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Waveform Smoothing Techniques for Electric Vehicle Wireless Charging Systems

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***Abstract:** Wireless power transfer (WPT) is an emerging technology that has the potential to revolutionize electric vehicle (EV) charging. This paper provides an overview of WPT technology and its application in the EV industry. The paper first discusses the basic principles of WPT, including inductive and resonant coupling, as well as the design considerations for efficient and safe charging. The paper then delves into the advantages and challenges of WPT for EVs, including convenience, safety, and potential infrastructure cost savings, as well as efficiency, regulatory, and standardization concerns. The paper also reviews recent research and development efforts in WPT technology for EVs, including both academic and industry efforts. Finally, the paper concludes with a discussion of the future prospects of WPT for EVs, emphasizing the need for continued research and development to overcome the challenges and maximize the potential benefits of this technology.*
***Keywords:** WPT, safe and efficient charging, development efforts, potential benefits*

I. INTRODUCTION

A. General

The trade market of electric vehicles (EVs) has gradually begun to grow. To revive the vehicle within a short span, high power charging devices or charging stations are required by the existing conductive charging method. Additional inconvenience is caused by incompatible plugs receptacles between different EV models. The deployment of 85 million autonomous vehicles, is expected by 2035, hence establishment of wireless charging is needed, to incorporate in such vehicles .WPT makes the system simplify, automatic, secure, economical and more efficient, whereas using of cables makes system so expensive.

B. Motivation

Electric vehicles (EVs) are becoming increasingly popular as a viable alternative to traditional gasoline-powered vehicles. The main motivation for using electric vehicles can be summarized in the following points:

1) *Environmental Benefits:* Electric vehicles are much cleaner than traditional gasoline-powered vehicles. They produce zero emissions, which means they do not contribute to air pollution, which is a major cause of global warming and climate change. With the shift towards renewable energy sources, the use of electric vehicles will help reduce greenhouse gas emissions and improve air quality.
2) *Lower Operating Costs:* Electric vehicles are cheaper to operate than gasoline-powered vehicles. Electricity is cheaper than gasoline, and the maintenance costs of electric vehicles are lower because they have fewer moving parts. EVs also have regenerative braking, which means that they can recover some of the energy used when braking and store it in the battery, which extends the vehicle's range.

C. Literature Survey

1) *Challenges in the Development of Advanced li-ion Batteries:* A review, Energy & environmental science: Li-ion battery technology has become very important in recent years as these batteries show great promise as power sources that can lead us to the electric vehicle (EV) revolution. The development of new materials for li-ion batteries is the focus of research in prominent groups in the field of materials science throughout the world. Li-ion batteries can be considered to be the most impressive sucess story of modern electrochemistry in the last two decades.
2) *Simultaneous mid-range Power Transfer to Multiple Devices, American Institute of Physics:* There has been substantial interest recently in exploiting high Q electromagnetic resonances interacting via their near i.e., Nonradioactive electromagnetic fields as a means of transferring power wirelessly and efficiently over distances up to several times the characteristic sizes of the resonators. In terms of applications, this scheme could fill the gap between traditional inductive systems, which require the source and device to be separated by a gap smaller than their characteristic sizes.

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3) *Dedicated Short-Range Communications (DSRC) Standards in the United States: Wireless* vehicular communication has the potential to enable a host of new applications, the most important of which are a class of safety applications that can prevent collisions and save thousands of lives. The automotive industry is working to develop the dedicated short-range communication (DSRC) technology, for use in vehicle-to-vehicle and vehicle-to-roadside communication.
4) *Output Power Stabilization for Wireless Power Transfer System Employing Primary-Side-Only Control:* Wireless vehicular communication has the potential to enable a host of new applications, the most important of which are a class of safety applications that can prevent collisions and save thousands of lives. The automotive industry is working to develop the dedicated short-range communication (DSRC) technology, for use in vehicle-to-vehicle and vehicle-to-roadside communication.

II. EXISTING MODEL

A. WORKING

The principle used in this project is Faraday's Law of Electromagnetic induction. Due to the Principle of Faraday's Law of Electromagnetic induction, the induced EMF energizes the receiver coil. On account of magnetic field, the variations in the coupling factor k which is calculated by k=M/L1L2.

