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Wireless Charger for Medium-Power Electric Vehicles

Nandana S. Nair
MTech Student
Department of Electrical and Electronics Engineering
Government Engineering College, Barton Hill

Prof. Anjana K. R.
Associate Professor
Department of Electrical and Electronics Engineering
Government Engineering College, Barton Hill

***Abstract*—The need for combustion-free transportation, due to the depletion of petroleum, has led to the idea of energy-efficient electric vehicles. The concept of effortless electric vehicle charging technology got realised when the wireless charging system was introduced. Different sorts of wireless charging methods have been proposed or implemented to date. Each of those topologies has its pros and cons related to various constraints like the efficiency of transferred power, the distance between the coils, tolerance to misalignment etc. Electric vehicles can be classified into different categories according to their power requirement as low-powered EVs (less than 1kW), medium-powered EVs (1-11kW) and high-powered EVs (greater than 11kW). Researchers have utilised various technologies for the transmission of power wirelessly, such as inductive coupling, magnetic resonance coupling, electromagnetic radiation, electric field coupling etc. This paper presents a wireless charger for electric vehicles which utilises magnetic resonance technology for power transfer. This technology allows the charger to achieve mid-range power transfer (up to a few metres). It is a current-fed converter-based wireless charger with LCC-S type compensation and operates at 85kHz frequency. Litz wire (AWG 38) can be used to make coils for power transfer. It could be wounded in a rectangular shape to obtain maximum mutual inductance during power transmission and to achieve high misalignment tolerance. Since the circuit is DC-powered, integration of renewable-energy powered sources is possible. The proposed circuit was simulated using MATLAB SIMULINK and results were obtained.**

***Keywords*—Wireless power transfer, Electric vehicle charging, Magnetic resonance coupling, Series-Series compensation, Medium-powered electric vehicle.**

