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Efficient Wireless Charging for Electric Vehicle

Yash Baviskar
Student, Department of Electrical Engineering
SVKM's Institute of Technology,Dhule
Maharshtra, India.

Madhavi Patil
Student, Department of Electrical Engineering
SVKM's Institute of Technology,Dhule
Maharshtra, India.

Sandeep Ushkewar
Assistant Professor, Department of Electrical Engineering
SVKM's Institute of Technology,Dhule
Maharshtra, India.

***Abstract*— In this project we designed a wireless power transmission charging circuit for electric vehicles to increase the battery life of the vehicle and also to sort out the issue of battery overheating due to plugged in charging. In plugged in charging heat losses are more and it directly affects the life of the battery so that Battery thermal management is the main issue for electric vehicles. There are mainly water cooled system is used in the electric vehicles right now for the cooling of the battery which is not so suitable for the EVs because the weight increases and it also acquires more size. Another alternative of the cooling system is air cooled system , which is we are using in the IC (internal combustion) engines right now , but in EVs this technology is not efficiently working due to more heat is produced at the time of charging of the battery. When we use wireless technology for the charging very less amount of heat is produced comparatively. Wireless power transmission with the help of inductive coupling is the main motive of our project.**

Keywords—Inductive, motive, internal combustion engines, coupling, plugged in, Thermal management.

I. INTRODUCTION

According to Government of India at the end of year 2021 about 75 % of the automobile market will be occupied by the Electric vehicles. Now a days IC engine vehicles are in used everywhere. But it has many drawbacks such as it runs on the gasoline and diesel engines so that they are conventional type of fuels and produces large amount of carbon emission as a side product which are very harmful for environment. Increasing demand is resulting in increasing in the price of the fuels.

So to overcome this, best option is the pure electric vehicles which will run on battery and will not produce any type of emission and which will be 100% eco friendly. But the major issue to use the electric vehicle is the time required for the charging of the EV and the lack of charging stations. In our project we are focusing on getting the things simple for the user with the help of wireless charging which is simply based on inductive coupling. Two plates will be placed one is on the car (receiving plate) and another is at the ground level (transmitting plate). So that user will not have to plug the charger always in the vehicles. When he will park the vehicle in the parking the charging will get started with about 97% efficiency and very less heat loss.

II. TYPES OF WIRELESS CHARGING

A. There are mainly four types of wireless charging based on operating techniques

1.Cpacitive wireless charging sysytem
2.Permenant magnetic gear wireless charging system
3.Inductive wireless charging system

1. Capacitive wireless charging system

Wireless transfer of energy between transmitter and receiver is accomplished by means of displacement current caused by the variation of electric field. Instead of magnets or coils as transmitter and receiver, coupling capacitors are used here for wireless transmission of power. The AC voltage first supplied to power factor correction circuit to improve efficiency and to maintain the voltage levels and to reduce the losses while transmitting the power. Then it is supplied to an H-bridge for the High-frequency AC voltage generation and this high frequency AC is applied to transmitting plate which causes the development of oscillating electric field that causes displacement current at receiver plate by means of electro static induction. The AC Voltage at receiver side is converted to DC to feed the battery through BMS by rectifier and filter circuits. Frequency, voltage, size of coupling capacitors and air-gap between transmitter and receiver affects the amount of power transferred. It's operating frequency is between 100 to 600 KHz.

2. Permanant magnetic gear wireless charging system

Here transmitter and receiver each consist of armature winding and synchronized permanent magnets inside the winding. At transmitter side operation is similar to motor operation. When we apply the AC current to transmitter winding it induces mechanical torque on transmitter magnet causes it's rotation. Due to the magnetic interaction change in transmitter, PM field causes torque on receiver PM which results it's rotation in synchronous with transmitter magnet. Now change in receiver permanent magnetic field causes the AC current production in winding i.e, receiver acts as generator as mechanical power input to the receiver PM converted into electrical output at receiver winding. The coupling of rotating permanent magnets is referred as **magnetic gear**. The generated AC power at receiver side fed to the battery after rectifying and filtering through power converters.

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3. Inductive wireless charging system

The basic principle of IWC is Faraday's law of induction. Here wireless transmission of power is achieved by mutual induction of magnetic field between transmitter and receiver coil. When the main AC supply applied to the transmitter coil, it creates AC magnetic field that passes through receiver coil and this magnetic field moves electrons in receiver coil causes AC power output. This AC output is rectified and filtered to Charge the EV's energy storage system. The amount of power transferred depends on frequency, mutual inductance and distance between transmitter and receiver coil. Operating frequency of IWC is between 19 to 50 KHz.

