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Simulation and Hardware development of a Wireless charging of EV in urban and Rural Areas

Poushali Pal[1*], Vaishna Sunil[1] and Nava Prakash[2]

[1]Translational Research and Professional Leadership Centre, Government Engineering College, 695035, Barton Hill Colony, Kunnukuzhy, 695035, Thiruvananthapuram, Kerala, Índia. [2]Department of Electronics and Communication Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India. *Author for correspondence. E-mail: poushali.nits@gmail.com

ABSTRACT. Electric vehicle is the most emerging and developed technology in the recent days due to its performance. The charging infrastructure of the electric vehicle is of great concern as it has the great impact on the performance of Electric Vehicle. Recently, many companies have developed the wireless charging method of EV with which the use of bulky cables can be avoided and the sparking during plugging/unplugging is also reduced. A model is simulated using MATLAB Simulink for wireless charging of EV. The simulation is carried out for different wireless power transfer method.

Keywords: EV, wireless charging, state-of-charge (SoC), track coil and pick-up coils, arduino

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Introduction

Electric vehicles (EVs) are considered one of the environment and user friendly alternative to the conventional vehicles which are using fossil fuels. Whereas, the EVs are using battery which can be recharged using renewable energy sources. Despite of having several advantages, EVs are not much highly rated due to lacking of some factors like affordable cost, high safety levels, high power density levels, long cycle lifetime and a low volume and weight.

The concept of wireless charging of Electric Vehicles (EVs) stands for a significant advancement in convenience and Sustainability in the automotive industry. EV requires fast,economical and reliable charging system for the efficient performance.This charging method removes the problem of plugging in the device compared to the other conventional wired charging system. Moreover, the wireless charging system is environment and user-friendly as there is no need of bulky cable.

Despite different advantages,there are some challenges of implementing the wireless charging of EV that is needed to be addressed.

Lithium-ion batteries are known for the competitive solution, but the energy densities available is less than 100Wh kg^{-1} at the finished battery level. Adding to it, the maintenance and energy costs are expected to be extra 1000USD per year to own and operate an EV as compared to a gasoline-based vehicle (Inoue et al., 2013). The charging system of the EV battery plays a key role for its market gain. So, it is necessary to have research on the existing charging methods of EV. On-road charging system of EVs is having great impact on reducing the battery capacities and increasing the driving range. The value of equivalent load resistance for maximizing the receiving power of EV is investigated. A novel on-road charging system is developed using a single transmitting and multiple receiving coils. In addition to that, the power control strategies for varying numbers of EVs are also presented (Tan et al., 2016)

The contactless power transfer method is possible with the inductive power transfer method and the transfer of electrical energy is possible without cables or contacts. A novel systematic modular design is presented that will increase the transfer efficiency and positioning flexibility of the consumer device (Kurschner et al., 2013)

WPT, is more convenient, the battery capacities of EVs can be reduced to 20% or even lesser than 20% WPT has many advantages like plugs, cables and outlets are unnecessary, they are friendlier in charging process, the charging process will not be getting interrupted with the environmental conditions and they require lower maintenance and are safer. Moreover, vandalism will be lower compared to a conductive charging system (Budhia et al., 2010). WPT also has some drawbacks, few can be pointed like, the efficiency decreases with the increase in the air gap between the coils as the coupling factor decreases (Elnail et al., 2018). Hence a ferromagnetic material is used to improve the coupling coefficient and quality factor, in order to get a maximum efficiency (Imura et al., 2009). The charging infrastructure and the material used plays significant role in the power transfer performance.

If a continuous charge while in motion is achieved, then the problems including, low battery energy density can be eliminated because as a heavy and high capacity battery will no longer be needed, the rate can be reduced. Hence it will bring out the advantage of lowering total EV costs, weight and its autonomy. Therefore, introducing this technology will boost up the EV adoption rate in the market. The dynamic charging of the battery will reduce the problems such as low battery energy density (Covic & Boys, 2013). Dynamic charging is developed in two ways, such as one large single transmitter track (Choi et al., 2013) or by an array of adjacent transmitter coils.

Most of the literature deals with the simulation of wireless charging method of EV. Real-time implementation of the wireless charging method is less in the existing literature. Moreover, the research on maximizing the power transfer capacity from the transmitter coil to receiver coil is less. So, in order to bridge the research gap, a wireless charging infrastructure designed and simulated in MATLAB. It also enlighten on the comparison of two different methods of wireless power transmission such as inductive coupling power transmission and capacitive coupling power transmission and a lab-scale model of wireless charging of EV is developed. The implemented model consists of two-way conversion with rectifier inverter circuit for the maximum power transfer and to improve the efficiency.

Application of wireless charging systems for EV in urban and rural areas

The application of wireless charging systems for electric vehicles (EVs) in urban and rural areas holds great promise for enhancing the adoption of electric mobility and improving overall sustainability. Wireless charging, also known as inductive charging, uses electromagnetic fields to transfer energy between a charging pad on the ground and a receiver installed in the vehicle, eliminating the need for physical connectors and providing a more convenient charging experience. Here's how it can be applied differently in urban and rural contexts:

Urban Areas

Urban environments are characterized by high population density, heavy traffic, and often limited parking space. Wireless charging systems could address several challenges in these areas:

a. Convenience and Accessibility

• **No Physical Plugging Required**: In busy urban settings, where time and convenience are critical, wireless charging allows drivers to charge their EVs without needing to physically plug into a charger. This can be especially beneficial for people living in apartments or densely populated areas where parking spaces may not be equipped with charging stations.

• Charging While Driving: Wireless charging embedded in roads, especially along high-traffic corridors, could allow EVs to charge while they are moving. This could drastically reduce the need for stationary charging infrastructure in cities.

b. Space Efficiency

• **Increased Parking Utilization**: Urban areas suffer from a lack of parking space, and retrofitting every parking space with wired charging infrastructure can be challenging. Wireless charging can make charging stations more compact, allowing for efficient use of space.

• **Street Infrastructure**: Wireless charging pads can be embedded into roads, sidewalks, or public spaces, reducing the need for standalone charging stations and allowing public infrastructure to double as a charging network.

c. Reduced Congestion

• **On-Street Charging**: Wireless charging embedded in public roads can enable EVs to charge while driving or while parked along city streets, reducing congestion around static charging stations. It could also eliminate the need for large charging station installations in areas that lack space or where traditional charging might interfere with urban planning.

d. Smart Grid Integration

• **Energy Management**: In urban areas, the integration of wireless charging systems with smart grids can allow for dynamic energy management, where power distribution adjusts based on demand and supply. EVs can be charged during off-peak hours or when excess renewable energy is available.