I. INTRODUCTION

WIreless power transmission (WPT) has been around ever since Nikola Tesla conducted experiments for the transmission of electrical energy without wires to develop a system that would be more efficient and reliable than conventional power transmission. Energy conservation is one of the main concerns for every ambitious researcher in the twenty-first century. In the transportation sector, fossil fuels are intensively used. For example, gasoline-powered cars with ICES are a significant source of pollution, global warming, and energy losses. An ever-growing number of nations have pledged to forbid the sale of internal combustion engine (ICE) vehicles in the future, while electric vehicles are gaining popularity as a substitute to minimise reliance on fossil fuels and achieve the goal of reducing carbon emissions. The primary advantages of electric vehicles are the elimination or reduction of local pollution and the improvement of overall efficiency. Therefore it has become the need of the hour to find solutions for electric vehicles' charging issues, given their broad adoption. There are three available methods of charging which are battery swapping, conductive charging, and wireless power transmission. Among these three methods, in WPT technology there is no electrical contact between the ground units and the vehicle assembly, hence chances of sparking are relatively very low. Hence, it can provide a higher level of safety. Also, it is simple to use. The drivers only need to park and align their cars with the charging zone. Moreover, WPT is maintenance-free, environmentally benign, and suitable for a wider range of applications Unlike fossil fuel driven vehicles, EVs utilise electricity, which may be generated by many renewable sources; EVs have zero emissions, and hence, can lessen dependency on fossil fuels and reduce greenhouse gas emissions. However, there are still a number of difficulties with EV technology, including limited driving distances and lengthy charging times. WPT is showing promise as a remedy for EV charging to overcome these drawbacks. The WPT system is more convenient, dependable, and safer than conventional wired chargers since it uses no wires to transfer electrical energy from a power source to a load. Wireless charging of EVs can be classed into fixed charging and dynamic charging. Inductive, resonant, capacitive, strongly coupled magnetic resonance, microwave and radio frequency, optical wireless power transfer etc are the technologies that are available yet for wireless power transfer. Peter K. Joseph et al. in [1] proposes a method of wireless power transmission (WPT) using magnetic resonance principle for low powered electric vehicles. Their work tries to optimise the charger with current source inverter (CSI) at the primary side rather than conventional voltage source converters (VSI) and series-series type compensation (SS-WPT) as a means for achieving higher coupling separation, higher misalignment tolerance and higher power transfer efficiency. Peter K. Joseph et al. in [2] analyses in detail about the different types of wireless charger topologies that have been implemented and proposed till date in plugged-in hybrid electric vehicles (PHEV) charging applications. It also states the disadvantages of conductive type recharging which includes cons of high starting current, physical plugging of wire, insulation damages and concerns about safety related to all of the above. Chathuranga M. et al. in [3] discusses one of the latest WPT techniques which is strongly coupled magnetic resonance (SCMR) and its capability of transferring energy efficiently over mid-range distance. The theory of SCMR is based on how two resonant objects with same frequency tend to exchange power efficiently while giving out only a small amount of energy, comparatively, in outward off-resonant objects. Xuezhe Wei et al. in [4] critically reviews wireless power transfer using strongly coupled magnetic resonance. It also gives an idea about existing WPT technologies, which are classified into electromagnetic radiation mode, electric field coupling mode and magnetic field coupling mode. The latter is further divided into two as electromagnetic induction or EMI (for short range) and strongly coupled magnetic resonance (for mid-range). Siqi Li et al. in [5] presents a review of WPT of electric vehicles (EVs). The paper presents a detailed analysis of every associated circuit component of the WPT like compensation network, power electronic converters, power control, design equations and so forth. It also discusses safety concerns, vehicle to grid (V2G) benefits, wireless communications, cost of implementation etc. Ravikiran Vaka et al. in [6] gives a detailed overview of different technologies in contactless power transfer (CPT) which includes capacitive CPT, inductive CPT and radiant CPT. This paper developed a method for EV charging using inductive CPT. The paper analyses high frequency converters and its control strategies. Songyan Niu et al. in [7] discusses the detailed history and commercialisation of WPT. The paper gives a detailed analysis about magnetic resonant WPT, its coupler structure and different types of conventional and modern couplers. It also elaborates about the different types of compensation topologies. Akhil A.G. et al. in [8] states various methods of WPT like microwave, laser, inductive coupling, magnetic resonance coupling etc. The paper discusses WPT using magnetic resonance for EVs. 3D modelling of circuit components was done using ANSYS TWIN BUILDER and ANSYS MAXWELL software and the equivalent circuit and its analyses was done using MATLAB. Otchere Peter Kweku in [9] demonstrates the method of inductive WPT for charging mobile phones. The paper gives an overview of inductive coupling and its design, resonant induction, microwave power transfer, laser power beaming etc. It also analyses the market scope and health and safety concerns. Daniel Barth et al. in [10] presents analytical computation of the eddy current losses in the litz wire. Litz wire is a combination of multi stranded wires which are twisted to form multiple bundles, in order to reduce the eddy current losses that can be caused by the proximity and skin effects. Litz wires are application-oriented and in this paper, the authors discuss the constraints to be considered while selecting the strand number, diameter and type of material of the Litz wire for a specific application. Longzhao Su et al. in [11] gives an overview of the recent trends in WPT technologies, fundamental principles of WPT, the state of art of WPT over the years and the applications of WPT in EV charging. The paper talks about the system architecture of WPT based EV, maximum efficiency tracking, comparative analysis of different types of coil structures in WPT systems, multi-frequency wireless chargers, bidirectional WPT and wireless charging of EVs. Nandagopal S. et al. in [12] describes the design and analysis of wireless power transfer systems using MATLAB. An 80V DC output was obtained when an AC input of 240V, 50Hz was given. The system was designed to operate using 125kHz frequency and by resonant magnetic coupling. Xu Liu et al. in [13] present a new design approach which shows that under certain conditions, the LCC-S compensated wireless power transfer system can be more energy efficient than S-S compensated WPT system, for the same load power.

II. PROBLEM STATEMENT

Even though multiple technologies were developed to charge the electric vehicles wirelessly, an efficient charging technology is yet to be developed for medium powered electric vehicles. For low and medium powered electric vehicles, the coupling separation and the efficiency of the power transfer are low when compared with the high powered electric vehicles. Existing voltage source based inverters allow the current to flow in the system in the reverse direction because the power converters are switched in high frequency. In order to improve the system performance, a series-series (SS) type compensation could be employed in the charger but it, along with the magnetic resonance operation, causes high current flow across the wireless coils which drastically increases the voltage through them. It calls for high insulation of the charger for safety and protection, which in turn, increases the cost of manufacture.