III. Plugged In Charging

There are so many chargers available for the charging of the EVs such as type 1, type 2, type 3 (based on the time required for charging).type 3 charger is the fastest among them all which required only 57 minutes to fully charged a EV of having battery capacity 40kw the charging having the rating of 50kwh so that we can see that there is a lot of energy loss in the charging and heat is also generated.

Fig.1 Plugged in Charging of EV

Electric vehicles chargers are classified according to the speed with which they recharge an EV's battery.

They are classified as follows:

i.Type 1

ii.Type 2

iii.Type 3 or DC fast charging

iType 1:

In Type 1 EV charging uses a standard household (120v) outlet to plug into the electric vehicle and takes more than 10 hours to charge an EV for approximately 75-80 miles. Level 1 charging is typically done at home or at your work place. Level 1 charger have the capability to charge most EV's on the market.

ii.Type 2:

Type 2 charging requires a specialized station which provides power at 240v. Level 2 chargers are typically found at workplace and public charging stations and will take about 4-10 hrs to charge a battery to 75-80 miles of range.

iii.Type 3:

Type 3 charging is also called as DC fast charging. It is currently the fastest charging solution in the EV market. DC fast charging are found at dedicated EV charging stations and charge a battery up to 90 miles range approximately 1 hours.

IV. Wireless Power Transmission Using Inductive Coupling

Resonant inductive coupling or magnetic phase synchronous coupling[5][6] is a phenomenon with inductive coupling where the coupling becomes stronger when the "secondary" (load-bearing) side of the loosely coupled coil resonates.[6] A resonant transformer of this type is often used in analog circuitry as a bandpass filter. Resonant inductive coupling is also used in wireless power systems for portable computers, phones, and vehicles. WiTricity type magnetic resonance coupling systems add another set of resonant coils on the "primary" (power source) side which pair with the coils on the secondary (load bearing) side.

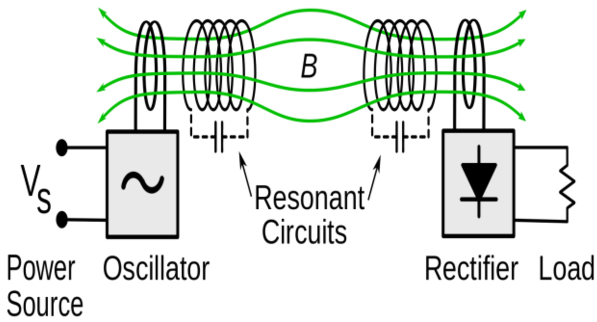

Fig.2 WPT using inductive coupling

Inductive coupling is the most basic type of wireless charging comparetively having more efficiency. Inductive Wireless Power Transfer (IWPT) Prototype

Two circuits are built to implement a successful wireless power transfer prototyping. The transmitter circuit contains a DC power source like a PV panel in real life. In order to have a magnetic flux in the coil, the current must be converted to AC. To do this, an oscillator must be placed in the transmitter circuit. This causes the DC voltage to fluctuate rapidly, thus simulating an AC voltage through the coil. The oscillator used for this circuit is a basic LC oscillator with three components: a capacitor, inductor coil, and switch. For larger scale, an inverter could be used instead of the oscillator. In order to have a good and stable wireless power transfer, the inductors need to have a good quality factor. Before finding the quality factor, the resonant frequency must be determined.Once the resonant frequency is calculated, the quality factor of the inductor coils can be determined to see if the selected values of inductance, capacitance, and the resonant frequency are feasible for the circuit. A good quality factor for a typical wireless power transfer system needs to be at least 100 or above [84-88]. To determine the quality factor of the coils, The DC voltage, the DC current, and the DC power are calculated respectively. The transmitter and receiver coils are arguably the most important components of the wireless power transfer circuit. The coils have to be constructed with the proper inductance that will create a magnetic flux big enough for the secondary coil to receive. Another key factor in finding the mutual inductance is the coupling coefficient. The coupling coefficient can be between 0 and 1 with 0 being no mutual inductance and 1 being the best mutual inductance.

V. WPT EFFECT ON BATTERY PERFORMANCE

In plugged in type of charging we are plug charger to the electric vehicle and then the charging gets started of the vehicle. Lithium ion battery is being used for the electric vehicles for driving of the traction motor.