Rural Areas

Rural areas present a different set of challenges and opportunities for wireless EV charging. These areas tend to have less population density and fewer charging stations, so the wireless charging infrastructure must be adapted to their specific needs.

a. Overcoming Infrastructure Challenges

- **Remote Locations**: Rural areas often lack sufficient EV charging infrastructure, which can create 'charging deserts.' Wireless charging can be more easily deployed in remote locations without the need for complex wiring or the installation of large charging stations. This makes it more cost-effective and accessible.
- **Integration with Rural Roads**: Wireless charging pads can be installed in rural roads or highways to create charging 'corridors.' As EVs travel longer distances between towns, wireless charging pads can allow for continuous charging on the go, reducing range anxiety for drivers.

b. Cost-Effectiveness

- **Lower Upfront Costs**: For rural municipalities or businesses, the cost of installing wireless charging pads may be lower than installing traditional charging stations, especially in areas where it is difficult to connect to the grid. Wireless charging solutions could thus be a more attractive investment.
- **Decentralized Charging Infrastructure**: Rather than building large centralized charging stations, rural areas could benefit from the decentralized nature of wireless charging, where smaller, localized charging points can be spread over a wider area. This can ensure better coverage without the need for major infrastructure projects.

c. EV Adoption Encouragement

- **Enabling Longer Distances**: Wireless charging infrastructure along rural highways and key routes can help make EVs more viable for people in rural areas by ensuring that they have the range to travel between small towns, without worrying about charging stations along the way.
- **Encouraging Rural EV Adoption**: As rural areas may have fewer public charging stations, the availability of wireless charging pads in homes, farms, or businesses could encourage EV adoption in regions where electric vehicle infrastructure is still nascent.

d. Integration with Renewable Energy

- **Solar and Wind Power**: Rural areas often have greater access to renewable energy sources like solar and wind. Wireless charging systems in these areas could be paired with decentralized renewable energy generation (e.g., solar panels on homes or wind farms) to charge EVs using clean energy, contributing to sustainable transportation solutions.

Barriers on installing EV in Urban and Rural areas

Though the EV plays a key role for maintaining sustainability and carbon management, still the development and implementation of efficient charging infrastructure is a challenge. The factors involved in the purchase of EV is discussed in the work (Sampath et al., 2016).

Grid integration,range tension and the need of standardization are the main issues that should be addressed while implementing the wireless charging of EV (Tan et al., 2016).

Some of the challenges in EV implementation can be listed as follows:

- Inadequate availability of the charging stations especially in the he rural areas which is one of the key reason of discouraging the EV adoption.
- High installation cost of charging station is also an important reason.
- Concerns about battery degradation and health is also effecting the deployment of EV.
- Insufficient Government Policy and Regulation is one of the key reason of adopting EV.
- Challenges of installing the wireless charging system in Urban areas due to limited space, high property cost.
- Efficient wireless charging system will be hard to maintain due to the high electromagnetic Inference and high density of buildings.

In the existing EV, the methods and techniques used for wireless charging in electric vehicles is discussed (Sampath et al., 2016). Capacitive power transfer and inductive power transfer which are the two main types of wireless charging are compared and contrasted.

Research Objectives

- Modelling of the wireless charging of EV with MATLAB Simulink.
- Analyse the different methods of wireless charging of EV.

- Implementation of wireless charging of EV using Inductive Power Transfer method.
- Development of prototype model of wireless charging of EV.

Ensuring high efficiency of power transfer is crucial to minimize energy losses during charging. DWC systems need to optimize the coupling between the road infrastructure and the vehicle to achieve efficient energy transfer while minimizing electromagnetic interference and energy dispersion (Palani et al., 2023).

Alignment and Positioning: Maintaining precise alignment and positioning between the charging infrastructure embedded in the road and the receiving coils on the vehicle is challenging, especially at high speeds. Variations in vehicle position and orientation must be accounted for to maintain effective power transfer (Panchal et al., 2018).

Safety: Ensuring safety for both vehicles and pedestrians is critical. DWC systems must mitigate electromagnetic radiation and ensure that electromagnetic fields generated during charging do not interfere with electronic devices or medical implants. Additionally, there are concerns about exposure to electromagnetic fields for drivers and passengers.

While wireless charging is convenient, it’s still generally less efficient than wired charging. In both urban and rural areas, advancements in technology will be required to improve efficiency and reduce energy losses, especially for fast-charging systems. The installation costs for wireless charging infrastructure, especially for embedding it in roads or developing large-scale wireless charging networks, can be high. Both urban and rural areas would need significant investment and planning to implement such systems effectively. The development of universal standards for wireless charging is crucial for widespread adoption. Policies will need to ensure compatibility between different EV models and charging systems, whether in urban or rural settings.

Wireless EV charging holds significant potential for transforming both urban and rural mobility. In urban areas, it can alleviate space constraints, enhance convenience, and integrate with smart city infrastructure. In rural areas, it can overcome challenges related to limited charging infrastructure, encourage EV adoption, and provide access to cleaner energy. With the right technological advancements, investments, and policies, wireless charging could be a key component in the future of sustainable transportation in both urban and rural environments.

Research methodology

The whole work is carried out in different phases Figure 1 represents the methodology of the work.

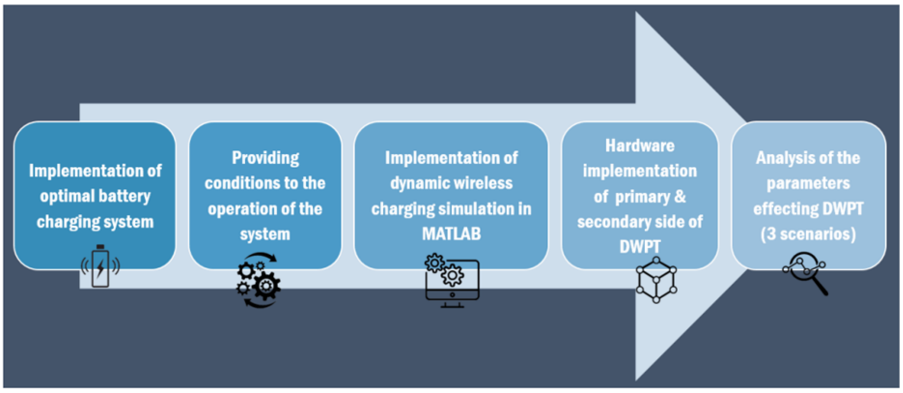

Figure 1. Methodology.