Addressing these challenges is crucial to ensure an effective method for the wireless charging of electric vehicles. As a means of reducing any chances of reverse current flow and source damage, a current source based inverter is used in this project. The problem with SS type compensator can be avoided by replacing it with another type of compensator which gives almost similar performance as the series-series type compensator. Therefore, in this work, LCC-S type compensation is used

III. TECHNICAL BACKGROUND

A. Wireless Power Transfer - Technologies

There are numerous techniques that can be employed for wireless power transmission that have been studied by researchers. Electric energy is transferred via three different technologies, each with a different sort of field involved. These three technologies; capacitive, inductive and radiant; take advantage of the electric, magnetic, and electromagnetic fields coupled into an electromagnetic wave as well as their unique coupling properties. Low losses, little electromagnetic emissions, and the capacity to transmit power through metal shields without creating eddy currents are the key benefits of the capacitive wireless power transmission system (WPTS). However, because of the relatively low energy density that can be stored in the area between the plates, the usage of capacitive WPTSs is restricted to very low power applications. In inductive coupling, a high frequency alternating current, typically between 10 kHz and 150 kHz, excites the transmitting coil. Inductive WPTSs are able to withstand significantly higher power than capacitive ones and can operate at higher power levels due to the greater energy density of the magnetic field in the empty space. Although they have these benefits, they also suffer from losses in the coil resistances, are rendered inoperable if a metallic body is placed in the path of the coils, and generate significant electromagnetic interference. The two topologies used by inductive WPTSs for power transfer are referred to as inductive coupling and resonant coupling WPTS. Power can be transferred over a distance several times greater than the size of the coupling devices with good efficiency using radiant WPTSs. This is accomplished by sending electromagnetic waves in a specific direction. Because the size of the coupling devices in radiant WPTSs is proportional to the wavelength of the electromagnetic waves, high-frequency waves like microwaves and lasers are utilised to keep it within reasonable bounds. In this project, magnetic resonance coupling (simply known as magnetic coupling) type WPT technology is used for transferring power from primary side to the secondary. Inductor and capacitor oscillation in the form of a magnetic and electric field, respectively, is known as magnetic resonance. With enough stimulation, energy oscillation and transmission are possible in magnetic resonance circuits. If the system's resonant energy exceeds the losses from the elements, it accumulates and moves to the secondary coil. The system works by using the resonance between the coils as its fundamental operating principle. The effectiveness and efficiency of magnetic coupling is dependent on various factors such as coil design, distance of separation between the coils and the frequency of operation. Massachusetts Institute of Technology was the first to propose resonant coupling, also known as resonant inductive coupling. The capacitors are connected in series or parallel to the transmitting and/or receiving coils in order to obtain various topologies. The effect of each topology on the wireless power transmission system performance varies. Resonant WPTS are more effective in terms of quality factor and power factor when compared to inductive wireless power transfer systems. In comparison to inductive WPTS, it can also transmit power over greater distances. The primary and secondary LC branches of resonant wireless power transmission systems are operated so that they can resonate at the supply frequency of the voltage source. That is

$$\omega = 1 / \sqrt{(LC)} \qquad (1)$$

At this frequency, the impedance becomes minimum (Z=R). The quality factor (Q) of a WPT system determines how effectively the energy is sent. The quality factor is the ratio of the energy stored in the system to the energy dissipated per cycle, and it is directly proportional to the resonant frequency and inversely proportional to the bandwidth of the resonance. Transfer efficiency will be high if the quality factor is high.

$$Q = \sqrt{(L/C)} \times 1/R \qquad (2)$$

The winding resistance should be as low as possible to preserve the high quality factor of WPT inductor coils. Premium materials like Litz wire can be utilised for this purpose.

B. Compensation Topology

Coils are spaced apart in wireless power transfer systems. Therefore, the coupling coefficient and mutual inductance are significantly impacted. As a result, the mutual inductance between two coils is low and the leakage inductance is significant. This inhibits the primary coil's capacity to transfer power to the secondary coil. Leakage inductance must be compensated for in order to get a higher mutual inductance. This makes it possible to run at resonance frequency and achieve pure resistive impedance. An arrangement of capacitors and/or inductors with regard to the primary and secondary coils is known as a compensator network. The primary and secondary coils are connected in series or parallel with capacitors that are set to resonate at the supply frequency in order to reduce coil inductance and increase energy transmission.Basic compensators come in four primary varieties: series-series (SS), series-parallel (SP), parallel-series (PS), and parallel-parallel (PP)[7]. The resonant WPTSs with the SS topology appear to be the best overall option from a comparison of the characteristics of the four mentioned topologies because they have many advantages, including higher efficiency, a smaller power supply sizing factor, a higher peak magnitude of the load resistance current, and less sensitivity of the figures of merit to the coupling coefficient and the quality factor of the receiving section. The greater receiving coil sizing factor, which rises with the receiving section's quality factor, is the only drawback. S-S compensation topology is not dependent on the coupling coefficient, therefore it can maintain the resonance condition throughout the coupling separation[1]. However, greater receiving coil sizing factor, which rises with the receiving section's quality factor is a major drawback. Therefore, a slightly modified version of series-series compensation topology is adopted in this work which is called the LCC-S compensation network. S-S and LCC-S are comparable in certain ways since they both have the same resonance compensation topology on the secondary side. Difference in primary side resonance compensation topologies, however, result in a wide range of variations in system characteristics. On the secondary side, SS exhibits constant current source characteristics while LCCS exhibits constant voltage source characteristics. Numerous desirable capabilities, including zero power angle operations and great design freedom, are offered by LCC compensation topologies, nevertheless, the inclusion of more resonant parts leads to complex tuning and an increase in system size and expense.

