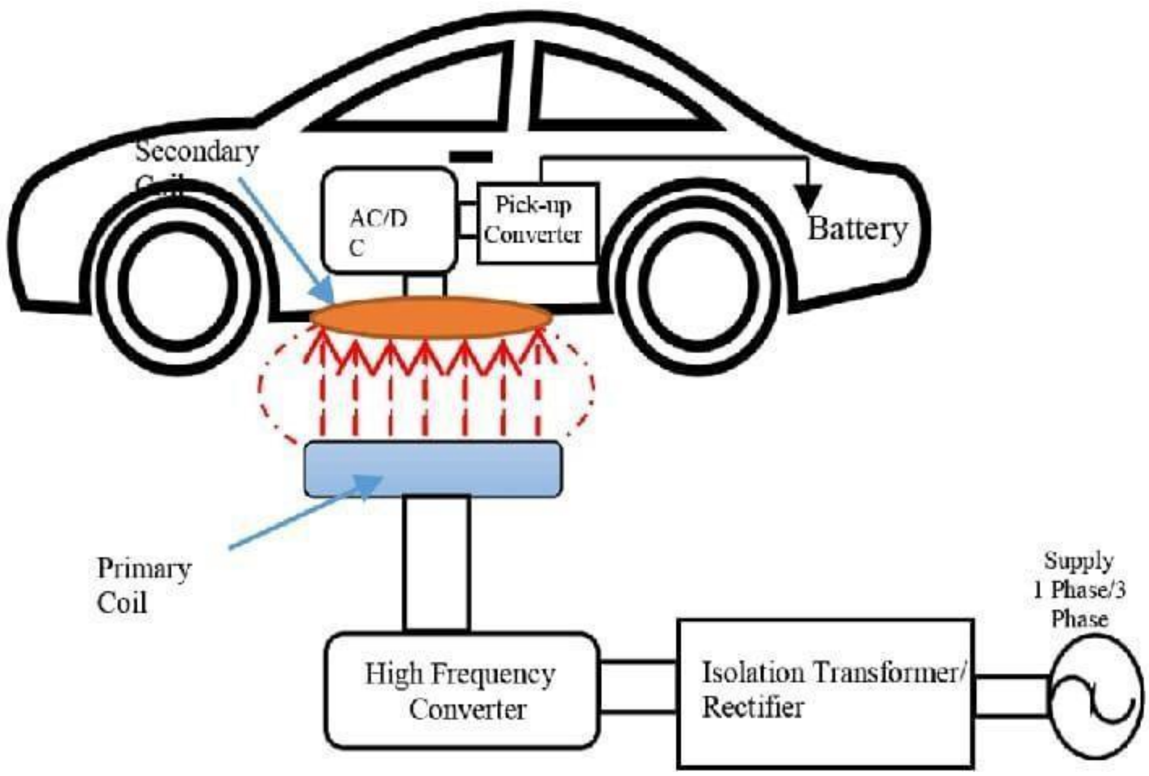

Fig 4.4: IPT for electric car

The quasi-dynamic and the dynamic IPT represent an actual solution for the driving range extension of EVs. Different works are reported on this. The opportunity of an inductive charging during the motion of the vehicle on highways is investigated, in the dynamic charging a track is present inside the road, consisting of multiple transmitting coils, thus allowing the power transfer towards the receiving coil that is inside the car, whenever the receiving coil is aligned, during the motion, to any of the road coils.

The inductive coupling between the electrical grid and the EV can be also exploited for a reverse power flow, that is from the vehicle to the grid. By exploiting reversible power electronics stages, the power is able to flow from the grid to the rechargeable battery and from the battery to the grid, according to the Vehicle-to-grid (V2G) idea. V2G is a wide- spread concept, belonging to the up-to-date idea of the active demand: in a smart electrical network, the consumer is able to become producer of energy.

In the case of a surplus of energy stored in some devices of the grid, the power can flow towards other devices requiring energy. The wireless power transfer can represent a support to V2G, and therefore be a Bi-Directional Inductive Power Transfer (BDIPT).

Several works are reported in the scientific literature regarding BDIPT .

4.2 The IPT: system description

A typical schematic of an Inductive Power Transfer system is shown. The DC-DC stage is highlighted in the figure. For battery charging applications, the electrical power flows from the DC-link to the battery.

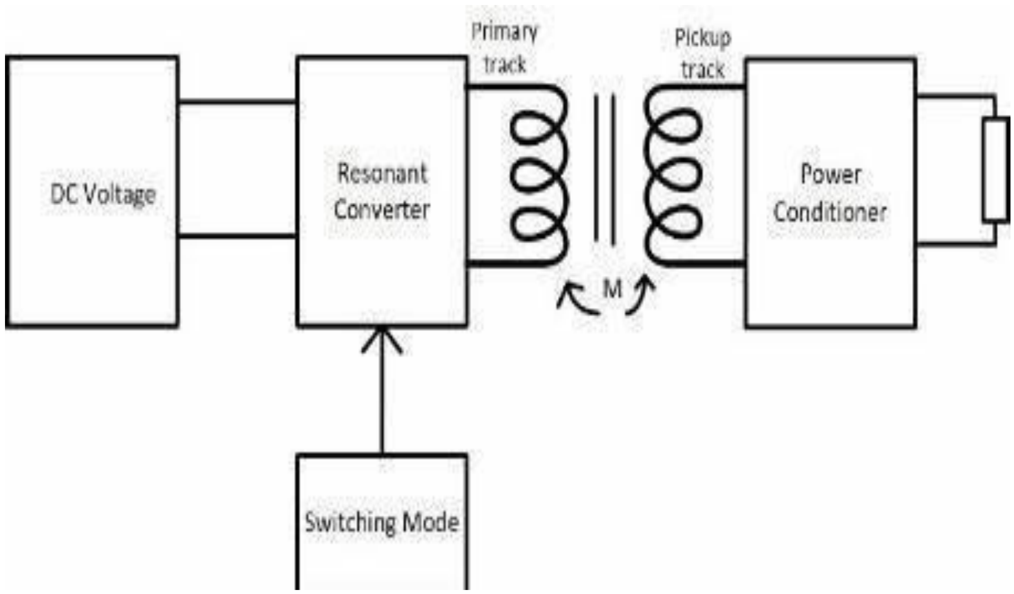

Fig 4.5: IPT schematic

The inductive power transfer occurs between two magnetically coupled coils. Their self-inductances are L1 and L2; the mutual inductance is M. L1 and L2 correspond respectively to the primary and the secondary coil. The primary-side DC voltage source is connected to the electrical grid; the secondary-side DC section is the load representing the battery to be charged. Since the power transfer between the coupled coils is in AC, two intermediate stages are needed: a DC-AC in the primary side and an AC-DC in the secondary side.

Since the coils are loosely coupled, a reactive network is needed in order to maximize the power transfer efficiency and to optimize the power factor, if the system works at the resonance. This reactive network is named compensation circuit and includes two capacitors, one for each side. In the example of the figure, both the compensation capacitors C1 and C2 are connected in series with the primary and the secondary coils.

4.2.1 Compensation network

A reactive network is required in order to maximize the power transfer efficiency towards the load and the power factor towards the source. Since the reactive elements needing to be compensated are the coupled inductors, the compensation elements are capacitors. According to the capacitor connected to the primary coil is the primary capacitor C1, whereas the capacitor connected to the secondary coil is the secondary capacitor C2. According to the type of connection between the coils and their compensation capacitors, four different compensation topologies are possible: series-series(SS), series-parallel (SP), parallel-series (PS) and parallel-parallel (PP). For each of these four solutions, the first word (letter) refers to the primary side, whereas the second word (letter) refers to the secondary side. Choosing a specific topology rather than another one depends on the specific application.

The SS choice allows to select the compensation capacitances depending only on the self-inductances, no matter what the load and the magnetic coupling are. Therefore, in case of misalignments between the coil, the system keeps working under resonance in spite of the mutual inductance variations. For these reasons, the SS topology turns out to be convenient for EV battery charging. Indeed, in IPT charging of vehicles, the perfect alignment between the coils just represents an ideal case and even small misalignments are unavoidable.

4.2.2 Rechargeable battery

Nowadays the lithium ion batteries represent the most widespread typology of battery, due to their high energy densities and long life-times. The lithium ion batteries well fit with several applications: portable electronics, electric vehicles, space .

aircraft power systems , stationary power storage. Among the lithium ion batteries, the Lithium Iron Phosphate (LiFePO4) ones represent an increasing option in the market, particularly for the EVs. LiFePO4 batteries feature high capacity and good stability on chemical and thermal characteristics.