The battery charging system is most crucial for EV. So, a controller-relay based system is designed for the efficient charging of the EV battery. The implantation is carried out through MATLAB simulation where the relay switch will operate based on the battery SoC. It will allow the battery to be charged if the SoC is less than 30% and maximum charging will upto 80% SoC. Before implementing the wireless power transfer in real time, it should be developed in software called MATLAB. And the analysis is carried out. The real time modelling is carried out by developing the primary and secondary side of the dynamic wireless power transfer. The model will be analyzed in four different scenarios for the further understanding and improvement of the model. This modelling is divided into two parts, one is the optimal charging system for dynamic wireless power transfer of EV and the second is dynamic wireless power transfer for EV. Even though these two systems are developed separately, optimal charging system is actually a part of EV (Elliott et al., 2006).

Before moving on to the work, an understanding was necessary to know about the feedback from the EV customers, there response about the EVs. A public survey was conducted for understanding the requirement and further improvement from the EV customers. The questions were general like the reasons behind their choice of adopting EV and the qualities they liked and want to improve further. These were asked among college students, government employees and other people who were using EV in daily basis in Thiruvananthapuram city and rural areas. The major part of the people demanded for the increase in the travelling range of EV. And when discussed about the wireless charging of the EV, most of them had a positive feedback on this technique. The results of the survey are shown in Figure 2.

The architecture of the dynamic wireless power transfer system developed for EV is shown in the Figure 2. The power from the supply grid is allowed for a two-stage conversion for improving the power factor and frequency using rectifier and inverters, where 230V AC is converted to DC-AC in high frequency range of 60-80 KHz. The Figure illustrates the working of the dynamic wireless power transfer along the electrified roadbed where the transmitting/track coils are deployed and how it can charge the battery of the EV, the power received to the receiving/pickup coils are allowed to pass through the charge controlling unit as shown in the Figure . A switching sensor has a function of optimal charging of the battery while moving on the electric roadbed. It will ensure a safe and efficient charging of the battery depending on the SOC of the battery. A feedback section is provided for the monitoring of SOC of the battery. This switch will allow the power to charge the battery only when the SOC level is below the mentioned value. The power received is AC, it is converted in to DC for charging the battery (Gerssen-Gondelach, & Faaij, 2012).

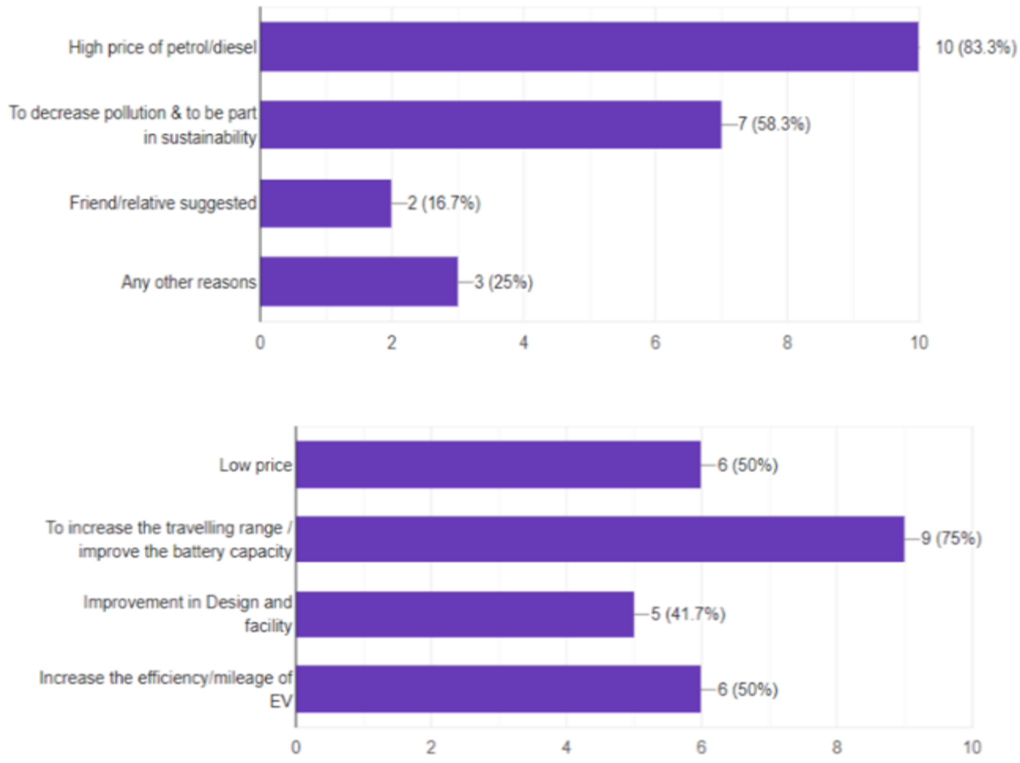

Figure 2. Survey results.

Modeling and Simulation of Dynamic Wireless Power Transfer

The model is designed on the basis on inductive wireless power transmission, which is commonly used for the wireless power transmission (Huh et Al., 2011a and b). This method is based on the principal of mutual induction between transmitter and the receiver coil. The losses in the both sides of the winding are not considered.

$$At = -Vt * It. \tag{1}$$

$$Ar = Vr * Ir. \tag{2}$$

Where At and Ar are the apparent power exchanged between the transmission and receiver end. Vt and It are the voltage and current respectively developed in the transmitter side whereas Vr and Ir are the voltage and current respectively developed in the receiver side. The active power transferred from the transmitting side to the receiving side can be expressed in the below stated equation.

$$Atr = \omega * Mi * It * Ir * \sin \varphi tr \quad (3)$$

Where Atr represents the active power, Mi is the mutual inductance developed; It and Ir are the root mean square.

