# A HIGH-EFFICIENCY DYNAMIC WIRELESS CHARGING SYSTEM FOR ELECTRIC VEHICLES IN MOTION

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**Abstract** - *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 MATLAB 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 gain efficiency up to 94%- 96% and take 50-60 minutes. 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.*

**Key Words: Wireless charging, Electric Vehicle (EV), Wireless Power Transfer (WPT)**

## 1.INTRODUCTION

Electric Vehicles have started their journey when General 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 in the technology of the electric automobile. Wireless Charging System (WCS) is working on the theory of Mutual induction is a phenomenon introduced by Sir Nikola Tesla in 1887 where an induced emf is caused in the second coil known as receiver coil can create electrical energy with a given current in the first coil known as transmitter coil.

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. Project design and S-S (series- series) WPT system with a 40 kHz to 85 kHz resonant frequency. They found that the WPT system is in better use for light-duty EV applications. But, one of the big challenges facing EV makers is the issue of dynamic charging. Since wireless charging of EV is introduced, two methods are very effective for WPT. They are capacitive wireless power transfer (CWPT) and resonant inductive power transfer (RIPT). Some researches show that efficiency and power density are much higher in inductive charging than capacitive charging. Also, inductive parameters significantly depend on the dimension of the coupling coils. Many researchers are working on how maximum power can be transferred to the receiving pad and increase the overall efficiency of EVs in dynamic conditions. Butthe efficiencies of most work are under 90 percent for RIPT also. The other factor which is affecting the overall efficiency is misalignment whiledriving the EV. The efficiency will be decreased with increase in misalignment between the transmitter coil and receiver coil. Project the coupling co-efficient decreases from 0.2 to 1.6 for 20% misalignment between the coils compared to misalignment free condition. Different types of shielding material can be used for magnetic field alignment and leakage flux reduction. It has been seen that ferrite object restricts the magnetic fields and will not cause any harm to the neighbor objects. Shapes of ferrite also depend on the coil. They can be Circular, circular striated, square, and rectangular, T-core, U-core, E-core, Double U, and striated blocks.

Wireless Charging Units (WCUs) are placed on the road so that when a vehicle is driven over the WCUs, catches power by using mutual induction for wireless charging, which is known as dynamic charging. By enhancing EVs transit range, it can solve the limited issue range. But there are two main obstacles in dynamic WCS, horizontal misalignment and large air- gap between the charging lane and the EV. The efficiency of power transfer mainly relies on the coil alignment and air-gap distance within the coils. The power transfer among two coupling coils increases when the distinct distance among the coils decreases. There are different types of coil structures such as circular pad (CP), circular rectangular pad (CRP), double-D pad (DDP), double-D quadrature pad (DDQP) bipolar pad (BPP), etc. Using DD and QDQ coil it is shown that the inductive system maintains maximum efficiency whether it is perfectly aligned or misaligned in the position of coils. Regarding the small vehicle, there is a variation of the average air-gap distance between 150 to300 mm. So, simulation and calculation between these ranges are discussed in this work. But it canincrease for larger vehicles. In this Project, dynamic WPT in the mean of mutual induction discussed elaborately. Then modeling of the transmitter coil and the receiver coil and simulation for WPT are shown by Ansys Maxwell software. Ansys Maxwell is a modeling and simulation software which analyze in electromechanical components common to wireless charging, electric machines, transformers and many more. Therefore, verify the output data with the help of mathematical expression. Also, load power and efficiency are calculated here. Finally, how much power an EV can collect from the charging lanewhile it is driven over it and how extra distance it can travel with this consumed power is calculated. There are many research works regarding simulation and calculation of transmitter coil and receivercoil of WPT. But there is no work till now which showed how much power we can get in dynamic WPT and how far we can go with this extra power.

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## 1.1 WIRELESS POWER TRANSFER

### A. WPT SYSTEM

In a generic WPT system for EV, high-frequency ac poweris supplied in the transmitter end and transfer the power to the receiver end over a specified distance. As RIPT is the most effective WPT for EV so, it is discussed here briefly and the whole structure is designed based on RIPT.