In order to optimize the use of the batteries, a detailed battery model is often required. In a complete dynamic model of Li-ion batteries, including nonlinear equilibrium potentials, temperature-dependencies, thermal effects and response to transient power demand, is proposed. The model, validated through experimental tests, is useful for the optimization of the battery runtime. In, a dynamic model of a LiFePO4 battery is proposed, with particular consideration of the nonlinear capacity effects. For a proper management of the battery charging system, an accurate knowledge of the current state of charge (SOC) of the battery is needed. Authors propose an algorithm for the SOC estimation, according to the nonlinear relationship between the state of charge and the open-circuit voltage of the battery. A typical charge profile of a Li-ion battery cell. There are mainly two charging modes: constant current mode and constant voltage mode. During the constant current mode, the current is kept fixed at a reference value, while the voltage increases up to a maximum value; then, the constant voltage mode starts, and the voltage is kept fixed at the maximum value, while the current decays to zero.

4.3 IPT and EV applications

The design of an Inductive Power Transfer system applied to an Electric Vehicle is considerably complex since several aspects need to be taken into account. Firstly, an IPT system is made of different electric subsystems requiring to be properly designed and controlled: in the design of the magnetic coupler some care has to be addressed to coupling efficiency, possible misalignments between the coils, weight and bulk; to regulate the amount and the direction of the power flow, the power electronics stages have to be properly controlled. Secondly, the implications arising from the installation and working of an IPT system are diverse: costs, infrastructural works, customer satisfaction, magnetic field exposure and other issues require careful considerations. In a critical review of the recent progress in wireless power transfer systems and applications is carried out, whereas in an overview of the main IPT technologies for EV battery charging is provided. In the following, the main aspects related to analysis, design and realization of IPT systems for EVs will be reported, with a reference to the state of the art.

4.3.1 Analysis and design of IPT systems

For an optimal design, the working principles of different types and topologies of IPT systems should be deeply understood first, independently of applications and power levels. The scientific literature focuses particularly on the maximum efficiency conditions, since the power transfer efficiency is a significant quality index for an IPT system. In a study on the efficiency maximization, by regulating different parameters such as frequency and mutual inductance, is carried out. An investigation on the relationship between optimal air gap and coil geometry is made as well. In a method for the efficiency optimization of a series loaded series resonant converter for contactless power transfer systems is suggested, particularly focusing on the regulation of different physical parameters (e.g. transformer ratio, characteristic impedance, operation frequency) and on the investigation of the effects produced by changing the physical separation between both halves of the ferromagnetic core.

The connection between input impedance and maximum transferred power is analyzed in, with an experimental validation on two layer square coils. The conditions for the efficiency optimization are evaluated in series-series (SS) and series-parallel (SP) compensation topologies. The impedance matching problem for IPT systems is investigated. The bifurcation phenomenon is analyzed in. A control oriented to the zero phase angle between input voltage and current should be implemented in order to minimize the VA ratings and therefore power losses and costs. A detailed analysis is carried out with respect to all the possible reactive compensation topologies. In some cases, such as in Railway Applications, the maximum power transfer is more significant than the maximum efficiency. The optimal switching frequency for the power transfer is gained: this frequency is different from the resonant frequency, corresponding to the maximum efficiency.

4.4 Magnetic couplers and design methodologies

In the literature, several IPT structures for k Watt automotive applications are tested in order to evaluate magnetic coupling and feasibility. Most of investigated structures include ferrite in order to optimize the power conversion efficiency. Ferrite is yet unfavorable if lightweight power pads are desired. A trade-off between coupling efficiency and weight usually arises. The coupling efficiency is mainly affected by misalignments between the transmitter and receiver coils. For IPT purposes, innovative geometries and core structures are investigated to further reduce the dependence of the power conversion efficiency on misalignments. A circular planar structure with ferrite bars is tested for a 2 kW Inductive Power Transfer. Two identical power pads are employed. Ferrite bars are placed in a radial disposition. The ferrite disk is sliced into bars to reduce the total weight. IPT occurs by means of a current across a planar coil winding placed upon the ferrite bars and following their circular disposition. A single-sided coil winding is used for each of the power pads. The lack of robustness against misalignment in the lateral direction, due to a considerable reduction of magnetic coupling factor for the single-sided configuration, is the main drawback of the specific planar structure.

So-called “Flux Pipe” magnetic structure consisting of a rectangular planar ferrite core for each power pad is proposed. The coil winding is rolled around the core. Therefore, the winding is “double-sided”. This structure features a more compact size and higher performances than the planar one, due to higher tolerance to lateral misalignments. A photograph of the structure is shown

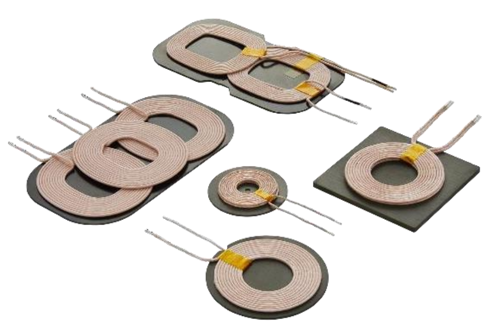

Fig 4.6: Magnetic coupler

A maximum 95% coupling efficiency is measured for a 1.5 kW output power and a 7 cm air gap. To lighten the whole structure, tests are also carried out after slicing. the core, thus building “split cores”. A negligible variation of magnetic coupling is measured, so that the “split-cores” can be employed for an efficient power transfer. The rectangular shape is modified to reduce the weight of the whole structure. A “H-shape” ferrite core is assembled. This structure, features almost the same coupling efficiency in comparison with the “Flux Pipe”, taking advantage from better misalignment-tolerance. Therefore, for electric cars, the H-shape structure represents a better compromise between weight, compactness, tolerance to lateral misalignment and efficiency Currently, the most attractive shape of magnetic coupler coils for IPT applied to EV wireless charging is the “Double D” (DD)

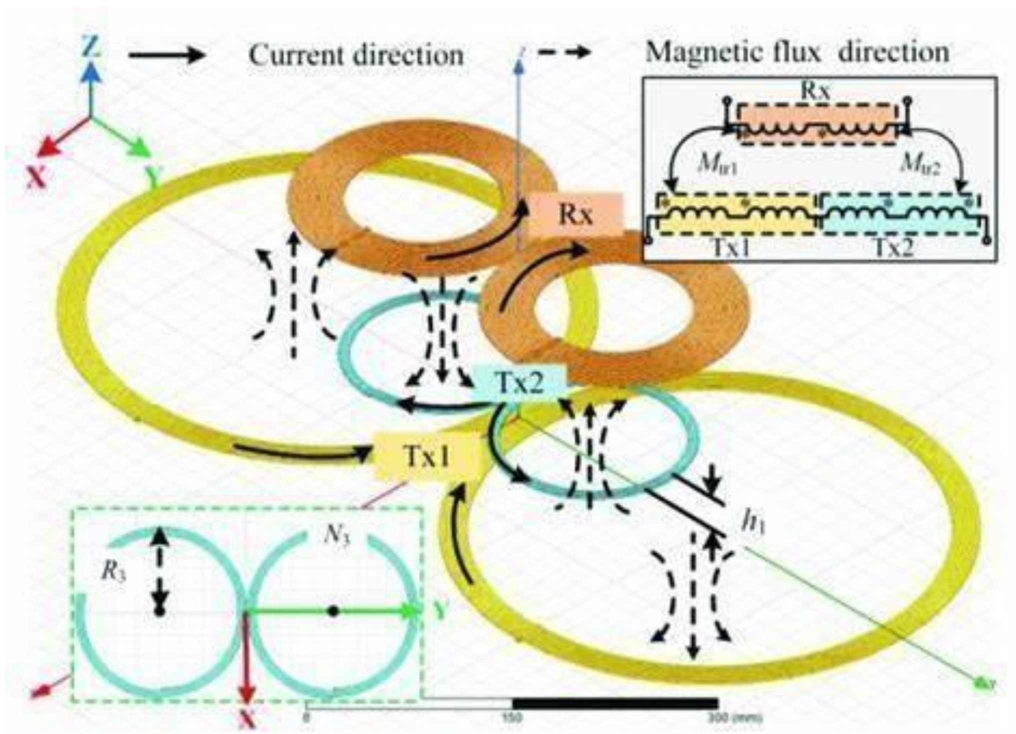

Fig 4.7: current flow in magnetic couplers

In a coreless solution consisting of two circular coils is proposed for wireless EV charging: an investigation on the optimal size of both the coils is carried out, together with a study on the best compensation, which turns out to be the parallel one. An accurate model is built by acquiring the values of mutual inductance corresponding to the different considered dimensions and keeping the air gap length and the structure weight constant. The maximum obtained efficiency is 85% at 20 cm of air gap. Due to the considerable number of design parameters in the evaluation of a proper magnetic coupling structure, a systematic methodology for the magnetic design can be useful. In, a design methodology of magnetic couplers for IPT systems addressed to household appliances and applicable to EV is proposed.