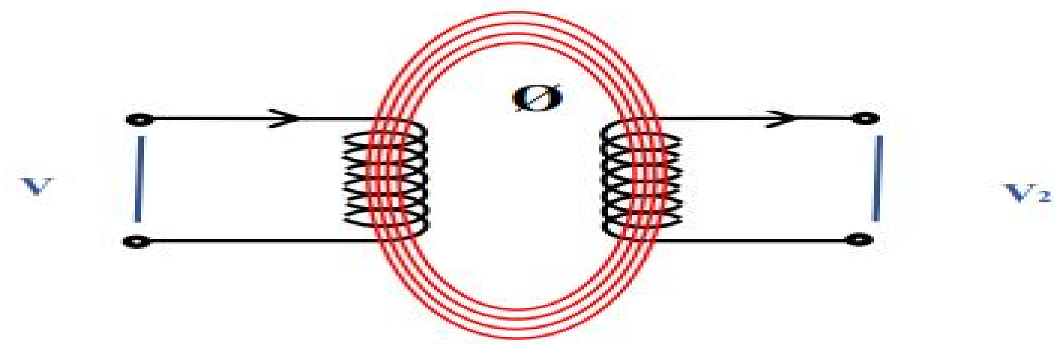

Fig-1: Overview of Mutual Inductance

Here Coil 1and Coil 2 are brought in proximity in magnetic field, the two-coil use to attract each other, which leads to voltage generation. This in turn changes or affects I current & V (voltage) in coil2. This is called as mutual inductance.

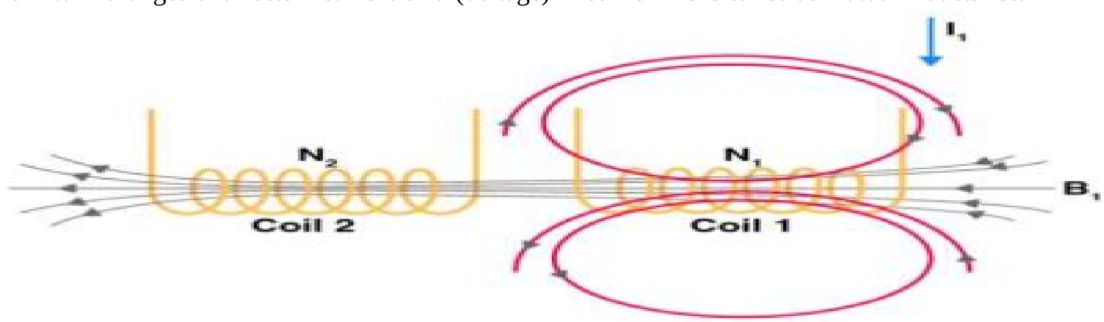

Fig-2: Overview of Flux Diagram

B. Issues With Existing Model

1) Electromagnetic Interference

Malfunction of electronic devices: EMI can cause electronic devices to malfunction or stop working altogether. This is particularly concerning in critical applications such as medical equipment, aircraft navigation systems, and automotive control systems.

Signal degradation: EMI can degrade the quality of signals transmitted over wires or through the air, leading to errors or reduced data rates. This is a particular concern in high-speed communication systems, such as Wi-Fi and cellular networks.

Interference with radio communication: EMI can cause interference with radio communication, leading to reduced signal strength and increased noise levels. This can affect the performance of radios used for communication and navigation.

2) Thermal Constraints

Thermal issues can arise in wireless charging systems due to several reasons, such as:

a) Efficiency Losses: Wireless charging systems can experience efficiency losses due to the conversion of electrical energy to magnetic fields and then back to electrical energy. These losses can cause the system to heat up, reducing the overall efficiency of the charging process.

b) Heat Dissipation: Wireless charging systems generate heat during charging, which can lead to the temperature rise of the charging device and the surrounding environment. The heat generated needs to be dissipated to prevent damage to the charging system and the device being charged.

c) Battery Overheating: Charging a battery wirelessly can cause it to heat up, and if the temperature exceeds safe limits, it can lead to battery damage and reduced lifespan.