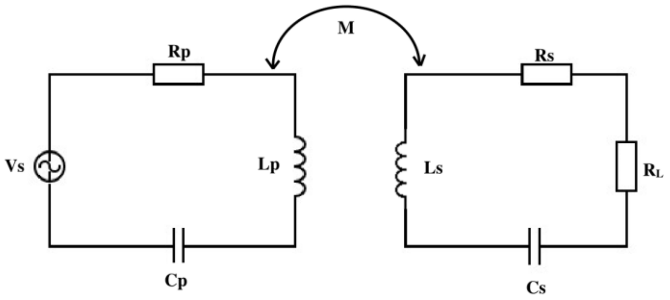

Fig 1: Magnetic resonance series-series compensation topology for WPT

C. Renewable Energy as Source

Since renewable energy resources can theoretically supply more than twice the world's energy requirements, they have a tremendous potential. Currently, renewable energy sources are capable of meeting about 15 to 20 percent of the world's total energy demand. The reverse current flow must be taken into account when integrating the renewable energy power source with a conventional converter. The transmitter side coil of the wireless charger needs AC power but the nature of the renewable energy source is DC, so a high-frequency converter is necessary. A reverse current flow will happen in the primary as a result of the transmitter side inverter's high frequency switching. The sensitive renewable source could be harmed by this reverse current flow. A current source inverter (CSI) can be used to mitigate the reverse current because reverse blocking diodes result in a significant loss of power in the system[1]. However, the magnetic resonance is distorted by the CSI - inductor interaction. A good inductance tuning strategy must be used to avoid that.

IV. PROPOSED TECHNOLOGY

A. Primary Side

The primary side of the circuit consists of a DC voltage source, an input inductor, an inverter, two compensation capacitors and an inductor and the transmitting coil. The DC source can be a renewable resource like solar energy source. The input side inductor is used to block the reverse current that may flow to the DC source. The inverter is made of MOSFETs with a gating pulse greater than 20KHz (25-100KHz). The input compensation capacitors and inductor values are determined from the transmission coil inductance and resonant frequency.

B. Secondary Side

The secondary side of the circuit has the secondary transmission coil, a compensation capacitor, bridge rectifier, a smoothing capacitor and the load. The smoothing capacitor is added on the load side to eliminate ripples. General purpose H-bridge diode rectifier is used to rectify the AC output of the secondary transmission coil to DC so that it can be further used to charge the battery.

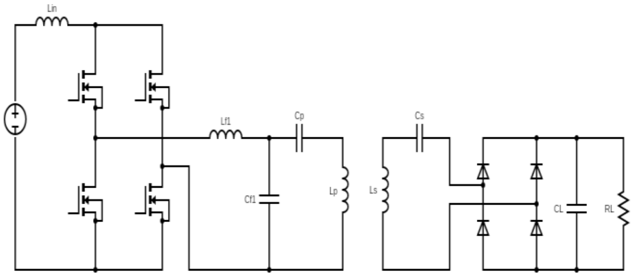

Fig 2 : Proposed Topology for WPT

C. Working

Depending on the MOSFET state, the switching period is separated into the t_{ON} and t_{OFF} intervals. The switches can be labelled as S_1 and S_3 on the upper side and S_4 and S_2 on the lower side, from left to right, respectively. During the positive half cycle i.e. t_{ON} , in the primary side, the positive leg mosfets S_1 and S_2 get turned ON and the current flows through the path charging capacitors C_{f1} and C_P, transmitting coil L_P and then back to the negative side of the DC source. The current path can be defined as,