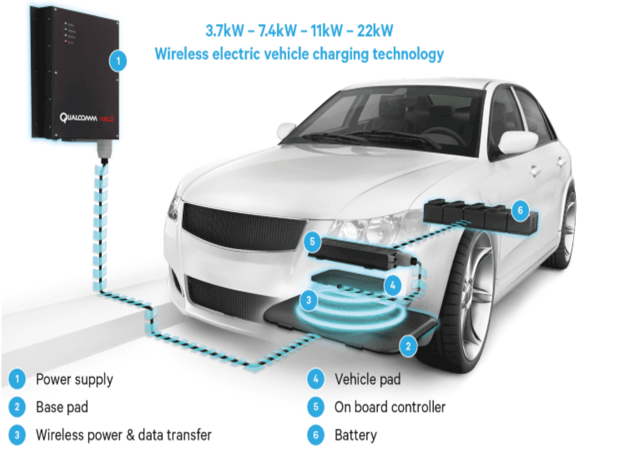

Fig.3 Actual Charging using inductive WPT

There are mainly water cooled system is used in the electric vehicles right now for the cooling of the battery which is not so suitable for the EVs because the weight increases and it also acquires more size. Another alternative of the cooling system is air cooled system , which is we are using in the IC (internal combustion) engines right now , but in EVs this technology is not efficiently working due to more heat is produced at the time of charging of the battery. When we use wireless technology for the charging very less amount of heat is produced comparatively.

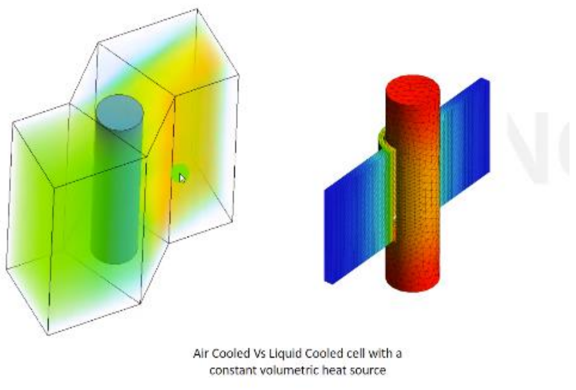

Fig.4 Types of battery cooling systems

Generally for an electric car 40 kilowatts battery is used (hyundai kona electric). Which requires a 50kwh rated charger to fully charge the vehicle in approximately 1 hour. So that we can see that there are so much losses are there which is in the form of heat. So that due to more amount of heat is generated while charging the chances of battery getting damage increases and life of the battery decreases and it also affects the performance of the battery. Batteries have to be babied. That's because batteries simply perform better when they don't have to deal with extreme heat or cold. When it comes to batteries for electric vehicles, so-called thermal management systems that ensure batteries operate within a certain temperature range, will be crucial to helping electric cars drive greater distances for a longer period of time.

VI. MODEL OF INDUCTIVE COUPLING WPT

Two circuits are built to implement a successful wireless power transfer prototyping. The transmitter circuit contains a DC power source like a PV panel in real life. In order to have a magnetic flux in the coil, the current must be converted to AC. To do this, an oscillator must be placed in the transmitter circuit. This causes the DC voltage to fluctuate rapidly, thus simulating an AC voltage through the coil. The oscillator used for this circuit is a basic LC oscillator with three components: a capacitor, inductor coil, and switch. For larger scale, an inverter could be used instead of the oscillator. In order to have a good and stable wireless power transfer, the inductors need to have a good quality factor. Before finding the quality factor, the resonant frequency must be determined as shown in equation (1).

$$f = 1/2\pi\sqrt{(LC)} \qquad (1)$$

Once the resonant frequency is calculated, the quality factor of the inductor coils can be determined to see if the selected values of inductance, capacitance, and the resonant frequency are feasible for the circuit. A good quality factor for a typical wireless power transfer system needs to be at least 100 or above [84-88]. To determine the quality factor of the coils, the equation (2) is used.

$$Q = (\omega L/R) = (2\pi f\, L)/R \qquad (2)$$

The transmitter and receiver coils are arguably the most important components of the wireless power transfer circuit. The coils have to be constructed with the proper inductance that will create a magnetic flux big enough for the secondary coil to receive. Another key factor in finding the mutual inductance is the coupling coefficient. The coupling coefficient can be between 0 and 1 with 0 being no mutual inductance and 1 being the best mutual inductance. By applying the equation (3), the mutual inductance between the two coils can be calculated .

$$M = K\sqrt{(L1.L2)} \qquad (3)$$

From above expression there are some points we have to be consider about the shape of the transmitting coils which we are going to use in WPT for the charging of the Electric vehicle