Several aspects are considered, such as the tolerance to misalignments and the air gap. By means of ferrite cores, a 90% efficiency at 1 cm of air gap and for 1 kW power level is gained. In, a method for the design of a coreless magnetic coupler with rectangular coils is proposed: a 82% efficiency is gained for a 15 cm air gap between the coils, considering a 2 kW prototype. In a standardized magnetic coupler is proposed for wireless EV charging: different sizes of DD (Double D) pads are simulated for different types of use and vehicle. A 10 kW power level can be transferred to charge sedans and SUVs in garage, car-park and roadway locations, considering a 40 cm air gap and a maximum 20 cm horizontal misalignment. Ina genetic algorithm is proposed for design and optimization of the track layout of coils for IPT.In a system design methodology is proposed, with particular focus on compensation, stability and control considerations.

4.4.1 Control strategies

Several control strategies are proposed in literature, in order to properly regulate the IPT system dynamic response and the amount of power flow. In case of Bi-Directional systems (BDIPT), the power flow direction needs to be regulated as well. A general investigation on stability and control of IPT systems for an extended range of power levels (up to 150 kW) is carried out in. In a dynamic control algorithm is provided for a BDIPT system.

A comparison between different control strategies for IPT systems is carried out, oriented to high power levels (e.g. EVs) and low power levels (e.g. mobile phones) respectively. In three control methods are mainly compared: phase shift control, frequency control and dual control. The voltage control is not considered due to the requirement of a further power.

The dual control, consisting in a combination of phase shift and frequency control, is proven to be the most convenient in terms of efficiency, stress on the electronic components and controllability.In four control methods are compared: voltage control, frequency control, duty cycle control and phase shift control.

The voltage control is not convenient, requiring a double converter stage. Among the other control strategies, the phase shift control is proven, both from simulations and experimental tests, to be the most convenient as far as costs and stability are concerned. Furthermore, it is compliant with the Qi standard by Wireless Power Consortium, concerning low power devices.

An alternative and reliable control method is the power-frequency strategy. In and the relationship between operating frequency and transferred power is exploited to regulate and limit the amount and the direction of the power flow, even if in order to guarantee the maximum efficiency, the system should be kept at the resonant frequency. This control strategy is validated on a 2 kW prototype of BDIPT system. No dedicated communication link is needed. The power frequency characteristic of a typical BDIPT system is shown, where is the resonant frequency. Based on this, the power-frequency control is developed.

The sensitivity of the power-frequency relationship with respect to the variation of the component values is evaluated in. A widely spread control strategy applied to IPT systems, particularly for EV charging and Bi-Directional power transfer, is the phase shift control. The phase shift control consists in the regulation of the power flow amount and direction through some control parameters corresponding to phase angles. The phase difference between the fundamental harmonics of primary and secondary voltages is kept at 90° in order to have maximum power factor and maximum efficiency.

According to the phase sign, whether the phase angle is +90° or -90°, the direction of the power flow is different, meaning that the power flows from the grid to the battery or from the battery to the grid. Instead, the power flow amount is regulated through the control of the phase angle between the legs of each power converter.

In the phase shift control is applied to an IPT system without compensation network in the secondary side, so that the detuning of this side is unlikely. In the phase shift control is exploited to control the power flow towards the battery of a 3 kW EV prototype, charged through IPT. The proposed topology is not usable for BDIPT. A dual-side control allows to improve efficiency and component stress with respect to a single-side control, especially for partial load conditions. Accurate considerations on operating frequency, hard- switching and soft switching working, technology of the power components, magnetic design and behavior for different air gaps are provided. For the section from the DC source to the battery, the peak efficiency is 95.8% at the minimum air gap of 10 cm. In a control based only on the information arising from the primary side is proposed, in order to avoid the need of a communication link between the power transmitter and the power receiver.

4.5 Safety Consideration

The analysis and the design of wireless battery chargers based on the IPT imply concern for the human safety. Three main sources of hazard should be considered: electrical shock, fire hazards and electromagnetic field exposure. Electrical shock and fire hazards are inherently due to the high voltages and currents in the primary and secondary coils if high power level systems are considered. Normal care should be taken in order to prevent these cases.

The Electromagnetic Field (EMF) exposure is a major concern for wireless charging, particularly in the case of wireless EV charging. In the IPT systems the operating frequencies generally are equal to tens of kHz, so that the radiation zone is the near field of the electromagnetic field. In the near field region, the field is mainly magnetic. The electric fields are generally more dangerous for the human safety rather than the magnetic fields, so that the radiation produced by the wireless chargers is considered quite safe for the human body. Nevertheless, if the power levels are high, the EMF exposure has to be taken into account for a rigorous consideration of the safety implications. This is the reason why the magnetic field exposure is a major concern for the IPT wireless EV charging, where an accurate investigation on the field distribution should be carried out. Considering the typical case of an electric car wireless charging, for the people inside the vehicle there is not a strong radiation hazard, because of the metal shielding represented by the chassis.

The most hazardous radiation zones are between the coils and around the coils. However, these areas are not always directly exposed to humans or animals. In spite of the larger distance from the magnetic coupler, another hazardous zone in need of consideration is the area around the car, because it exposes directly to the general public. There are mainly two international groups that set standards and guidelines concerning the human exposure to the electromagnetic fields: the International Committee on Electromagnetic Safety (ICES) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). These guidelines deal with general public and occupationally exposed population.

The standard by ICES also focuses on different parts of the human body in presenting its guidelines. Few simulation and experimental results have been presented in the scientific literature concerning the radiation produced by IPT-based wireless chargers. In the magnetic coupling structure previously proposed in is investigated also as far as the compliance with the ICNIRP exposure limits is concerned. The particular combination of cylindrical shape and ferrite disposition aims at containing most of the magnetic flux inside the coupling structure, so that the flux density decreases rapidly outside the charger. Nevertheless, experimental results concerning the radiation are not provided in this work. Apart from the direct coupling to the body,sometimes an indirect coupling can occur as well. Examples of potential indirect coupling are the EMF coupling to medical implantable devices or the physical contact of the body with objects which are strongly exposed to the magnetic field. In this Chapter the main applications of wireless battery charging have been addressed, considering the power levels ranging from the µW of Wireless Sensor Networks (WSN) to the hundreds of kW of Railway Applications, passing through the following applications: electric toothbrush, consumer electronic devices, household appliances and Electric Vehicles (EVs). A technical background on the Inductive Power Transfer systems has been given, particularly focusing on the electronic and the magnetic design. A general overview and the state of the art concerning the IPT applied to the EVs have been provided, considering magnetic couplers, design methodologies, control strategies and safety issues. In the next two Chapters the contribution of this thesis will be reported.

The proposed work focuses mainly on the E-bike application. An IPT system for the wireless battery charging of an electric bicycle will be proposed, with particular attention on the magnetic and the electronic design issues.

After that, an analytical study on a typical Bi- Directional IPT system will be provided. This work has contributed to deeply understand the power flow in a BDIPT system as function of different control parameters. The analytical results have been validated through electronic simulations.

A control algorithm for the maximization of the power transfer efficiency will be proposed as well. This algorithm represents an original research contribution, since a power tracking method aiming at the efficiency optimization in IPT systems was not known in the scientific literature. Alternative solutions of inductive coupling will be investigated as well, according to a deep analysis through a 3D magnetic simulator. An optimal solution in terms of efficiency and tolerance to misalignments will be proposed as far as wireless E-vehicle battery charging is concerned.

The experimental results in terms of power transfer efficiency and magnetic characterization of the assembled prototype will be explained, focusing particularly on the coupling efficiency and on the physiological compatibility of the system.

CHAPTER 5
Design of an IPT system for E-bike battery charging

5.1 Inductive power transfer

The Inductive Power Transfer (IPT) can be exploited for Electric Vehicle (EV) battery charging. The IPT consists of a wireless power flow between two magnetically coupled coils. Therefore, through IPT the battery charging can occur wirelessly. The lack of wires brings some benefits in terms of comfort and safety: the vehicle could be automatically charged without the need of a plug-in operation and no electrocution risk would involve the user. Depending on whether the vehicle is stationary or in motion, and whether the driver is inside the vehicle or not, there are three types of IPT-based battery charging: static, semi-dynamic and dynamic. The static IPT occurs when the vehicle is stationary and nobody is inside it, i.e. during the parking time; the semi-dynamic IPT occurs when the vehicle is stationary and the driver is inside it, i.e. during the stop at traffic red lights for cars or during the bus stop for electric buses; the dynamic IPT occurs when the car is in motion, i.e. along motorways. Yet the dynamic wireless battery charging features some drawbacks.