3) Distance

a) Power Transmission Efficiency: Wireless charging systems are designed to transmit power wirelessly through the air, but the efficiency of power transmission decreases with increasing distance between the transmitter and receiver coils. This means that the farther the charging distance, the less efficient the power transmission, resulting in a lower charging rate.

b) Magnetic Field Strength: The strength of the magnetic field produced by the charging coils decreases with increasing distance between them. This means that the farther apart the coils are, the weaker the magnetic field and the lower the charging rate.

c) Interference: Electromagnetic interference (EMI) from other devices and materials can interfere with the magnetic field and reduce the charging distance.

C. Innovation

Our Proposal here is to make use of Power Electronic converters owing to their higher rating and their ability to work without using too much resources.

Along with the use of power electronics we also propose to make use of Filters (preferably Passive Filters) to subdue the effects of harmonics and produce a clean DC Voltage.

Fifth generation HEXFETS from international rectifier utilize advanced processing techniques to achieve extremely low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET power MOSFETS are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications.

D. Advantages Of Pe Devices

One such Power Electronic device is the advanced version of the MOSFET known as IRFN250.

Some advantages of this device over its predecessors are mentioned below.

1) Dynamic dv/dt rating
2) 175°c operating temperature
3) Fast switching
4) Fully avalanche rated
5) Ease of paralleling
6) Simple drive requirements to-247ac
7) Lead-free
8) Silent Operation
9) More Life
10) High Efficiency

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III. PROPOSED MODEL

A. Block Diagram

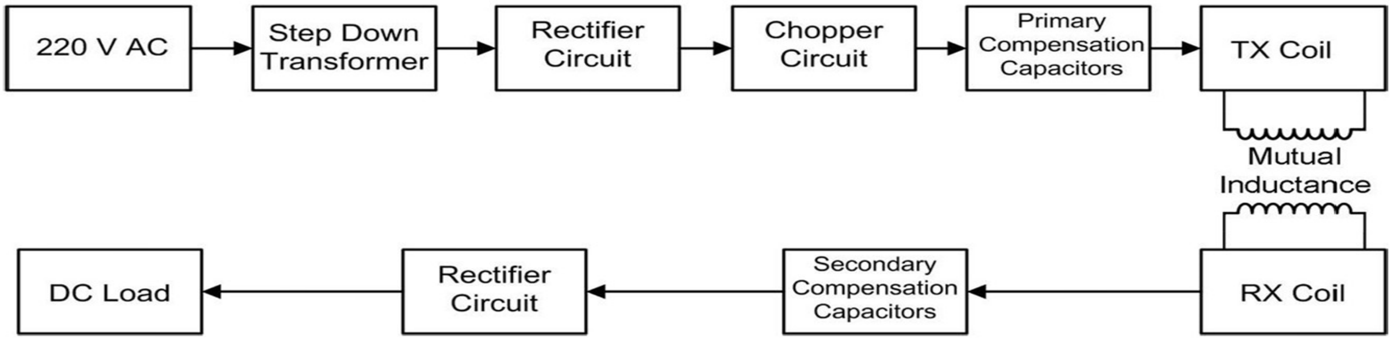

Fig-3: General Block Diagram of a wireless charging module

When an electric vehicle (EV) charging circuit is connected to the grid, the AC power from the grid is fed into the AC-DC converter, which converts the AC power into DC power that is suitable for charging the EV battery. The process of connecting an EV charging circuit to the grid is typically done by plugging the charging cable into a charging port on the EV and then connecting the other end of the cable to a charging station or an electrical outlet.

Once the charging circuit is connected to the grid, the charging process begins. The AC-DC converter converts the AC power from the grid into DC power, which is then supplied to the EV battery. The Battery Management System (BMS) monitors the battery's state of charge, voltage, and temperature, and regulates the charging process to ensure that the battery is charged safely and efficiently. The Charger Control Unit (CCU) manages the charging process and communicates with the EV and BMS to ensure that the battery is charged according to its requirements.

During the charging process, the charging circuit draws electrical power from the grid. The amount of power drawn depends on the charging rate and the capacity of the battery. The charging rate can be adjusted based on the available power from the grid and the battery's charging requirements.

It is important to note that when an EV charging circuit is connected to the grid, it can also affect the grid's stability and power quality. The large amount of power drawn by the charging circuit can cause voltage fluctuations and harmonic distortions in the grid. Therefore, it is essential to design and operate the charging circuit in a way that minimizes the impact on the grid.