### 1) RESONANT INDUCTIVE POWER TRANSFER

IPT method can transfer power by the inductive coil. It is the most efficient process for WPT in the static method where the receiver coil is in the centered position over the transmitter coil. But if we think of dynamic charging then the receiver coil is movable as shown in Fig. 1 and can barely collect the magnetic flux from the transmitter coil. Hence a capacitor is used on the transmitter side and as well as on the receiver side known as a compensation network to resonant the transmitter coil and the receiver coil. This method is called the RIPT method. RIPT method is the most efficient - among all technologies to transfer power wirelessly in short-range. There are four compensation networks in the RIPT method, series- series (s-s) compensation, series-parallel (s-p) compensation, parallel- parallel (p-p) compensation, and parallel- series (p-s) compensation. In this work, s-s compensation is used because, in the s-s compensation network, maximum power is transferred to the receiving pad. Also, RIPT has a higher switching frequency compared to IPT.

### B. CHARGING METHOD

Low-frequency ac power from the grid is converted into a high frequency ac through ac-dc converter and dc-ac inverter. To ensure maximum power transfer to the receiving end, s-s compensation topology is used in the transmitter coil and the receiver coil. The transmitting pad is typically mounted beneath the surface of the road and the receiving pad is mounted underneath the vehicle. The receiver pad is usually mounted lower from the frame of the EV to help to catch more magnetic flux. The high-frequency AC is then converted into DC by using an AC/DC converter and sent to the battery bank. The battery management system (BMS). Here, the main work is focused on the transmitter coil and the receiver coil as it is the most important part of the whole system assuming the other parameters ideal. Varying the properties of these two coils can bring improvement in the overall efficiency.

### 2) EQUIVALENT CIRCUIT DIAGRAM

In this Project, 70A current is used because there is no abrupt voltage drop in the resonance case until the input current is 70A. Also, the increase in input current will increase the overall efficiency. The resonant frequency is set to 85 kHz an equivalent circuit diagram for the RIPT system. In the receiver end, an AC/DC is converter is used to convert the high- frequency ac to dc output. $C_1$ and $C_2$ are resonant capacitors of transmitting pad and receiving pad respectively. The circuit simulation is done in LT spice circuit simulation software. In this software, direct mutual induction representation is not possible. Hence simulated for the load current.

**Need for Wireless Power Transfer**

Conventional wired systems introduce several challenges such as cable degradation, connector corrosion, spark generation, and limited mobility. Wireless systems overcome these limitations and improve reliability, safety, and operational flexibility.

**Classification of Wireless Power Transfer**

Wireless power transfer systems can be classified into:

1.InductivePowerTransfer(IPT)
2.CapacitivePowerTransfer(CPT)
3.HybridPowerTransfer(HPT)
4.MicrowavePowerTransfer
5. Laser-based Power Transfer

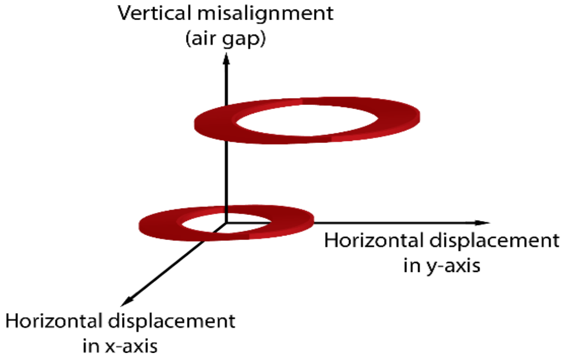

**Fig.1.2.1** Transmitter coil and receiver coil misalignment

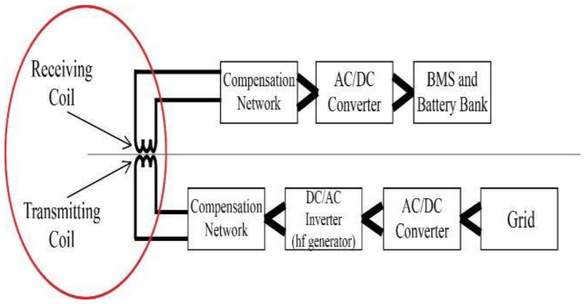

**Fig.1.2.2** Block diagram of grid-to-vehicle (G2V) wireless charging system for an EV.

The grid-to-vehicle (G2V) wireless charging system transfers electrical energy from the utility grid to the battery of an electric vehicle without using physical connectors. Initially, AC power from the grid is converted into DC and then inverted into high-frequency AC using a DC/AC inverter. The transmitter-side compensation network tunes the system to resonance and supplies the transmitting coil, which generates an alternating magnetic field. The receiving coil mounted on the vehicle captures this magnetic field and induces an AC voltage. The receiver-side compensation network enhances power transfer by matching the resonant frequency. The induced AC power is rectified into DC and supplied to the Battery Management System (BMS), which controls and protects the battery charging process. This contactless charging method improves convenience, safety, and reliability for electric vehicle applications.