The motion of the vehicle implies a widespread infrastructure of power transmission buried inside the road in order to have adequate charging times and therefore for an efficient dynamic charging high costs are required. IPT is cheaper in static and semi-dynamic options, since the same charging time is covered by the use of a minor number of coils in comparison with the dynamic case, due to the stationary state of the vehicle. Static IPT is feasible for private EVs which could stay stationary for some hours, whereas semi-dynamic IPT is particularly appropriate for public electric means of transportations, such as cabs or buses,

To continuously move across the day and therefore requiring frequent charging operations if a proper autonomy is wanted without increasing the battery size .

Considering that the wireless battery charging is inherently less efficient than the conventional wire-based battery charging, the benefits brought by the wireless method in terms of comfort and safety need to be notable in order to make the static IPT really attractive for EV battery charging. The frequent movements of a vehicle may require to charge its battery many times across the whole day. This particularly fits with the case of electric bicycles, being very smart and comfortable to be driven in the congested traffic, typical of the urban scenario.

The bike is potentially an ideal means of transportation for frequent transfers throughout the day. Furthermore, the E-bike represents a smart, green and light solution of urban mobility. More and more people are supposed to be driving electric bicycles in the next future. IPT would therefore represent a brilliant solution of battery charging for parked E-bikes, due to different reasons. First of all, every time the cyclist parks the E-bike, it would be automatically recharged without the bothersome and potentially dangerous plug-in operation.

Later, in case of multi parking areas for E-bikes, each bicycle could be recharged and no wire would be visible. In the next paragraphs an IPT system for E-bike wireless battery charging will be proposed. After a general description of a typical IPT system, the single subsystems will be described and the design criteria which have been followed for the proposed system will be explained. The here proposed IPT system aims at charging a 36 V 10 Ah LiFePO4 battery.

5.2 Design of the IPT system

The DC-DC stage model of the proposed IPT system for wireless Ebike battery charging. As far as the actual inductive power transfer is concerned, the self- inductances related to the coupled coils are L1 and L2, whereas the mutual inductance is M. L1 and L2 correspond respectively to the primary and the secondary coil. The primary-side DC voltage source is connected to the electrical grid; the secondary-side DC section is the load representing the battery to be charged A SS capacitive compensation is proposed, as highlighted by the figure, being both C1 and C2 connected in series with the coupled coils.

This choice allows to select the compensation capacitances depending only on the self-inductances: this choice is therefore independent of the load and the magnetic coupling. In addition to this, as explained in the following, the SS choice allows to easily manage the main battery charging mode, which is the constant current mode. For the electric car battery charging, the IPT usually consists of a transmitter coil placed on the road and a receiving coil placed on the bottom part of the chassis. As far as the E-bike IPT battery charging is concerned, the scientific literature provides few works. The commercial actors provide few examples as well.

The receiving coil is mounted on the kickstand, whereas the transmitting coil is buried inside the pavement. The bicycle coil is placed on the side of the front basket and the grid-connected coil is installed next to a wall, both in a vertical position. The wireless charging operation occurs at a 5 cm distance between the coils. In the receiver part is under the saddle of the bicycle. In the proposed E-bike wireless battery charging system, the supposed position for the receiver coil is on the bicycle front wheel, parallel to it. While the bicycle stands in public parking areas, the front wheel is supposed to be fixed to a support. The power transmitter could house inside this support. A compact solution of magnetic coupling is therefore well-suited for this application. A flat structure seems to be appropriate and a circular shape properly fits with the wheel. charging in order to reduce the leakage magnetic flux, thus optimizing the power transfer efficiency even for large air gaps between the coils. For the proposed E-bike IPT system no ferromagnetic material is employed, in order to obtain a light-weight, compact and cheap structure. In IPT systems for EV battery charging, the current trend is to build a large transmitter coil and a smaller receiver coil. The reduced size of the receiver coil is generally due to the space restrictions in a movable system like a vehicle. The larger size of the transmitter coil allows to produce high amounts of power, thus creating a more uniform magnetic field in the receiver region. Nevertheless, in the proposed system, primary and secondary coil windings have been chosen identical in order to minimize the total leakage flux. This represents the conventional solution for loosely coupled coils. In addition to this, due to its geometrical symmetry, this choice fits the possibility of a bi-directional power transfer.

In a Bi-Directional IPT (BDIPT) system, the power can flow not only from the grid to the battery, but also in the opposite direction. In the BDIPT, the role of power transmitter or power receiver can be alternatively played by both the coils: in the grid-to-battery power flow the primary coil is the power transmitter and the secondary coil is the power receiver; in the battery-to-grid power flow the secondary coil is the power transmitter and the primary coil is the power receiver. The interchangeability of power transmitter and power receiver can be guaranteed by reversible DC-AC and AC-DC stages, being able to respectively convert into an AC-DC and a DC-AC in the transition from a grid-to-battery to a battery-to-grid power flow. The diameter of each coil has been chosen according to space constraints in the E-bike wheel. The number of turns of each coil is oriented to a trade-off between different aspects: the coupling coefficient, the power losses due to the length of the wire, the skin effect, the bifurcation phenomena. This trade-off is well explained in. In order to evaluate the electrical features of the coupled coils according to the number of turns, a magnetic field simulation has been implemented through a FEM 2D software, that is a magnetic simulator based on Finite Element Method .The magnetic field has been produced by injecting a 26 A current into the upper coil, referring to the figure. In order to obtain the primary self-inductance L1, the flux of this magnetic field through the surface of the same coil has been considered, and the secondary self-inductance L2 is supposed to be the same since the coils are identical. The common value of the self-inductances is represented by L. To obtain the mutual inductance M, the flux of the magnetic field through the surface of the lower coil, referring to the figure, has been considered. The electric model features of the magnetic coupling structure, as obtained from FEMM analysisby setting a 3 cm air gap, k is the coupling coefficient of the magnetic structure.

5.3 Bi-directional Inductive power transfer (BDIPT)

IPT well fits with the idea of a "Bi-Directional" power transfer, meaning that the power is able to flow from the grid to the load or, alternatively, from the load to other users of the grid. A Bi-Directional Inductive Power Transfer (BDIPT) system is therefore exploitable to accomplish the Vehicle-To-Grid (V2G) concept, consisting in the possibility to use the EV battery as storage element for other users of the grid or other vehicles as well, in the scenario of a multi-parking area. The V2G idea belongs to the philosophy of the active demand, where the user plays the double role of consumer and producer of electrical energy.

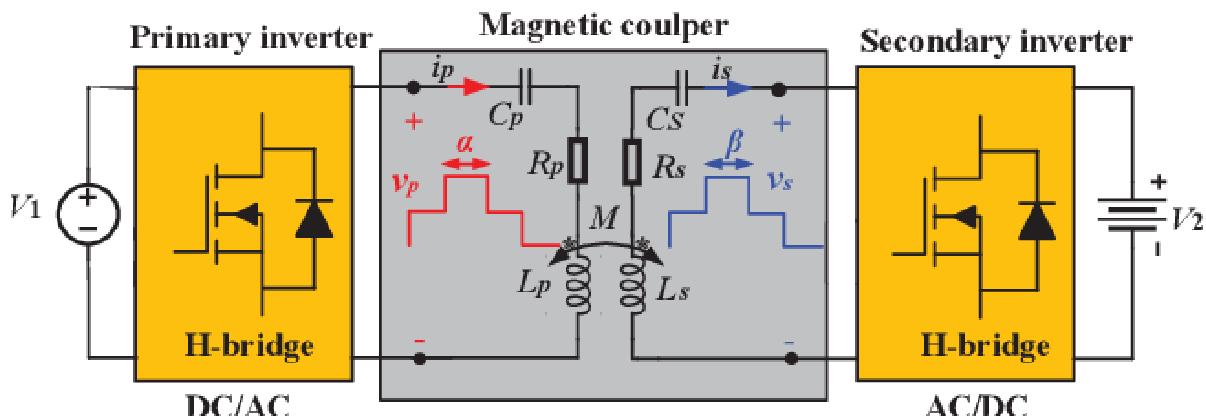

Fig 5.1: Bi directional Inductive power transfer(BDIPT)

The compensation capacitive topology is the one proposed for the assembled prototype, that is series-series (SS). R1 and R2 represent the power losses in the primary and secondary side respectively. The DC-AC stage from Vdc to the primary side and the AC-DC stage from the secondary side to V batt are two reversible rectifiers: the primary full-bridge converter (S1-S2- S3-S4) producing the AC waveform V1 and the secondary full-bridge converter (M1-M2-M3- M4) producing the AC waveform V2. Depending on the phase delay between V1 and V2, the power flow direction can be determined. If a power transfer aiming at the battery charging is desired, a phase lead of V2 with respect to V1 shall occur. If maximum power factor is desired, the phase lead is set at 90°. In the following, a detailed mathematical analysis of this BDIPT circuit, concerning the power flow and its dependence on several parameters, will be carried out.