To address this issue, some EV charging systems incorporate features such as peak shaving, load balancing, and smart grid integration. These features enable the charging system to adjust the charging rate based on the available power from the grid and the grid's stability. By optimizing the charging process, these features can help minimize the impact of EV charging on the grid and ensure that the charging process is safe, efficient, and reliable.

B. Circuit Diagram

The circuit diagram of the proposed system is realized below using the aforementioned power electronic devices. The Primary Side consists of the following devices: Rectifier, Inverters, LC Filters.

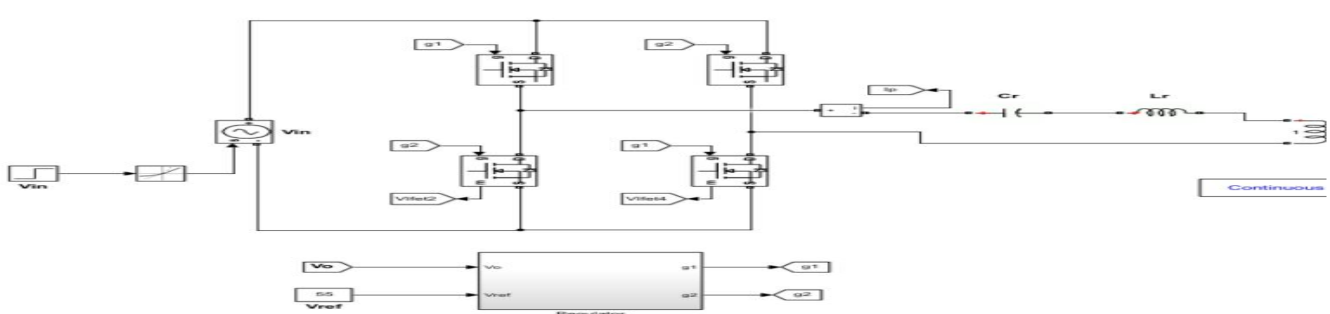

Fig-4: Circuit Diagram of the Primary Side

The secondary side consists of rectifier, Super capacitor and the battery.

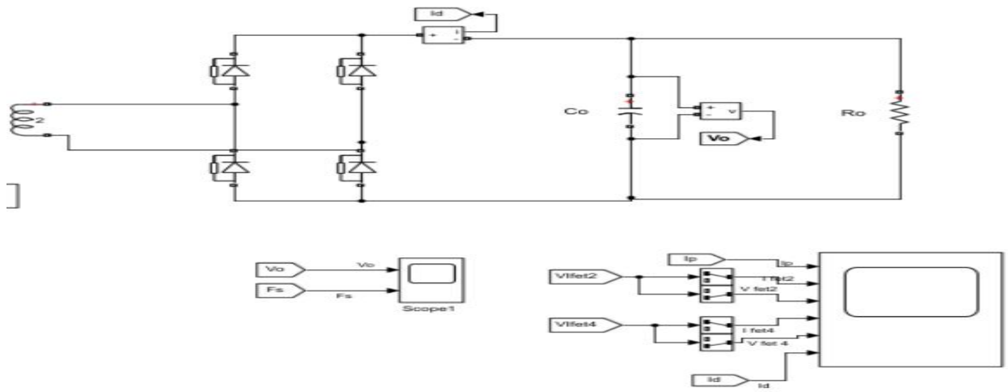

Fig-5: Circuit Diagram of the Secondary Side

IV. COMPONENTS

A. Rectifier

Rectifier is an electronic circuit that converts alternating current (AC) to direct current (DC). It is a crucial component in many electronic devices, including power supplies, battery chargers, and motor drives.

The basic function of a rectifier is to convert the AC voltage into a pulsating DC voltage. The output of a rectifier consists of a series of positive half-cycles of voltage that are separated by zero voltage points or negative half-cycles of voltage. The output of the rectifier can be smoothed using a filter to reduce the ripple and produce a more stable DC voltage.

Now rectifier is a process of conversion to DC to AC. It is the second stage of conversion process. It converts the AC voltage waveform to a rectified voltage.

The reason as to why this method is preferred over the other B2 Configuration, is that it provides certain advantages such as no center tap transformer need, high transformer utilization factor, so for the advantages it provides compared to other methods, this configuration is used.