The block Diagram of the proposed system is shown in the Figure 3. It mainly consist of two parts such as Ground assembly (GA) which is laid in the road and Vehicle assembly (VA) which is placed in the vehicle. The power transfer from the transmitter side to the receiver side will be done in high frequency to increase the power transfer capability. Through the inductive wireless power transmission principal, the power get transmitted to the secondary winding, where again the AC received is rectified to convert the AC to DC, for the proper charging of the DC battery attached to the electric vehicle, charge controller is used between them (Roh et al., 2011). The detailed circuit diagram with specification is provided in the Figure 4. The input source voltage from the grid is taken as 230V, which rectified and allowed to pass through a high frequency inverter to convert the DC to AC for the inductive coupling wireless power transmission Due to the magnetic field, an induced output will be developed in the secondary winding which is placed in the vehicle assembly, for charging the battery, the AC obtained is converted to 24V DC. The charging schedule for the battery will be monitored and controlled using the embedded controller-relay circuit placed inside the vehicle The voltage sensor is used for determining the state-of-charge (SoC) of the battery by measuring the voltage. The block diagram of the battery charge monitoring and controlling unit is shown in the Figure 5. It includes Arduino UNO as the programmable microcontroller which will be helping with the indication of the voltage availability in the EV battery, accordingly switching the relay module and displaying the respective voltage in the LCD display connected to the battery pack.

The power transfer capability of the system is increased by the insertion of the capacitor in series with the coil. The level of the performance was determined by monitoring the voltage at different levels.

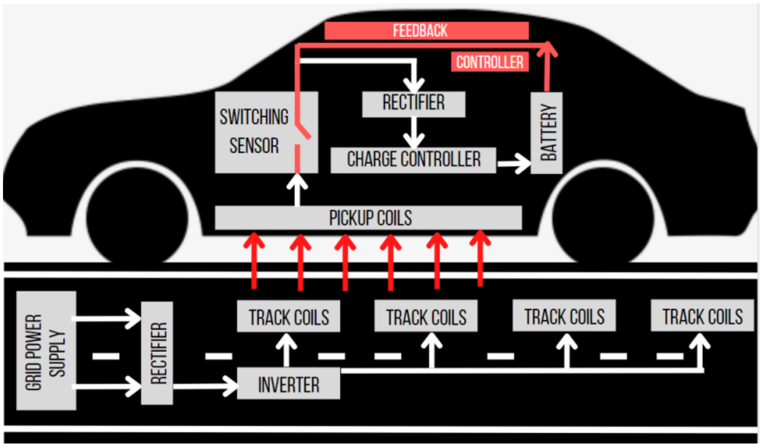

Figure 3. Block diagram of the proposed model.

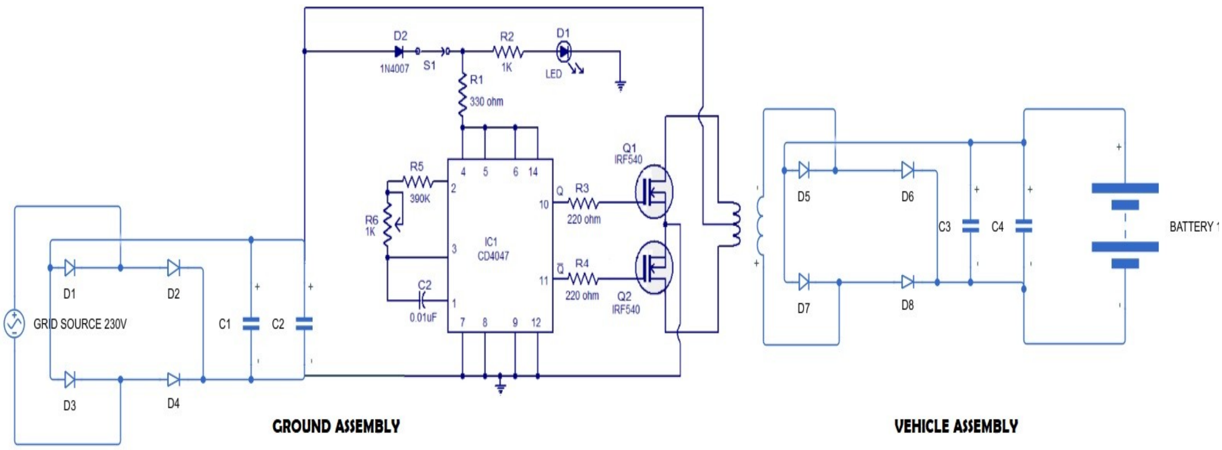

Figure 4. Circuit diagram of the proposed model.

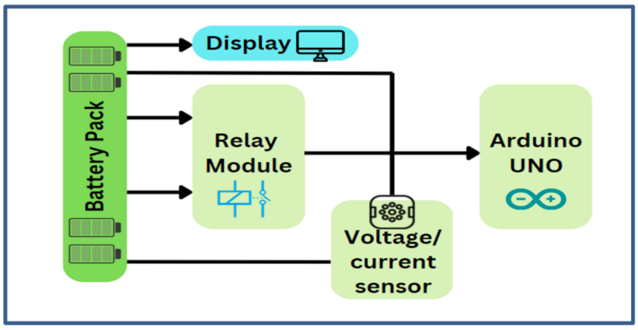

Figure 5. Block diagram of the charge controller and controlling unit.

The Simulink model of the wireless charging of EV is shown in the Figure 6. The model is developed with the AC source of 240 volt and inverter and rectifier circuit in the transmitter side and a rectifier with a 24V voltage regulator for the efficient charging of the EV 24V battery. The specification of the elements used and the purpose is shown in the tabular format in Table 1.

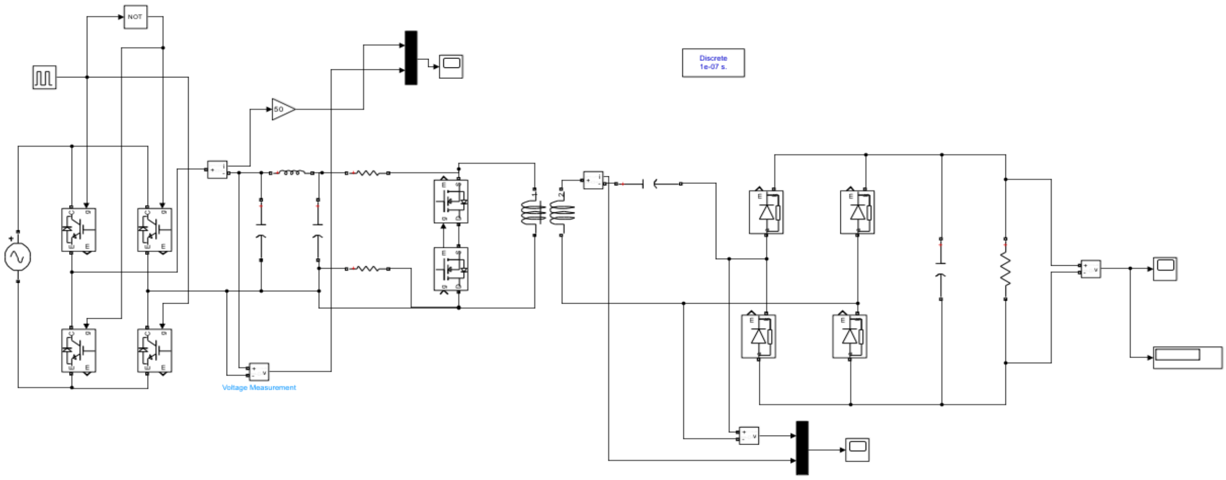

Figure 6 Simulink model of inductive wireless charging method of EV.