5.4 Control

A control action is required on the IPT system in order to regulate the power flow towards the E-bike battery. Although the control can be implemented in different ways according to the peculiar topologies that are employed, the common goal is to produce the desired output at the battery section. As explained in Chapter I, the main stages of a typical lithium ion battery are the constant current stage and the constant voltage stage. The control action is therefore dependent on the specific stage of the battery charging process. During the constant current stage, the goal is to keep the battery current fixed at a certain value, whereas during the constant voltage stage, the battery voltage needs to be kept fixed at a certain value.

The compensation topology of the proposed IPT system is series-series (SS). The output of the SS topology is roughly equivalent to a current source at the resonant frequency, so that in this case the control is more easily effective during the constant current stage. If a proper frequency is chosen as the system operating frequency, the SS output is equivalent to a voltage source, so that at this frequency the constant voltage stage is more easily controllable. the efficiency of the system has been studied as function of the phase control parameters, aiming at the implementation of an algorithm for the efficiency optimization.

The Inductive Power Transfer is implemented through the magnetic coupling between two coils. For the experimental prototype, two circular coils have been used. For the designed IPT system a laboratory prototype has been assembled and several experimental tests have been carried out to test the proper working and to measure the power efficiency and the produced magnetic field. The application target for this prototype corresponds to a power range, useful for the charging of an electric bicycle battery. In the next subparagraphs, the different parts of the assembled IPT prototype will be described. Vdc represents the DC output of the grid-connected AC-DC stage.

The load resistance RL represents the input of the battery charging control network. In the power transmitter side, the DC-AC is implemented through a half-bridge inverter, including the nMOS M1 and M2. In the power receiver subsystem, a conventional four-diode rectifier is employed (D1-D2-D3-D4). In order to reduce power losses, Schottky diodes are used. M is the mutual inductance, linked to the self-inductances and the coupling coefficient.

CHAPTER 6

BLOCK DIAGRAM OF WIRELESS CHARGING OF EV'S

6.1 BLOCK DIAGRAM

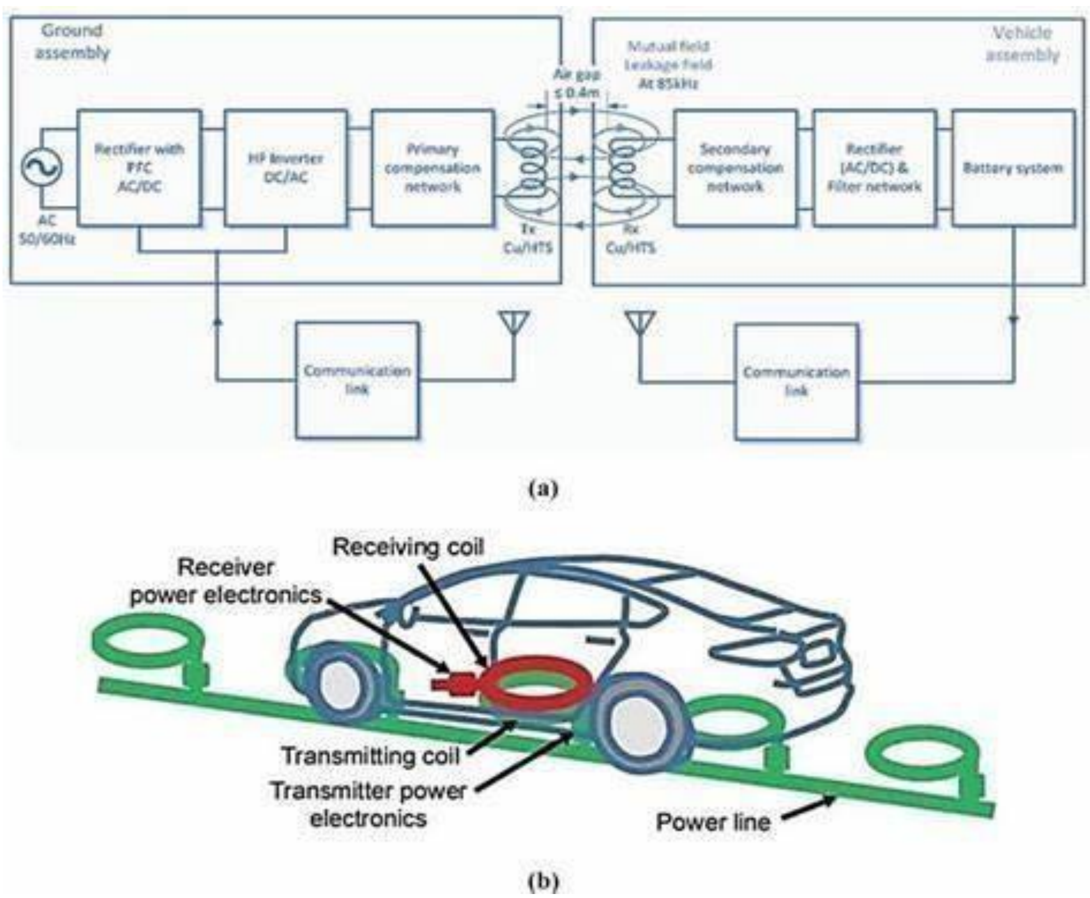

Fig 6.1: Block diagram of wireless charging of EV'S

Wireless charging for electric vehicles (EVs) is an exciting development in EV technology, offering a convenient alternative to traditional plug-in charging.

Wireless EV charging primarily uses inductive charging, which involves transferring energy between two coils—one in the charging station (or ground pad) and one in the vehicle (or receiver pad). When alternating current (AC) flows through the charging coil in the ground pad, it creates a magnetic field. This magnetic field induces a current in the receiver coil in the vehicle.

For efficient energy transfer, the vehicle's charging coil needs to be properly aligned with the charging pad. Some systems use guidance technologies to help align the vehicle, while others are designed to accommodate minor misalignments.

Advanced systems often include communication protocols between the vehicle and the charging station to manage the charging process and ensure safety. No need to plug in cables, which simplifies the charging process and reduces wear on connectors.

Reduced physical connections can lead to fewer maintenance issues and potential problems with connectors or ports. Eliminates the need for visible charging cables and ports, which can be more aesthetically pleasing and less cluttered.

Wireless charging is generally less efficient compared to wired charging. There's some energy loss due to the nature of inductive transfer.The technology is currently more expensive to install and maintain compared to conventional wired charging solutions. Proper alignment is crucial for efficient charging, and some systems might struggle with misalignment.

There are ongoing research and development efforts to enable dynamic wireless charging, where vehicles can be charged while driving over specially equipped roadways. Improvements in technology are continually enhancing the efficiency and power transfer capabilities of wireless charging systems. Efforts are underway to standardize wireless charging technology to ensure compatibility across different EV models and manufacturers.

BMW and Mercedes-Benz, Both manufacturers have introduced wireless charging systems for their electric vehicles. A company offering aftermarket wireless charging solutions for certain EV models. A company working on dynamic wireless charging solutions for roadways.

Wireless charging for EVs is a promising technology that could become more common as the technology matures and costs decrease. It's an exciting area of innovation that aligns with the broader trend of making EV ownership more convenient and user-friendly. Preventing wormhole attacks in the Ad hoc On-Demand Distance Vector (AODV) routing protocol using NS2 (Network Simulator 2) requires implementing countermeasures to detect and mitigate such attacks.

Neighbourhood Information Exchange: Implement secure neighbourhood information exchange between neighbouring nodes. This can be done by adding secure authentication mechanisms to the hello messages exchanged in AODV. Modify the AODV source code (e.g., aodv.cc and aodv.h) to include secure neighbour authentication. ### Electric Vehicles: A Comprehensive Overview

Electric vehicles (EVs) are revolutionizing the automotive industry by providing a cleaner, more efficient alternative to traditional internal combustion engine vehicles. Here’s a detailed note on electric vehicles, covering their types, benefits, challenges, and the future outlook. BEVs are powered entirely by electricity stored in onboard batteries. They do not have an internal combustion engine and produce zero tailpipe emissions.