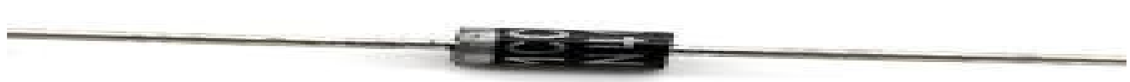

Fig-6: Rectifier IN5402

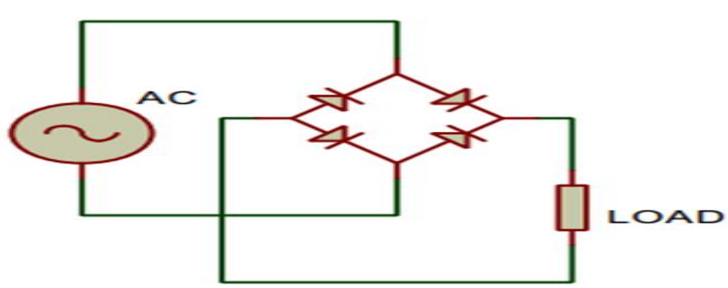

Fig-7: Circuit Diagram of a Full Wave Rectifier

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B. Inverter

An inverter is an electronic circuit that converts direct current (DC) to alternating current (AC). Inverters are used in many electronic devices, including solar power systems, electric vehicles, and air conditioning units.

The basic function of an inverter is to convert the DC voltage into a sinusoidal AC voltage that can be used to power AC devices. Inverters use complex electronic circuitry to create a waveform that closely approximates a sine wave, which is the ideal waveform for powering most AC devices.

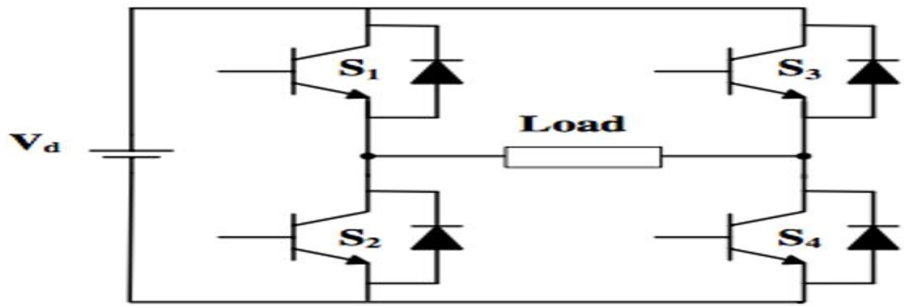

Fig-8: Circuit Diagram of an Inverter

C. LC Filter

An LC filter is an electronic circuit that uses inductors (L) and capacitors (C) to filter or smooth out unwanted noise or ripple from a power supply or signal. The name LC filter is derived from the two components used in the filter, the inductor and the capacitor.

The basic function of an LC filter is to suppress or attenuate high-frequency signals, while allowing low-frequency signals to pass through the circuit. This is achieved by using a combination of inductors and capacitors to create a resonant circuit that is tuned to a specific frequency range. The resonant circuit selectively filters out the unwanted high-frequency signals, while allowing the desired low-frequency signals to pass through.

Fig-9: A Standard LC Filter

D. Transformer

A transformer is an electrical device that is basically used to couple the output signal from one part of the circuit to the other part. During the process, the transformer can also modify the characteristics such as the amplitude level of the input signal. A transformer basically belongs to the category of passive electrical components and devices. The changes or the modifications in input signals introduced by the transformers mainly deal with the amplitude of the signal and do not let the frequency of the signal get affected during the process. The operation of transformers is based on the basic principles of electromagnetic induction and mutual induction.