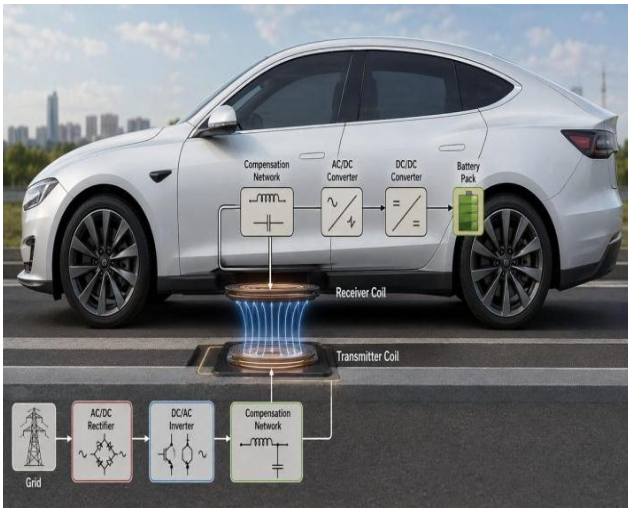

**Fig 1.2.3**: Overall Architecture of an Electric Vehicle Wireless Charging System

## 2. COIL DESIGN

### A. TRANSMITTER COIL AND RECEIVER COIL

There are different shapes of coil used in WPT systems. Among them, the circular coil is the most effective structure in high-frequency wireless transfers as there are no sharp edges. So, the eddy current is kept to minimum. The high magnetic field produced by the coil causes better performance in the WPT system. The proposed transmitter coil and the receiver coil.

### B. COIL SPECIFICATIONS

Many parameters affect the performance of circular coil such as outer radius, inner radius, pitch, number of turns, and the radius of conductor. The parameter set for the transmitter coil and the receiver coil is shown in Table 1. In this work, the size of both coils is the same.

**TABLE 1:** Specification of the transmitter coil and the receiver coil.

| Name | Transmitter coil | Receiver coil |
|---|---|---|
| mber of Turns | 18 | 18 |
| ner coil radius | 140mm | 140mm |
| ter coil radius | 232.5mm | 232.5mm |
| Radius Change | 5.3mm | 5.3mm |
| Radius of conductor | 2.34mm | 2.34mm |
| Pitch | 0 | 0 |

The mutual inductance between the transmitter and receiver coils is

$$M = k\sqrt{L_1 L_2}$$

Where:

- M = Mutual inductance (H)
- k = Coupling coefficient
- L1= Primary coil inductance
- L2 = Secondary coil inductance

## 3. SIMULATION AND RESULTS

The Below MATLAB/Simulink model represents a complete Wireless Power Transfer (WPT) system for charging an Electric Vehicle (EV). The simulation begins with an AC voltage source, which is converted into DC using a full-bridge diode rectifier placed at the left side of the model. The rectified output is filtered using a DC-link capacitor to provide a smooth and constant DC voltage. This DC voltage is then supplied to a high-frequency full-bridge inverter consisting of four MOSFET switches (S1, S2, S3, and S4). The switching pulses for the inverter are generated by a PI Controller and PWM Generator, located at the bottom of the model, which regulates the output voltage by comparing the measured DC output voltage with a reference value (400 V). The inverter converts the DC supply into high-frequency AC, which is applied to the primary resonant compensation network formed by capacitor C1 and the transmitter coil. The transmitter coil is magnetically coupled to the receiver coil through an air gap, representing wireless energy transfer. On the receiver side, another compensation capacitor (C2) is connected to maintain resonance and maximize power transfer efficiency. The received AC power is then converted back to DC using a second full-bridge diode rectifier, and the output is filtered by a capacitor before being supplied to the battery model, which represents the EV battery. Various voltage and current sensors are included throughout the model to measure parameters such as input current, DC-link voltage, inverter current, output voltage, battery current, and charging power. Mean blocks and scopes are used to calculate and display average power, voltage, current, and battery charging characteristics. This simulation demonstrates the complete process of converting grid AC power into regulated DC power and transferring it wirelessly to charge an electric vehicle battery efficiently.