PHEVs combine an internal combustion engine with an electric motor and a rechargeable battery. They can be driven using electric power alone for short distances before the engine kicks in Toyota Prius Prime, Ford Fusion Energy, Mitsubishi Outlander PHEV. HEVs use both an internal combustion engine and an electric motor, but the battery is not plug-in. The battery is charged through regenerative braking and the engine. EREVs are similar to PHEVs but are primarily electric with a small internal combustion engine used only as a generator to extend range when the battery is depleted.

BEVs and PHEVs reduce greenhouse gas emissions and air pollutants, contributing to improved air quality and climate change mitigation. EVs are more energy-efficient than conventional vehicles, converting a higher percentage of energy from the battery to power the wheels. Charging an EV is generally cheaper than fueling a gasoline or diesel vehicle. EVs have fewer moving parts and do not require oil changes, leading to lower maintenance costs. Electric motors provide instant torque and smooth acceleration. EVs operate more quietly compared to internal combustion engine vehicles.

6.2 WORKING

Wireless charging for electric vehicles (EVs) is based on inductive power transfer, a technology that allows for energy to be transferred without physical connectors. Wireless charging, also known as inductive charging, relies on electromagnetic fields to transfer energy between two coils: a transmitter coil (located in the charging pad) and a receiver coil (located in the vehicle).

Energy is transferred between the charging pad and the vehicle through a magnetic field created by the transmitter coil. This is based on Faraday's Law of Induction, which states that a changing magnetic field can induce an electric current in a nearby coil. To increase efficiency and allow for some degree of misalignment between the coils, many wireless charging systems use resonant inductive coupling. This involves tuning the transmitter and receiver coils to the same resonant frequency, allowing for more efficient energy transfer. Includes the transmitter coil, power electronics, and control systems.

Converts electrical energy from the power source into a high-frequency alternating current (AC) that generates a magnetic field. This magnetic field is used to transfer energy to the receiver coil in the vehicle. Includes the receiver coil, power electronics, and control systems. Receives the energy from the magnetic field and converts it back into direct current (DC) to charge the vehicle's battery.

Both the charging pad and vehicle receiver have power electronics to manage the conversion between AC and DC, regulate the power transfer, and ensure safe operation. Ensures efficient energy transfer and manages communication between the charging pad and vehicle to optimize charging performance. The vehicle is positioned over the charging pad. The alignment of the coils is critical for efficient energy transfer, though systems are designed to accommodate some misalignment. The charging pad generates a high-frequency AC current that creates a fluctuating magnetic field. The receiver coil in the vehicle captures the magnetic field and induces an electric current in the coil.

The induced AC current in the vehicle's receiver coil is converted to DC by the onboard power electronics. The DC power is then used to charge the vehicle's battery. Many systems include a communication protocol to exchange information between the charging pad and the vehicle. This communication can provide status updates, control charging rates, and ensure safety by detecting any issues.

6.3 Wireless charging in motion

Wireless charging of electric vehicles (EVs) while they are in motion, also known as dynamic wireless charging or in-motion charging, is an advanced technology that aims to extend the driving range of EVs and provide continuous charging while on the road. Dynamic wireless charging relies on the same fundamental principles as static wireless charging but is designed to operate while the vehicle is moving.

Dynamic wireless charging uses electromagnetic fields to transfer energy between a stationary charging infrastructure and a moving vehicle, similar to the principle of static wireless charging. This principle is used to enhance efficiency and allow energy transfer over greater distances, even while the vehicle is moving. Both the transmitter (embedded in the road) and receiver (on the vehicle) coils are tuned to resonate at the same frequency.

These coils are embedded in the road surface or embedded in special charging lanes. They generate an alternating magnetic field when energized. Provides the electrical energy needed to create the magnetic field. Manage power delivery, communication with the vehicle, and ensure safety. Located on the underside of the vehicle, this coil captures the magnetic field generated by the transmitter coils in the road.

Converts the induced alternating current (AC) into direct current (DC) to charge the vehicle’s battery. Manages the charging process and ensures the battery is charged efficiently and safely. The system may use sensors or positioning technology to detect the vehicle’s presence and alignment over the charging lanes. Some systems include guidance technologies to help align the vehicle with the charging coils embedded in the road. The transmitter coils embedded in the roadway create an alternating magnetic field when supplied with electrical power. The receiver coil on the vehicle captures the magnetic field, inducing an electric current in the coil. The induced AC current is converted to DC by the vehicle’s power electronics. The DC power is used to charge the vehicle’s battery while the vehicle is in motion.

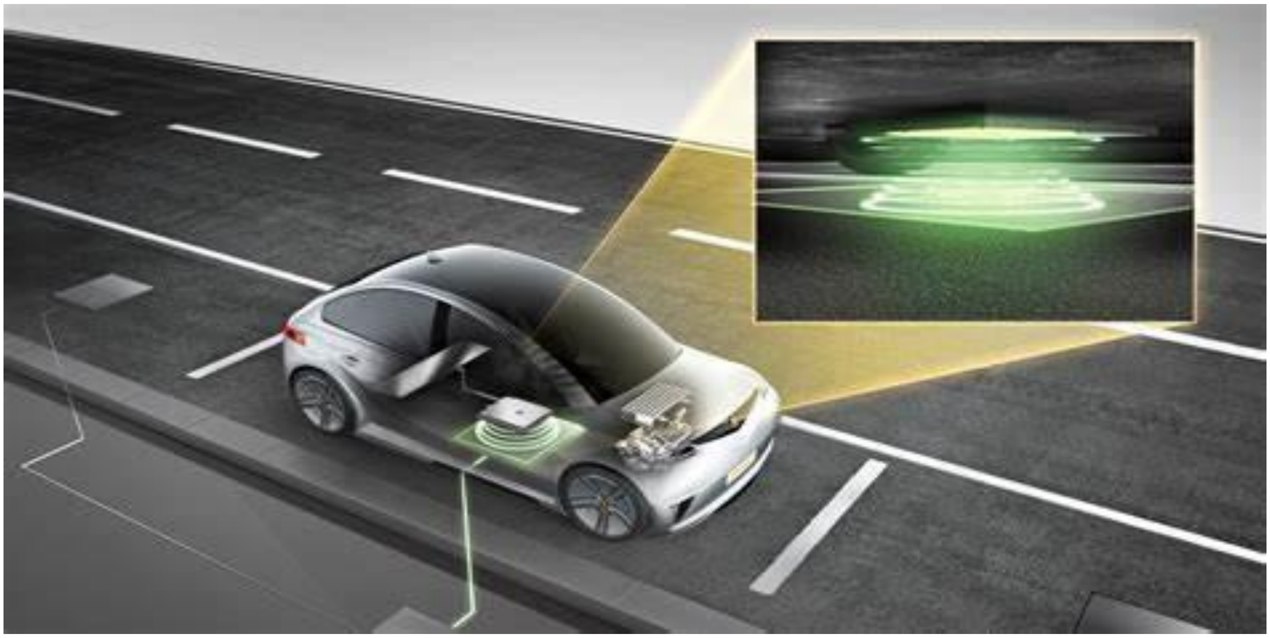

Fig 6.2: Wireless charging in motion

Many dynamic wireless charging systems include communication protocols between the road infrastructure and the vehicle to manage power delivery, monitor charging status, and ensure safety. Coils are embedded in the road surface or in special charging lanes, allowing continuous charging as the vehicle drives over these sections. Pilot projects and experimental systems in various countries. Some systems use overhead or ground-based transmitter systems to create a magnetic field, though these are less common for dynamic charging due to complexity and cost. Provides continuous charging while driving, which can significantly extend the driving range of EVs and reduce range anxiety. Allows for smaller battery packs since the vehicle can be continuously charged, reducing the need for large, heavy batteries. Reduces the need for frequentstops to charge and can be integrated into existing road infrastructure. Installing and maintaining the infrastructure for dynamic wireless charging can be expensive and complex. Energy transfer efficiency can be lower compared to static charging, especially with varying alignment and distances.

Ensuring proper alignment and safety while the vehicle is in motion is technically challenging and requires advanced systems and controls. Developing and implementing standardized systems that are compatible with different vehicle models and manufacturers. Ongoing research aims to improve the efficiency, safety, and cost-effectiveness of dynamic wireless charging systems. Dynamic charging could be integrated with smart road infrastructure and autonomous driving technologies to optimize the charging process and enhance vehicle safety. Various pilot programs and experimental systems are being tested globally to evaluate the feasibility and effectiveness of dynamic wireless charging.