The MATLAB Simulink model will provide the idea of power transfer amount in each stage of the wireless charging method. The efficiency of the developed Simulink model will be compared using different power transfer methods such as inductive power transfer method, capacitive power transfer method and coupled magnetic resonance wireless power transfer method.

The validation process of the MATLAB Simulink model is done by the prototype model development of wireless charging of EV. The actual data is used for the prototype model.

Table 1. Specification of the required equipment.

Sl. No.	Name of the equipment	Specification	Purpose of use
1	Diode Rectifier	IN4001	Half wave Rectifier
2	Capacitor	10µF	To remove the harmonics
3	Transmitter and Receiver coil	Copper wire	For wireless power transmission
4	MOSFET	Q1IRF540	For switching Module
5	Battery	24V	For storing the energy
6	Micro-controller	Arduino UNO	For monitoring and controlling the unit
7	Voltage/current sensor	20-50V	To measure the voltage/current flowing to the battery
8	Display Screen	2*row LCD	To display the required parameters
9	Inverter	Single phase inverter	To convert the DC power into single phase AC output

The main constraints of the wireless EV charging system is the high initial cost and limited power transfer efficiency operation. The plug-in charging system will provide trouble for the EV owners as the high voltage battery inside the vehicle required periodic charges.

An EV wireless charging can be done by parking it at the top of the base panel without any manual connection.Power loss in wireless charging is approximately higher compared to the conventional power transfer. In addition to that, the distance upto which a wireless charger can transmit the power using electromagnetic induction is constrained.

The circuit diagram of the charge monitoring and controlling unit in EV is shown in the Figure 7. LCD display is used for monitoring the state-of-charge of the battery continuously. Arduino UNO is a programmable micro-controller which is used for the controlling and monitoring of the charging parameters.

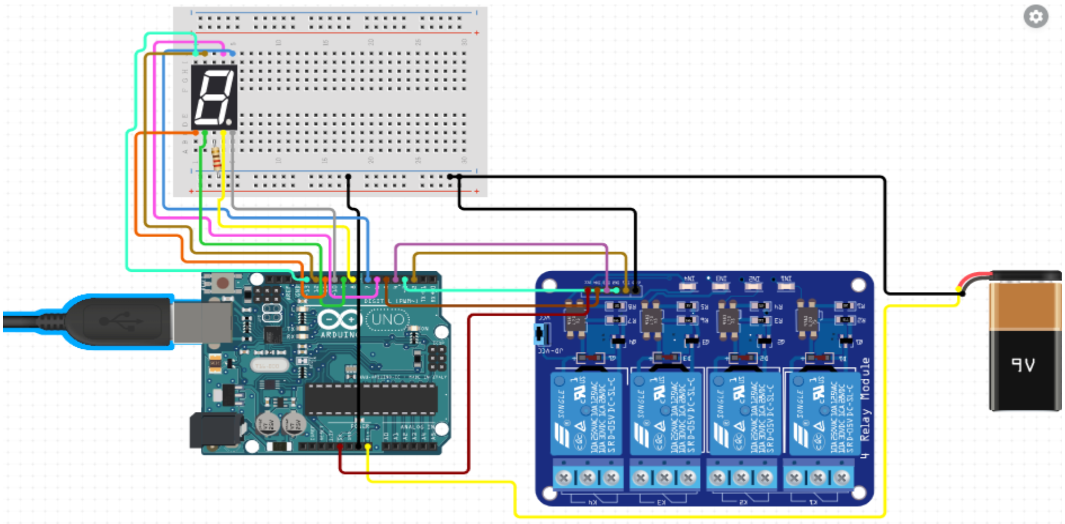

Figure 7. Wiring diagram of charge monitoring and controlling unit in EV.

Results and discussion

The simulated results are shown in the Figures 8(a), 8(b) and 8(c). Figure 8(a) denotes the input voltage delivered to the circuit from the main supply grid that is 240V. Figure 8(b) and 8(c) states the voltage from the secondary winding, which is examined to be around 24V AC. Then the voltage is allowed to pass through the rectifier, hence the voltage delivered to the EV battery is 24V DC. It's clearly shown in the Figure 6(b), the voltage gradually increases from 0V to 24V and then it remains stable.