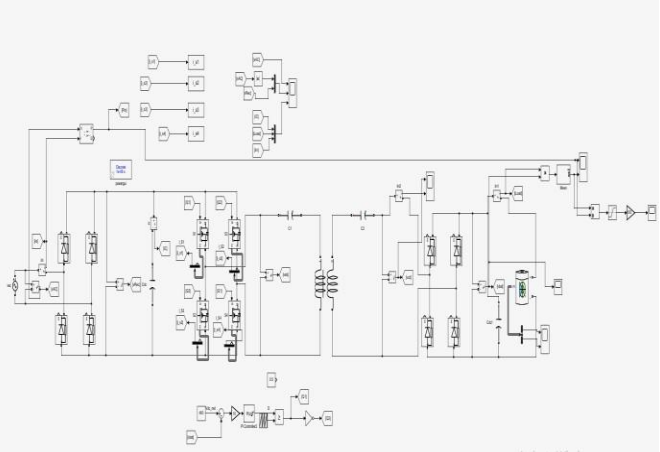

**Fig 3.1:** Simulation Circuit of Wireless power transfer (WPT).

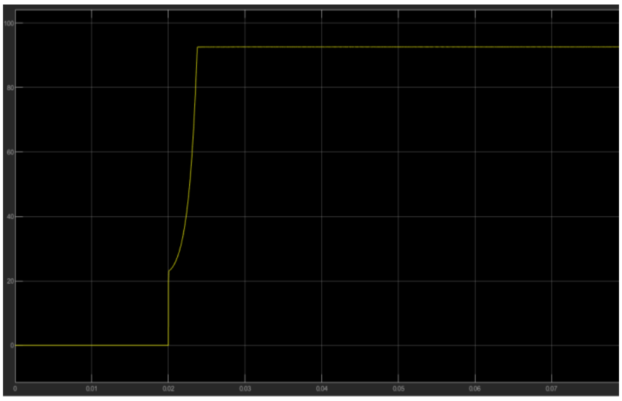

**Fig 3.2:** Waveform of maximum efficiency for k=0.9 in Wireless power transfer (WPT).

The scope output shows the variation of output DC voltage with respect to time. The voltage remains low until 0.02 s, after which the wireless charging system is enabled. The voltage rapidly increases and reaches the desired value of approximately 400 V. The PI controller regulates the output voltage and maintains a stable charging voltage for the electric vehicle battery, demonstrating effective voltage control and successful operation of the wireless power transfer system.

The Efficiency that can be obtained is approximately 94% for 150mm of air gap and Coupling coefficient is approximately (k=0.9).

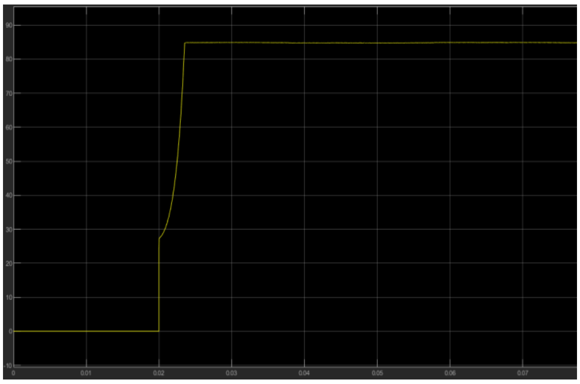

**Fig 3.3:** Input and output power values

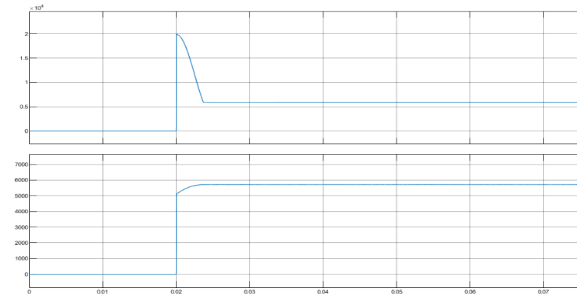

**Fig 3.4:** Waveform of efficiency for k= 0.7 in Wireless power transfer (WPT).

The scope output shows the variation of output DC voltage with respect to time. The voltage remains low until 0.02 s, after which the wireless charging system is enabled. The voltage rapidly increases and reaches the desired value of approximately 400 V. The PI controller regulates the output voltage and maintains a stable charging voltage for the electric vehicle battery, demonstrating effective voltage control and successful operation of the wireless power transfer system.

The Efficiency that can be obtained is approximately 85% for 200mm of air gap and Coupling coefficient is approximately(k=0.7).