Dynamic wireless charging represents a promising advancement in EV technology, with the potential to transform how electric vehicles are used and charged. As technology evolves and infrastructure develops, dynamic wireless charging could become a key component of future transportation systems.

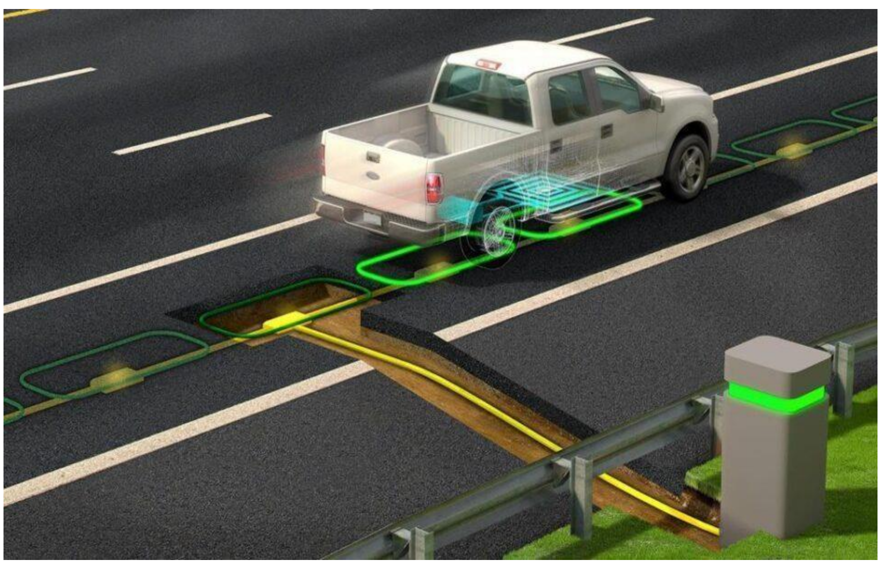

Fig 6.3: Dynamic Wireless charging of EV'S

CHAPTER 7

RESULT

7.1 MODEL

Fig 7.1: Wireless charging model

It have a underground power lines and it energized the primary coil. Primary coil produce a magnetic field. Ev have secondary coil in the bottom and it links with the magnetic field. Then power is transferred to secondary coil from primary coil by mutual induction and battery is charged. It is helpful to reduces the weight of the vehicle because of it only requires a small battery Installation of wireless charging pads or stations in public and private parking spaces, highways, and other strategic locations. Equipping EVs with wireless charging receivers and ensuring compatibility with various charging standards. Establishing industry-wide standards for wireless charging technology, ensuring interoperability and safety. Integrating wireless charging infrastructure with the electrical grid, managing power distribution and energy storage. Developing and implementing regulations, incentives, and policies to support widespread adoption. Raising awareness about the benefits and convenience of wireless charging, addressing range anxiety and promoting EV adoption. Fostering partnerships among automakers, technology providers, and infrastructure developers to drive innovation and economies of scale.

Fig 7.2: Transmitter model of Wireless charging

This is the fundamental technology behind wireless charging. Both the charging infrastructure (ground based) and the vehicle are equipped with coils of wire. Alignment and Efficiency: For efficient power transfer, the coils need to be properly aligned.

As the vehicle moves over the charging area (which could be embedded in the road or another designated area), the charging coils continuously detect each other and maintain the power transfer.

Wireless charging systems for moving EVs must meet stringent safety standards to ensure they do not pose risks to vehicles, passengers, or the surrounding environment.

There are several challenges to overcome, such as the cost of infrastructure deployment, efficiency losses during power transfer, and ensuring compatibility with different vehicle types and charging requirements

As of now, wireless charging while moving is still in the experimental and developmental stages. To calculate the amount of energy used for charging an EV vehicle, you can follow.

7.1.1 TRANSMITER CIRCUIT

2222N TRANSISTOR- The 2222N transistor acts as a high-frequency power switch ,turning on and off to control the flow of energy between the transmitter and receiver coils.

RESISTOR (10K) -In a wireless charging transmitter, a 10kΩ resistor is used to Limit the current through the transmitter coil.

POWER SUPPLY (5V)- 5V supply is used to power the control circuitry, communication interface, and sensing circuits.

COPPER WIRE (10 LOOP 10) -To produce magnetic field lines.

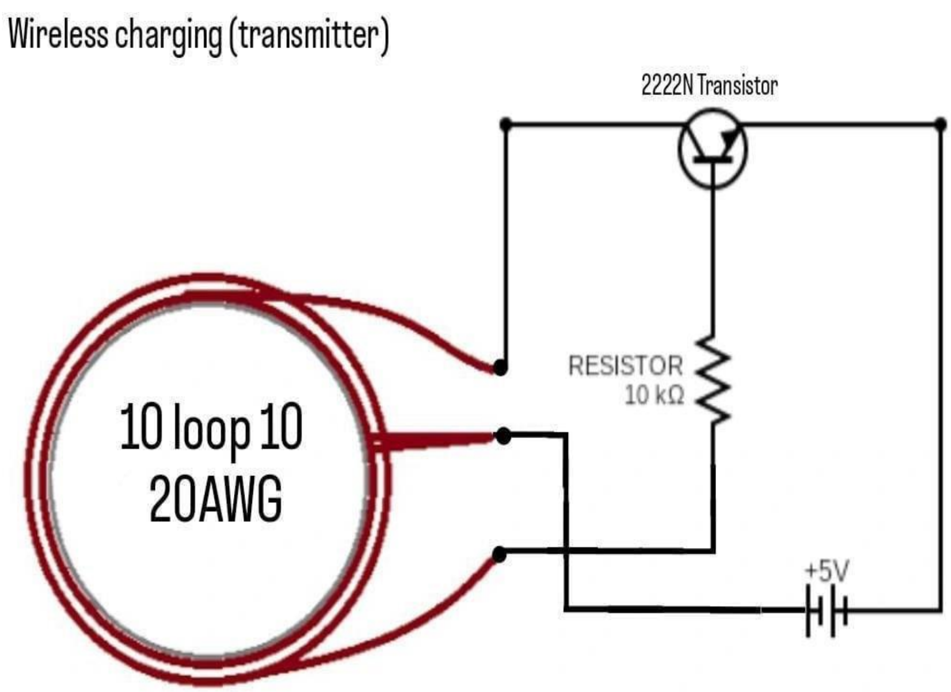

Fig 7.3: Wireless charging transmitter circuit

7.1.2 RECEIVER CIRCUIT

Bridge Rectifier Bridge rectifiers as a type of full-wave rectifier that uses four or more diodes in a bridge circuit configuration to efficiently convert alternating (AC) current to a direct (DC) current.

CAPACITOR (10uF , 100uF)- The most common use for capacitors is energy storage, power conditioning, electronic noise filtering, remote sensing and signal coupling/decoupling.

POWER SUPPLY (5V)- 5V supply is used to power the control circuitry, communication interface, and sensing circuits.

COPPER WIRE 20 LOOPS- It's known for its conductivity and durability, making it suitable for transmitting electrical signals over long distances.