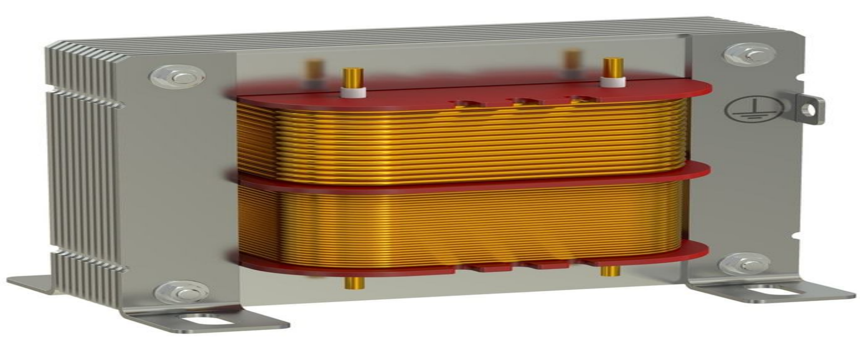

Fig-10: A Transformer

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E. Super Capacitors

A supercapacitor, also known as an ultracapacitor or electric double-layer capacitor (EDLC), is a type of electrochemical energy storage device that has a higher energy density than traditional capacitors but lower than batteries. Supercapacitors are designed to bridge the gap between traditional capacitors, which can store only a small amount of charge, and batteries, which have high energy density but slow discharge rates.

Supercapacitors consist of two electrodes, typically made of carbon, with a separator between them, and an electrolyte that allows ions to flow between the electrodes. When a voltage is applied to the electrodes, the ions accumulate on the surface of the electrodes, creating a double layer of charge. This double layer of charge enables supercapacitors to store and release electrical energy quickly and efficiently.

Fig-11: Super Capacitors

F. Battery

A battery is a device that converts chemical energy contained within its active materials directly into electric energy by means of an oxidation - reduction(redox) reaction. This type of reaction involves the transfer of electrons from one material to another via an electric circuit.

While the term battery is often used the cell is the actual electrochemical unit used to generate or store electric energy.

Fig-12: Battery used in an Electric Vehicle

V. SIMULATION RESULTS

A model was realized using MATLAB/SIMULINK and experimental results was recorded.

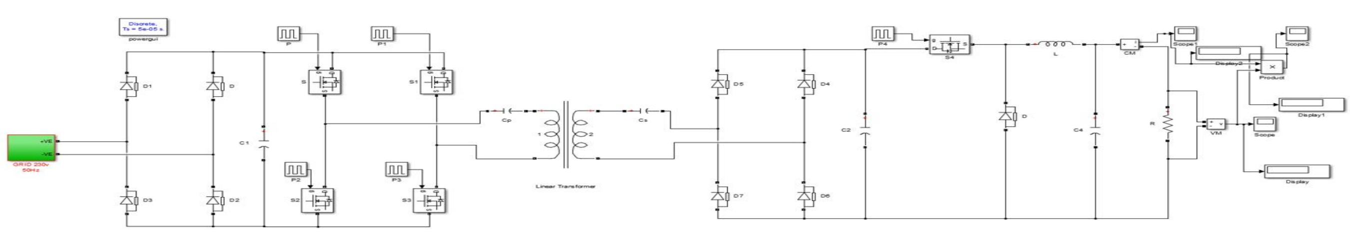

Fig-13: SIMULINK Circuit Diagram

To determine the effect of using a PE Device along with LC Filter, we first made a simulation wherein the devices were not connected to the circuit and the output was recorded.

The resulting waveform (Fig 14) was similar to the final output of the current waveform but with a lot of spikes, this indicated the presence of harmonics and other noises and disturbances.

The circuit is then equipped with the PE Devices and the filters and the output is recorded once again. This time the signal (Fig 15) is much cleaner as compared to previous circuit.