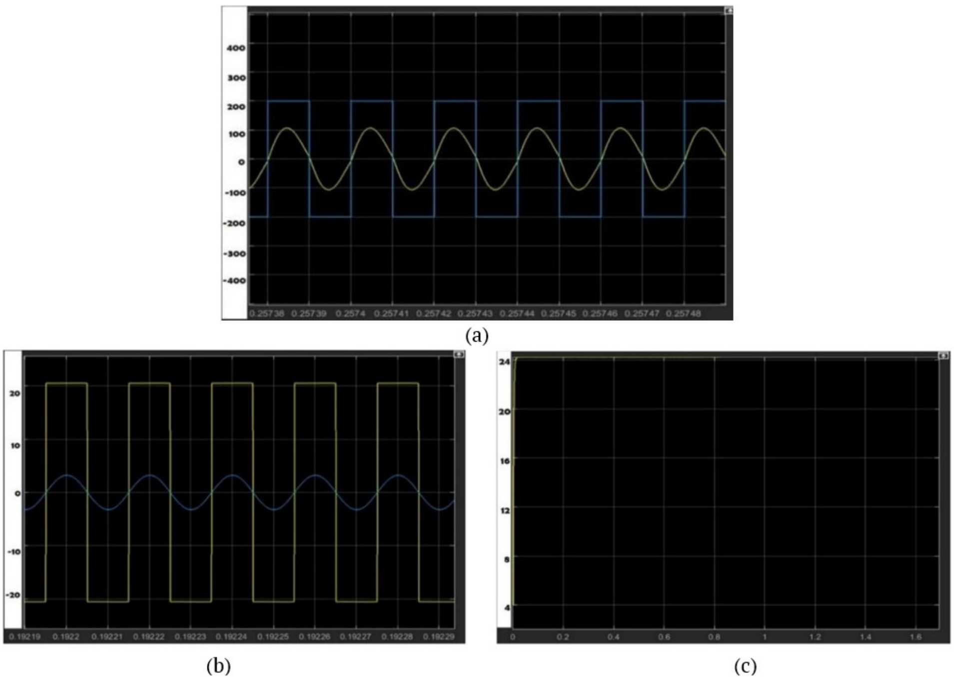

Figure 8. (a) Input voltage from the grid. Output voltage in the receiver side (b) The voltage across the secondary winding (c) The voltage across the battery.

There are mainly two methods for the wireless power transmission. One is the inductive coupling power transmission and the second is capacitive coupling power transmission. A voltage comparison respective to the two methods of wireless power transmission is shown in the Table 2. In both the methods, as the distance between the primary and secondary winding increases the coupling factor decreases which in turn decreases the power transfer and efficiency of the power transmission drops down.

Table 2. Specifications of the components.

Sl. No.	Component	Specification
1	Battery	13.5 V, 3000 mA
2	Arduino UNO	Atmega328P
3	Voltage sensor	25 V
4	Current sensor	ACS712,30A
5	DC Motor	12 V
6	Relay	5 V
7	DC-DC Buck converter	12 V, 25 W

Hardware implementation

Hardware implementation has been done in two parts, one is the optimal charging system for dynamic wireless power transfer of EV and the second is wireless charging of EV

Optimal charging system for dynamic wireless power transfer of EV

The circuit diagram of the proposed model for the efficient charging system is shown in the Figure 9. The system consists of the embedded controller arduino IDE. It has a set of analog and digital input and output pins for interfacing it with different expansion boards and other circuits. The board has total 14 digital pins, 6 analog pins for input and is programmable by arduino IDE through a type B USB cable. It can be powered by a USB cable connected from any source and also accept the external source of voltage between 7 and 20V. Voltage and current sensor are used for the instantaneous measuring of the voltage and current in the circuit. Relay is used for the switching of the condition given in the arduino Uno based on the SOC of the battery. The specifications of the components used in the model are shown in the Table 2.

Current measurement is important for the safe functioning of devices but measuring the current is an intrusive task which cannot be detected directly. Hence a sensor is required, ACS712 current sensor is used for the purpose without affecting the performance of the system. It works in the principle of sensing the magnetic field by applying Faraday's law or Ampere law.

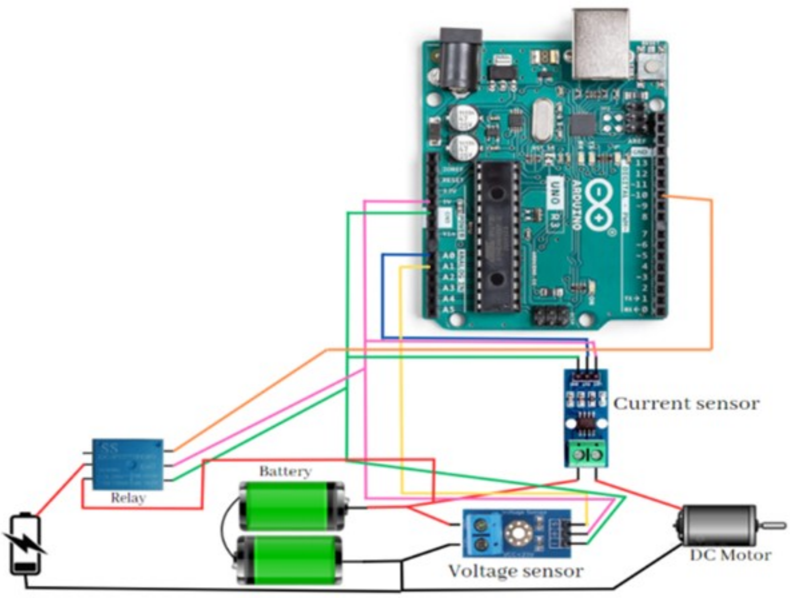

Figure 9. Circuit diagram of the model.

Measuring the voltage can be achieved without affecting the working of the system (Li & Mi, 2015) These also sense the magnetic flux to calculate the voltage across the nodes. Relay module is used for the opening and closing of the circuit. It is an electrical switch operated by electromagnet. It is operated by a low power signal powered from the micro controller attached with it. According to the condition given in the micro controller, activation conducts and the electromagnet pulls to either open or close an electrical circuit. Relay module is placed between the charger of the battery and the battery. As a simple load DC motor is connected across the battery to drain the voltage from the battery. The hardware model done is shown in the Figure 10. A 12V motor connected across the battery as a load. As the motor is consuming power from the battery, there is a variation in the SOC that is, variation in the voltage across the battery.

Figure 10. Hardware model of optimal charging system for dynamic wireless power transfer of EV.

Figure 11. shows the variation in the values sensed via voltage and current sensor. The relay will operate when the voltage value reaches 11.15V. Until then the relay is open, not allowing the power from the charger to charge the battery. Once the voltage sensor gives an input value of 11.15V to the micro-controller, the decision sends to close the relay in order to allow the charger to charge battery.