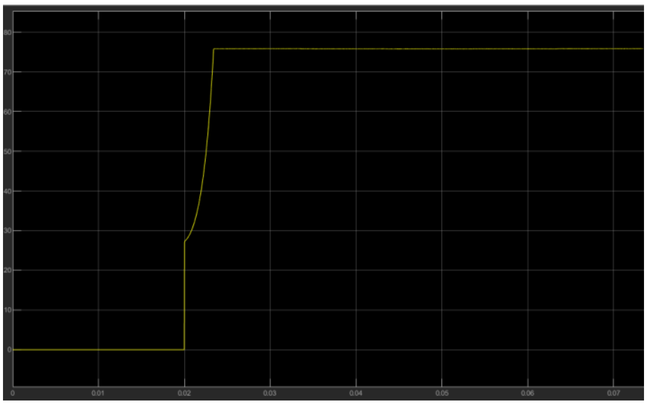

**Fig 3.5:** Waveform of efficiency for k= 0.6 in Wireless power transfer (WPT).

The scope output shows the variation of output DC voltage with respect to time. The voltage remains low until 0.02 s, after which the wireless charging system is enabled. The voltage rapidly increases and reaches the desired value of approximately 400 V. The PI controller regulates the output voltage and maintains a stable charging voltage for the electric vehicle battery, demonstrating effective voltage control and successful operation of the wireless power transfer system. The Efficiency that can be obtained is approximately 75% for 250mm of air gap and Coupling coefficient is approximately (k=0.6).

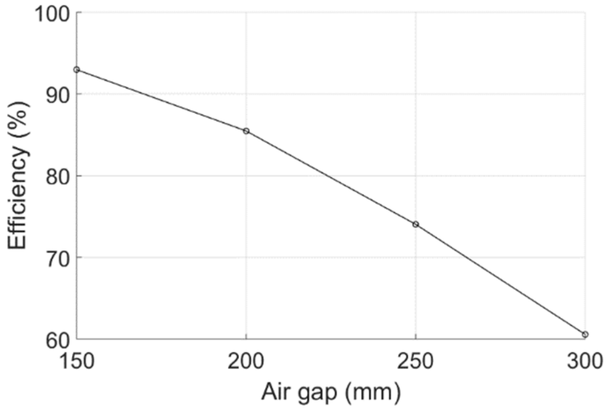

**Fig 3.6:** Decreasing efficiency with the increase in air gap

At the minimum measured air gap of 150mm, the system achieves its highest efficiency of approximately 94%. And as the air gap is increased to 200mm, the efficiency steadily drops to 85% and when the air gap is increased to 250mm the efficiency is further drops to 75% and at the maximum measured air gap of 300mm the efficiency plummets to its lowest point of 61%.

The graph demonstrates a strong, inversely proportional relationship between the air gap distance and system efficiency. For dynamic wireless charging to remain viable while driving, optimizing vehicle ground clearance or implementing advanced impedance matching networks is crucial to mitigate these efficiency losses over larger distances.

## 4. CONCLUSIONS

Research on WPT is getting popular these years. This project work compares the most famous WPT technologies and develops an effective one known RIPT. The RIPT method is used for resonating the transmitter coil frequency and receiver coil frequency. It shows how air gap and misalignment affect the WPT while the EV is driven in the charging lane. Firstly, WPT is simulated in the MATLAB simulation software to see the reduction in mutual inductance for air gap and horizontal displacement between the coils in x- axis and y-axis. Then verify the output data, The calculation for load power and efficiency for the 150mm air gap is shown. From the load power, the time for the full charge of the battery of an EV can be easily determined. Hence, a model is established to see the power transfer for different speeds and finally how far the EV can go with this consumed power. But, how efficiently the receiver pad can catch the power from the transmitter pad is also depends on the speed of the EV. Shielding materials like ferrite plates and aluminum plates can be used to transfer more power to the receiving end. This work helps to understand the wireless charging of EVs in the track for high resonant frequency in the means of RIPT and can be extended for future work in this field.

Simulation results show that electrical energy is transferred efficiently across the air gap without any physical connection. The output DC voltage rises quickly and stabilizes around the reference value of approximately 400 V, confirming proper closed-loop control and stable charging performance. The battery receives a regulated DC supply suitable for charging, while the resonant compensation network improves power transfer efficiency and reduces switching losses. The model validates the feasibility of using wireless charging technology as a safe, convenient, and reliable solution for electric vehicles.

The main purpose of this Project work is to show the wireless power transfer of an EV while it is in motion based on vertical and horizontal misalignment. Misalignment of coils are also designed and simulated for getting aclearand broad knowledge about dynamic WPT. Overall, the project proves that wireless power transfer can provide effective battery charging and has strong potential to support the growing adoption of electric vehicles by eliminating charging cables and enhancing user convenience.

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