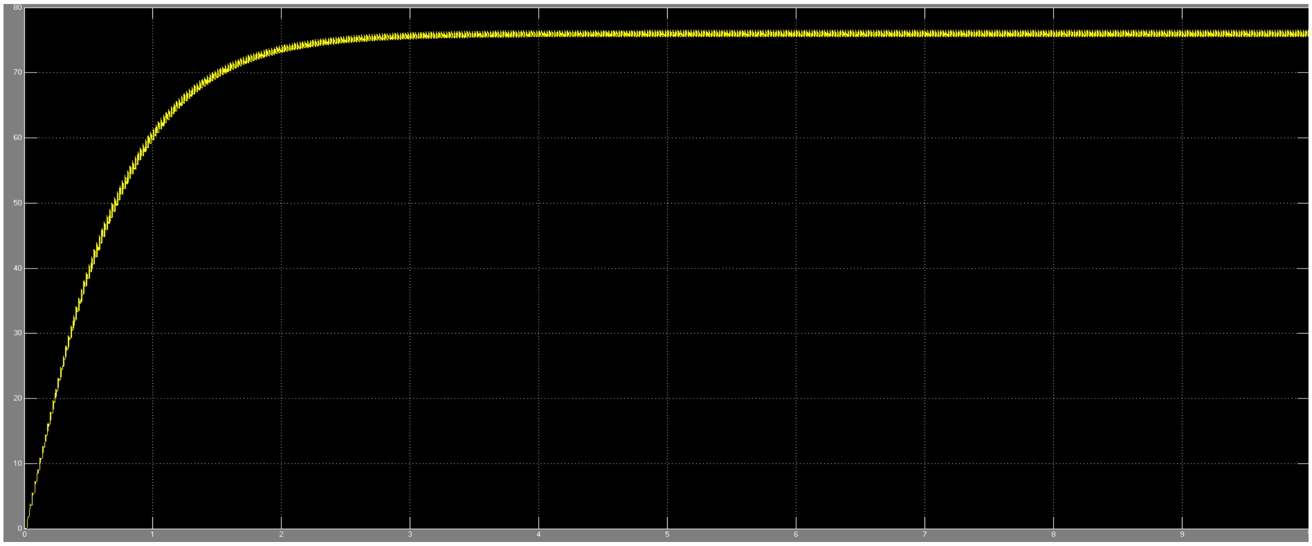

Fig-14: SIMULINK Result with No Filters Attached

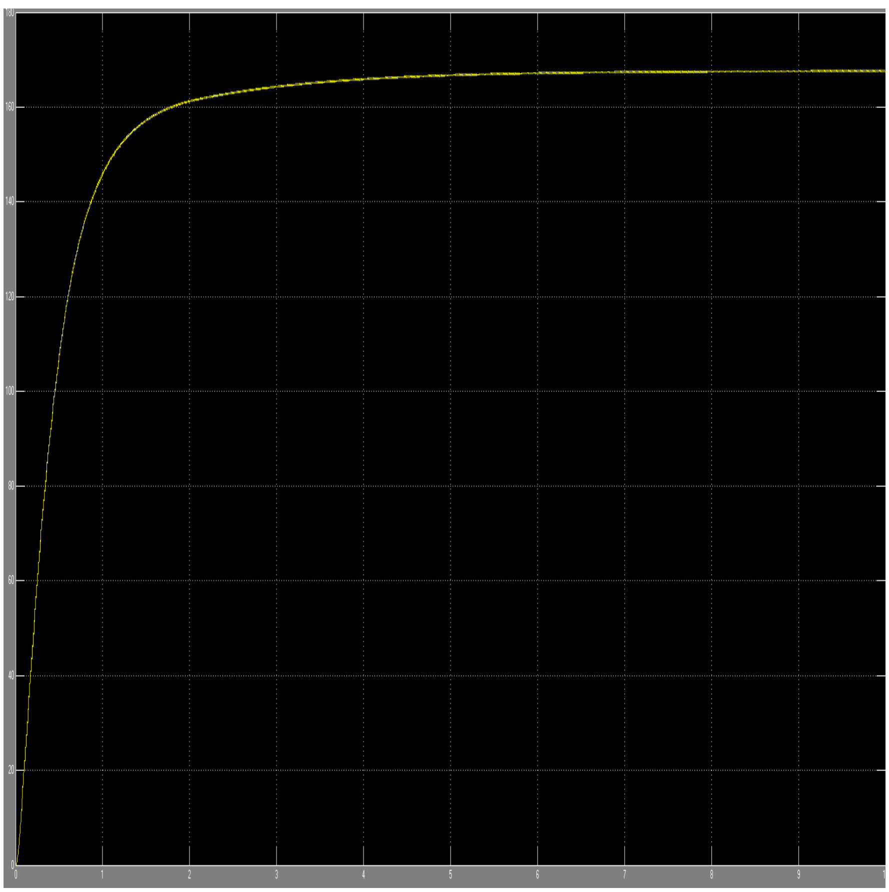

Fig-15: SIMULINK Result with Filters Attached

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VI. PROTOTYPE

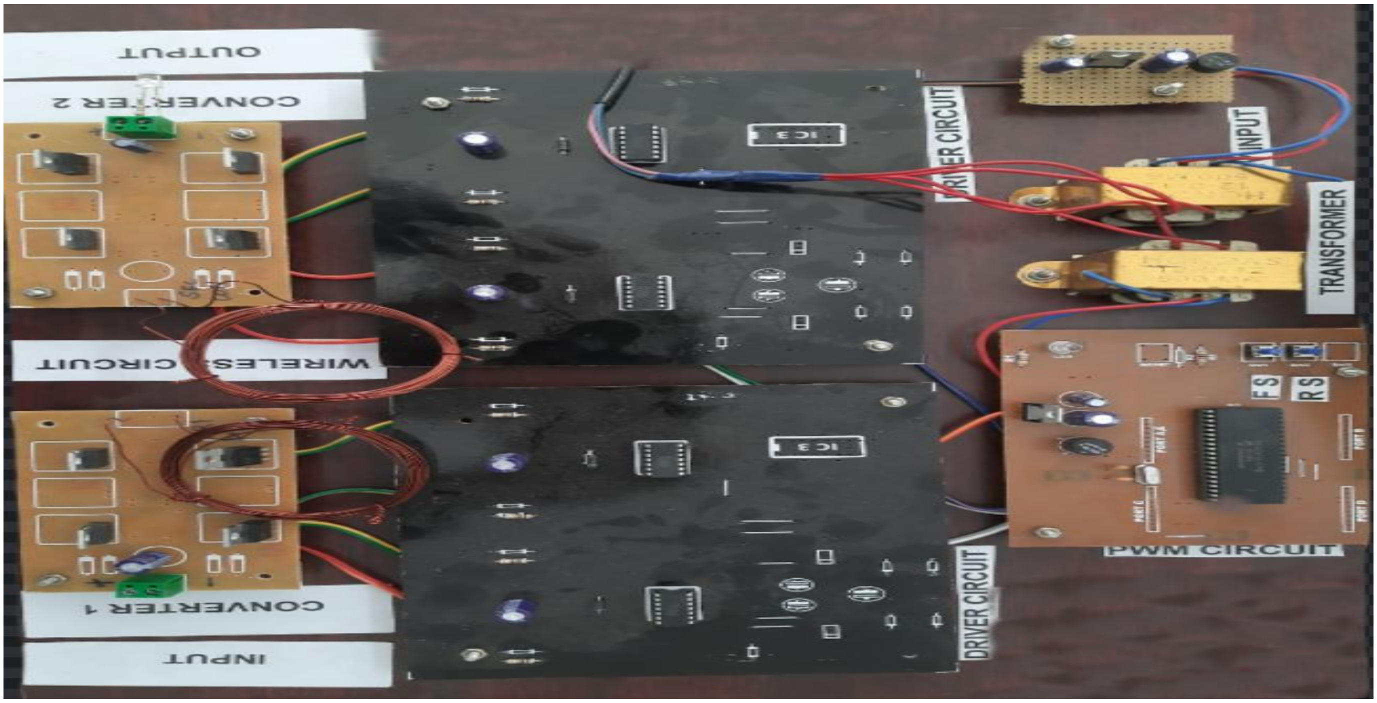

Fig-16: Prototype of the proposed model

This protoype contains all the aforementioned devices like the Full Wave Rectifier Circuit , Inverter, Filter, Transformer Etc.

VII.FUTURE SCOPE

With improvements in communication technology the systems can produces less electromagnetic interference which can result in less hindrance in day to day usage.

Proper mitigation techniques can be used to protect the battery in case of any faults. Typically a BMS system along with a heat sensing device such as a Thermostat can be used to monitor the health of the battery.

Along with these an IoT system should be utilized to send distress signals to nearby helplines in case of any anomaly such as overheating.

VIII. CONCLUSION

A WCS using inductive coupling has been designed and simulated in MATLAB/Simulink environment. The measurements used for the above parameters show reliable results for proposed theme. In the prototype zero visible heating of the used relays was notified. The above delivered system is economical and highly beneficial because it uses inverters, rectifiers and filters to handle a different coupling factor. . This WCS has many advantages and disadvantages over conductive charging system, which is discussed in above sections. With the use of Filter and PE Devices, the output waveforms become smoother, which is very essential for battery charging.

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