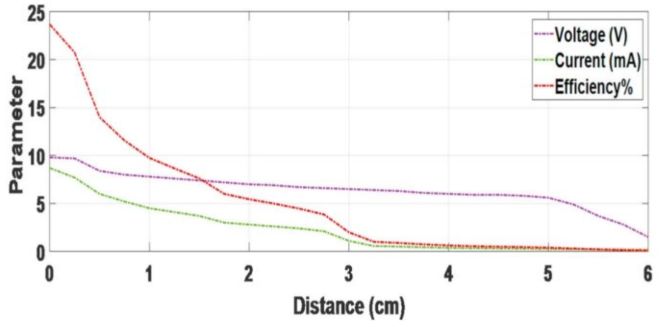

Fig.5 Voltage transferred, current and efficiency versus the distance in cm with Square plates

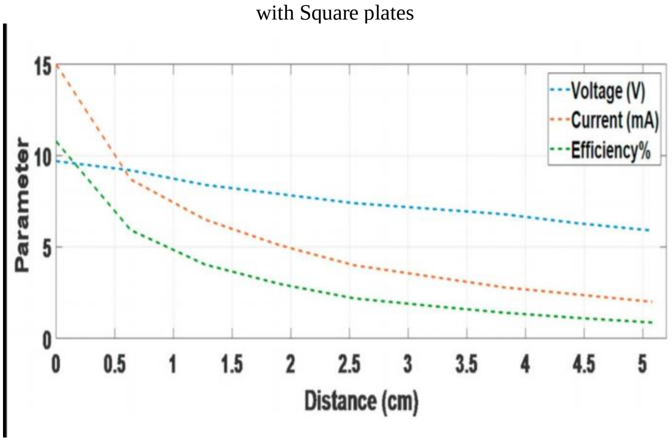

Fig.6 Voltage transferred, current and efficiency versus the distance in cm with round coils

From above two waveforms we can clearly conclude that square shaped plates are much more efficient than that of the round plates so we suggest that we must have to use square shaped plates for the inductive coupling for the charging of the electric vehicle. Also we can conclude from the above graph that distance plays an important role in the inductive coupling of the two plates, As the distance increases the efficiency decreases, So that distance and efficiency are inversely proportional to each others. The quality factor for the square coils is greater than or equal to 100, so this makes them acceptable to use in a wireless power transfer system. In order for the circuit to operate at proper resonance. Samples of the experimental measurements characteristics are shown in figures 5, and 6 for round and square coils respectively. It is observed that the magnetic field between the two coils decreases as the distance between them increases. In magnetic induction wireless power transfer, current passes through the transmitting, which produces a varying magnetic field, thus inducing a current in the receiving coil, which helps to charge the electric vehicle. Its power transfer efficiency depends on the closeness of the two coils.

VII. FUTURE SCOPE

The electric vehicles global wireless charging market is predicted to record a CAGR of 45% during the period from 2018 to 2023. However, there are important issues which they have to be addressed and to be researched such as passenger vehicles, storage lifetime, uncertainty incorporation, the suitable size of for a wireless charging passenger EV's battery, the required city wireless charging infrastructure, investigating energy and environmental impacts, the impact of charging lanes over the traffic, and using this technology in other applications. Some other research points have to be targeted such as removing battery range concern, improving battery efficiency, autonomous charging park investigation, EV solar roofs, fast wireless chargers standardization for various EV models, exploration of ultra AC, DC fast charging competences, dynamic charging, wireless rad charging, and the adoption of 11-22 kW charging capacity or more. So, the future for wireless power has the potential to achieve great things. Compared to the possibilities wireless power transfer has, this work is a fraction of what it could do and with more research, this technology will be able to reach a greater impact in the future. Efficiency enhancement utilizing an optimization gadget, design, strategies with their control for wireless charging systems under various load scenarios are studied.

VIII. CONCLUSION

Various wireless power transfer (WPT) approaches are presented along with their advantages and drawbacks. The paper presents an adequate in brief review of recent EV wireless power charging researches. It has also an experimental small-scale-model for a better understanding of the wireless concept. The power transfer efficiency of the inductive power transfer is much greater than that of the round coil and helps create a better overall wireless power transfer system. Although the square coils are much more efficient than the round coils, the efficiency is still very low. There are various scenarios that could possibly improve this. A recommendation could be made to use a thicker wire that creates a bigger length in the coil as well. Having a bigger coil length could also help increase the inductance and magnetic field, which would, in turn, could possibly create a higher transfer efficiency. Inductive wireless power transfer prototypes are experimentally implemented for round and rectangular coils. In addition, another model is implemented for better conceptual understanding. The work at all emphasis on the promising future and growing market for the wireless electric vehicles charging technology.

Its Efficiency is about 97% so it will minimize the heat losses during charging and battery life and efficiency will get increased. Size of the battery will also get reduced and as a result of it cost will also get decrease.

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