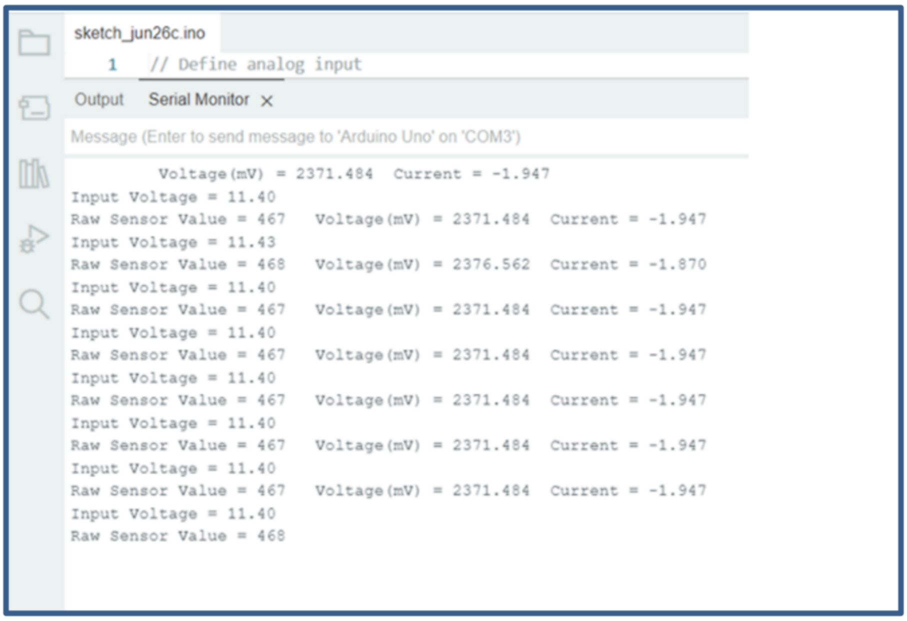

Figure 11. Voltage and current sensor values obtained from arduino.

Dynamic wireless power transfer of EV

The circuit diagram of the dynamic wireless power transfer is shown in the Figure 12. The specifications of the components used in the model are shown in the Table 3 (Humfrey et al., 2019).

230v is supplied from the power grid to the step down transformer of 230/12V, 1A. A step down transformer reduces the voltage of an alternating current from the input by creating a fluctuating magnetic field. The output from the transformer is 12V AC that is passed through the 36 SWG copper winding. Approximately 20 m copper wire is used in the primary side that is the electric roadbed. Designed in 20 segments each segment having 30 turns of diameter 5 cm.

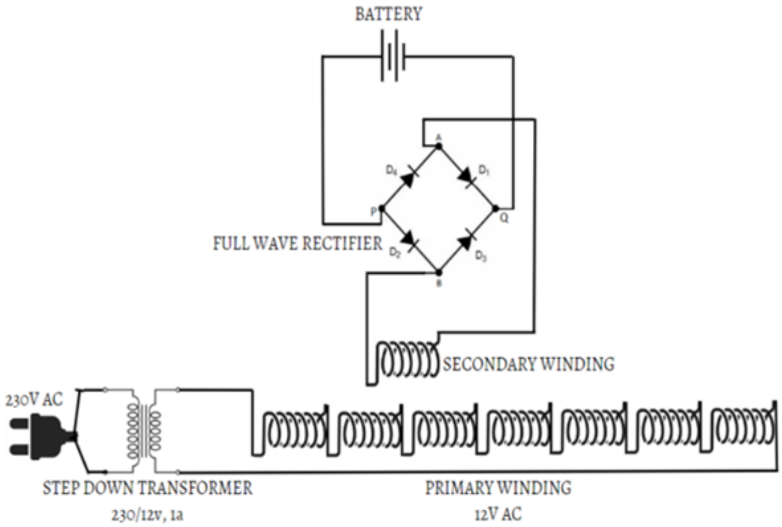

Figure 12. Circuit diagram of the model.

Table 3. Specifications of the components.

Sl. No.	Component	Specification
1	Battery	12 V, 3000 mA
2	Step down transformer	230 / 12 V, 1 A
3	Copper wire (1)	38 SWG, 20 M
4	Copper wire (2)	26 SWG
5	Diode 1N4001	1 A, 50 V

The secondary winding of 26 SWG is placed under the EV with 3 turns of diameter 5cm. The DC battery should be charged via DC supply, hence a full wave bridge rectifier is used to convert the AC to DC (Mohamed et al., 2022). EV then is allowed to pass above the electric roadbed without physical contact. It is observed that DC voltage ranging 6-25mV is developed in the secondary winding placed in the EV. The hardware model of dynamic wireless power transfer developed is shown in the Figures 13, 14 and 15.

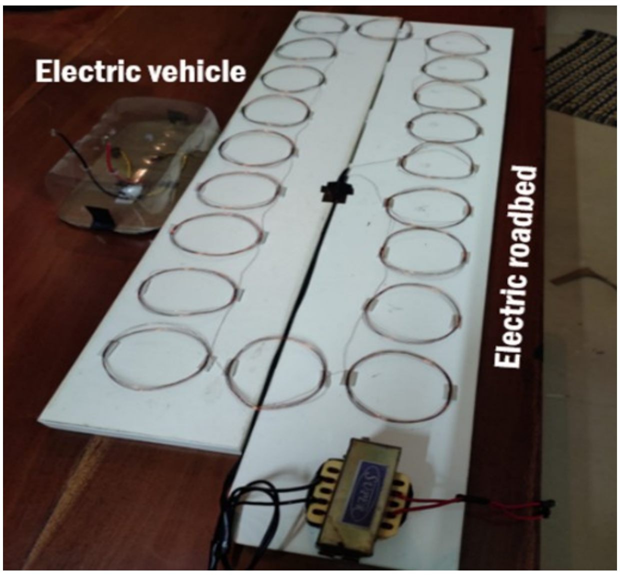

Figure 13. Hardware model of dynamic wireless power transfer.

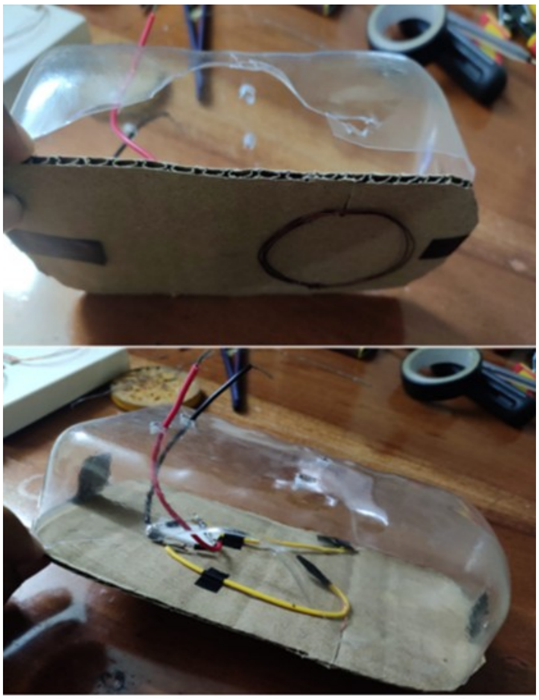

Figure 14. Hardware model of EV.