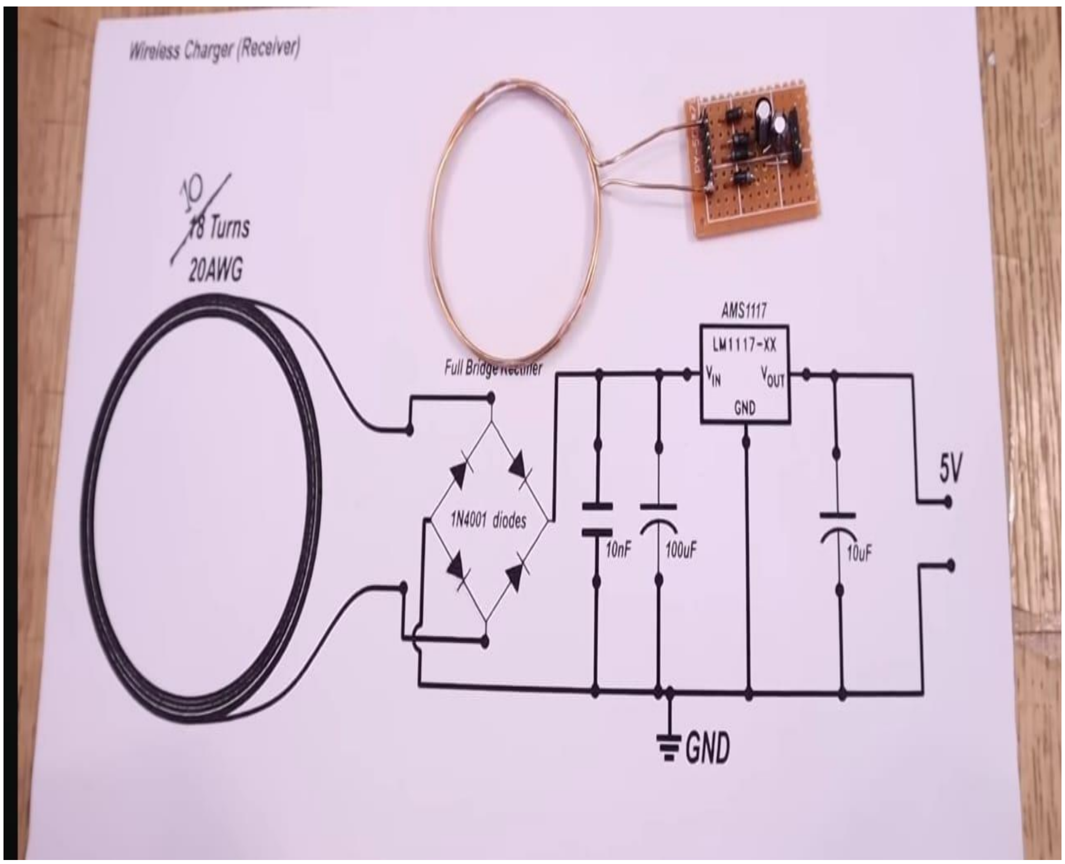

Fig 7.4: Wireless charging receiver circuit

LIMITATIONS

Power Transfer Efficiency:

Wireless charging systems, especially those designed for dynamic applications, typically experience lower efficiency compared to traditional plug-in charging methods. The efficiency can drop significantly when transferring power over a distance, especially with the vehicle in motion.

Heat Generation:

Increased energy loss can lead to higher heat generation, which may affect the system's performance and longevity.

Installation Costs:

Embedding wireless charging infrastructure into roadways or installing charging lanes involves significant costs. The construction and maintenance of such infrastructure can be expensive.

Safety Concerns:

The generation of electromagnetic fields for wireless power transfer could raise safety and health concerns. Ensuring these fields are within safe limits is crucial.

Vehicle and Battery Compatibility:

Different EVs may have different charging requirements and specifications, making it challenging to develop a one-size-fits-all solution. Standardizing the technology across various vehicle models is essential but difficult. Dynamic charging systems need to integrate seamlessly with the vehicle’s battery management system to ensure proper charging and avoid potential battery damage.

ADVANTAGES

Extended Driving Range

Continuous Charging: Dynamic wireless charging allows EVs to be charged while driving, effectively extending the vehicle's driving range beyond the capacity of its onboard battery alone.

Reduced Range Anxiety: By enabling continuous energy supply, it alleviates concerns about running out of charge, making long-distance travel more feasible and reducing range anxiety.

Reduced Battery Size and Cost

Smaller Battery Packs: With the ability to charge on the move, EVs may require smaller battery packs to achieve the same range, as the vehicle is receiving a constant charge.

Cost Savings: Smaller battery packs not only reduce the vehicle's weight but also lower the cost of the battery, which can make EVs more affordable.

Increased Convenience

Minimized Charging Stops: Drivers can avoid frequent stops at charging stations since the vehicle is being charged continuously while in motion.

Seamless Integration: It integrates charging into the driving routine, reducing the need for dedicated charging time or finding charging stations.

Enhanced Infrastructure Utilization

Optimized Road Use: Dynamic charging systems can be implemented in high-traffic areas or along key routes, allowing for efficient use of existing road infrastructure and reducing the need for additional charging stations.

Smart Road Integration: It can be integrated with smart infrastructure to provide real- time data and manage energy distribution more effectively**.**

1. Environmental Benefits

Reduced Battery Production Impact: Smaller batteries lead to less resource extraction and production, reducing the environmental impact associated with battery manufacturing.

Lower Emissions: Continuous charging can reduce the reliance on larger, less efficient batteries, contributing to lower overall emissions from the production and disposal of batteries.

2. Potential for Dynamic Charging Lanes

Dedicated Charging Lanes: Highways and specific routes could be equipped with embedded charging systems, enabling continuous power supply and making EV travel more practical for long-distance commutes.

Optimized Traffic Flow: Integrating dynamic charging with intelligent transportation systems could optimize traffic flow and enhance road safety.

3. Innovation and Technological Advancement

Technological Leadership: Adopting dynamic wireless charging pushes the envelope of EV technology, driving innovation in electromagnetics, power electronics, and infrastructure development.

Future Integration: It lays the groundwork for integrating EVs with future smart transportation systems, including autonomous vehicles and advanced road management.

4. Reduced Demand on Charging Infrastructure

Decreased Charging Station Load: With vehicles charging on the move, the demand for stationary charging infrastructure may be reduced, potentially lowering the strain on existing charging networks and expanding their capacity.

5. Encouragement of EV Adoption

Enhanced EV Appeal: The convenience and extended range provided by dynamic wireless charging can make EVs more attractive to a broader range of consumers, accelerating the adoption of electric vehicles.

6. Improved Traffic Efficiency

Potential for Coordinated Charging: Dynamic charging could be part of a broader traffic management system that optimizes when and where vehicles are charged, potentially reducing congestion and improving overall traffic efficiency.

CONCLUSION

Wireless charging technology has the potential to revolutionize the Electric Vehicle(EV) industry, offering a convenient, efficient, and sustainable charging experience .With its ability to eliminate range anxiety, reduce charging time, and increase user adoption, wireless charging is poised to play a crucial role in the widespread acceptance of EVs. While technical, infrastructure, and regulatory challenges remain, the benefits of wireless charging far outweigh the costs. As the industry continues to evolve, it is essential to prioritize standardization, interoperability, and collaboration to ensure seamless integration and widespread adoption.

With wireless charging, the future of transportation is electric, effortless, and sustainable. Dynamic wireless charging for electric vehicles (EVs) represents a transformative advancement in EV technology, offering a range of compelling benefits that address some of the key challenges associated with electric mobility. By enabling continuous charging while the vehicle is in motion, this technology promises to enhance the practicality and efficiency of electric vehicles in several significant ways.

One of the most notable advantages of dynamic wireless charging is the ability to significantly extend the driving range of EVs. By providing an ongoing power supply, it reduces range anxiety and allows for more seamless long-distance travel, which can increase the attractiveness of EVs for a wider audience. With the ability to charge while driving, EVs can potentially use smaller battery packs. This not only lowers the cost of the vehicle but also reduces the environmental impact associated with battery production and disposal.

Continuous charging minimizes the need for frequent stops at charging stations, integrating the charging process into the vehicle's normal operation and enhancing overall convenience for the driver. Dynamic charging can optimize the use of existing road infrastructure and contribute to a reduction in the environmental impact of battery manufacturing. By incorporating smart road technologies, it offers the potential for better traffic management and reduced emissions.

The development and implementation of dynamic wireless charging push the boundaries of current technology, fostering innovation in electromagnetics and power electronics. This, in turn, can lead to advancements in other related fields, such as autonomous driving and smart transportation systems. Despite its numerous advantages, dynamic wireless charging faces challenges, including high infrastructure costs, technical complexity, and efficiency issues. However, ongoing research and development efforts are focused on addressing these challenges, and advancements are expected to make the technology more viable and widespread in the future.

In conclusion, dynamic wireless charging represents a significant step forward in the evolution of electric vehicles. It has the potential to address many of the limitations of current EV charging solutions and to pave the way for more widespread adoption of electric vehicles. Asthe technology continues to evolve and become more integrated into our transportation infrastructure, it could play a crucial role in shaping the future of sustainable and efficient mobility.

FUTURE SCOPE

High-Power Charging: Advancements in high-power wireless charging will enable faster charging speeds, making long-distance EV travel more practical.

Expanded Infrastructure: Widespread adoption of wireless charging infrastructure in urban and rural areas, making EVs more accessible.

Multi-Standard Compatibility: Standardization of wireless charging protocols, ensuring interoperability across different manufacturers and regions.

Cost Reduction: Economies of scale and technological advancements will drive down costs, making wireless charging more affordable.

Increased Efficiency: Improvements in wireless charging efficiency, reducing energy loss and environmental impact.

New Business Models: Wireless charging will enable innovative business models, such as charging as-a-service and energy subscription plans.

Global Adoption: Wireless EV charging will become a global phenomenon ,transforming the transportation landscape and reducing our reliance on fossil fuels.

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