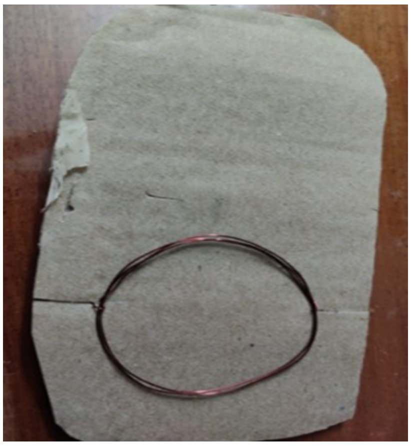

Figure 15. Secondary coils deployed in EV.

More detailed view of the secondary winding which is placed in the EV is shown in the Figure 15.

Result and analysis

The results obtained using the MATLAB Simulink is shown in this section. Figure 16 shows the graphical representation of the input voltage from the grid. The supply voltage from the grid is 230V AC. After the two-stage conversion, it is delivered to primary winding of dynamic wireless power transfer. After the wireless power transfer, the result of the obtained voltage in receiver side is represented in the Figure 17. Around 20V is obtained in the receiver side. After the conversion of AC to DC to charge the battery, the output voltage across the battery obtained is represented in Figure 18. With the regulator, the voltage supplied to the battery was changed to DC 24V.

Wireless power transfer can be achieved through two techniques, inductive wireless power transmission and capacitive wireless power transmission (Liu et al., 2024). The comparison of the output voltage for the abovementioned wireless power transfer method is shown in the Table 4. It is clear from the Figure 18 that the capability of the power transfer between the primary and secondary winding will vary according to the distance between them.

The Capacitive and Inductive wireless power transfer are the main two methods of Wireless charging.In this section ,the merit and limitations of these two methods is discussed.

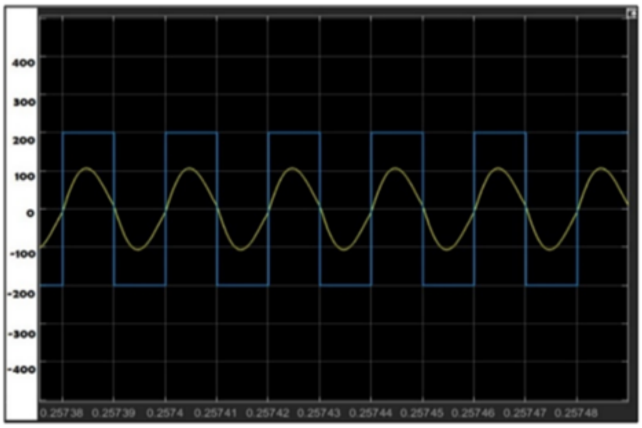

Figure 16. Graphical representation of the Grid input voltage

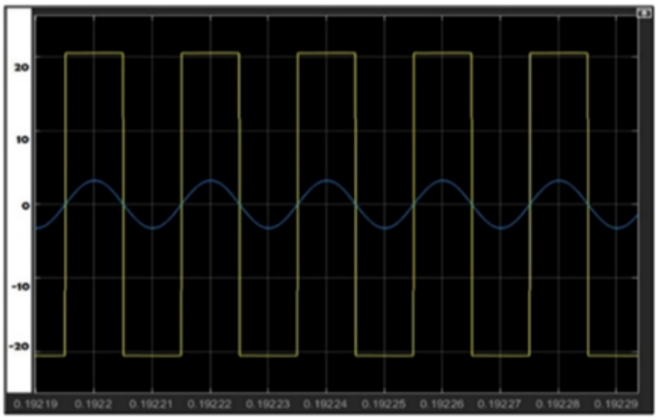

Figure 17. Voltage across the primary winding.

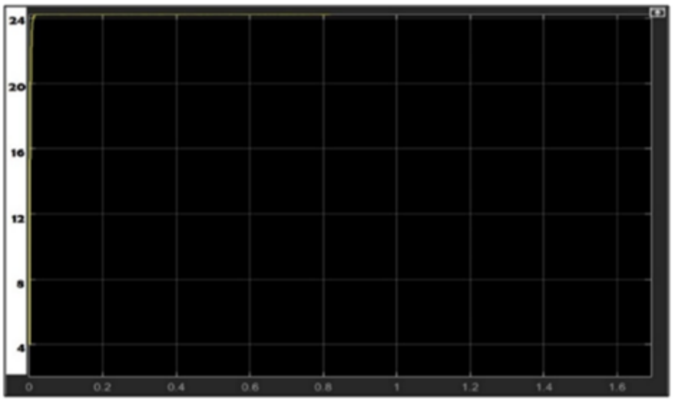

Figure 18. The output voltage of the battery.

The capacitive Power transfer method is suited only for low power applications while the Inductive Power transfer can be used for both low and high power applications.The Inductive Power Transfer is working as the same principal of Transformer.For achieving the maximum Power Transfer in IPT, the gap between the Primary and Secondary winding should be properly adjusted.

Capacitive power transfer involves the use of electric fields to transfer power wirelessly between the charging infrastructure (typically a charging pad or plate on the ground) and the receiving coil or plate on the EV.The high power transmission is possible with the Capacitive Transformer with the compensating circuit that provides high voltage at the input and output for the transmission of high power.The compensating capacitor can be connected in different way with the coil (Zhang & Zhang, 2016). These combinations are:

- Parallel-parallel (PP)
- Parallel-series (PS)
- Series-parallel (SP)
- Series-series

Table 4. Efficiency comparison for different wireless power transfer method.

Sl. No.	Wireless power transfer method	Transmitter side Voltage	Receiver side Voltage	Output Power range	Conclusion
1.	Inductive coupling power transfer	230V	25.6V	>10KW	The distance between the coils can be wider as several meters.
2.	Capacitive Coupling power transfer	230V	12.2V	Lower range	The distance between the coils should be in the range of 10-4 to 10-3 m.

Conclusion

The wireless charging of EV is implemented in this paper. The simulation is carried out using MATLAB Simulink and based on the simulation, the prototype model of wireless charging of EV is developed. The real-time voltage and current data of both the transmitter and receiver side are measured. In addition to that, the efficient charging schedule is implemented for the EV battery using the controller-relay module.

The real-time implementation will be done as future work and the implementation will be carried out for different weather condition and charging-discharging characteristics of the EV battery, distance travel, time required for charging will be continuously monitored.

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