$$V_S^+ - S_1 - L_{f1} - C_P - L_P - S_2 - V_S^-$$

At the end of t_{ON} , the switches S_1 and S_2 are turned off by forced commutation. But due to the presence of stored energy in the winding inductance current cannot be zero instantaneously. Hence, the current flows through feedback diodes in the switches, thereby feeding back the energy to the source and keeping the load voltage equal to the source voltage. Due to magnetic resonance coupling, the receiving coil in the secondary side gets energised, charging the capacitor and sending power to the load through the positive leg of the rectifier. During the negative half cycle, i.e. t_{OFF} , the switches S_3 and S_4 are triggered. The capacitors in the primary side discharges through the transmitting coil, back to the DC source through the negative leg of the inverter. The current flows through the path,

$$V_S^+ - S_3 - L_P - C_P - L_{f1} - S_4 - V_S^+$$

At the end of t_{OFF} , the switches S_3 and S_4 are turned off by forced commutation.Hence, the current flows through feedback diodes in the switches, thereby feeding back some energy to the source. This helps in maintaining the load voltage equal to the source voltage. Again, the power is transferred to the secondary coil and to the load when the secondary compensation capacitor discharges through the negative side of the rectifier.

D. Design

According to IEC61980 and SAEJ2957, the operational frequency of the electric vehicle should be 85KHz. For a medium-powered electric vehicle, power requirement for class II-type (medium-power EV) charging is above 3kW. For an LLC-S compensated WPT, the resonance frequency condition is given by,

$$\omega_0^2 = 1/LC \tag{3}$$

The impedance of the system is minimum at this frequency. This resonant frequency is directly proportional to the quality factor (Q) of a WPT system. Quality factor is directly related to the rate at which energy is dissipated in the system. Higher quality factors correspond to sharper resonance peaks and narrower bandwidths, indicating less energy loss per cycle. Transfer efficiency will be high if the quality factor is high.

$$Q = 1 / R \times \sqrt{(L/C)} \tag{4}$$

In order to ensure high quality factor, winding losses should be kept low for which the winding resistance should be minimum. The winding resistance of the Litz wire can be calculated using the formula,

$$R = \rho \times (L/A) \tag{5}$$

where R is the winding resistance, ρ is the resistivity of the Litz wire in Ω-metres, L is the length of the wire in metres and A is the cross sectional area of the wire in square metres.

Litz wire is designed to reduce the skin effect that causes the current to concentrate near the surface of the conductor thereby increasing the resistance, in high frequency applications. Therefore, while calculating the cross-sectional area of the litz wire, a correction factor for skin effect(f_C) should be considered. Hence, the effective cross-sectional area of the litz wire can be computed using the equation,

$$A_{eff} = A \times f_c \tag{6}$$

where A_{eff} is the effective cross-sectional area of the litz wire, A is the total cross-sectional area of that wire and fc is the correction factor for skin effect. The value of f_c is specific to litz wire construction and the frequency of operation. It can be obtained from the manufacturer's datasheet or design tables. Therefore, the effective winding resistance of the litz wire can be calculated using,

$$R_{Litz} = \rho \times (L / A_{eff}) \quad (7)$$

where R_{Litz} is the effective winding resistance of the litz wire in Ω. For transmission and receiving coil, Litz wire of strand gauge of AWG 38(Diameter = 0.1007mm) can be selected which is the appropriate one for the selected operating frequency of 85kHz. The coils can be wound in rectangular shape to obtain maximum coupling, transfer efficiency and misalignment tolerance. The inductance of rectangular shaped coil can be obtained from inductance of a rectangular coil with dimensions is computed as;

$$L=\mu_0^2\times[(a+b)\times\log((4\times(a+b))/d)-a\times\log(a+\sqrt{(a^2+b^2)})-b\times\log(b+\sqrt{(a^2+b^2)}) + 2\times \sqrt{\ } a^2 + b^2 + (d-2\times(a+b))] \quad (8)$$

where ’a’ and ’b’ are the length and the breadth of the rectangle in metres, respectively and ’d’ is the coil’s diameter. Here, the length and breadth considered for both the primary and secondary coils are 0.3cm each, respectively. The diameter of the selected Litz wire is 0.1007mm. Each wireless transformer is built to have a specific coupling coefficient (k), in order to provide the desired output voltage in a circuit. The coefficient of coupling is a parameter that describes the extent of magnetic coupling between the coils. The value of k ranges from 0 to 1 where 0 indicates no magnetic coupling and 1 indicates perfect magnetic coupling. For ideal coupling, the value of k will be 1 but for practical wireless coupling, the value of k will be between 0.3 and 0.5 due to the leakage flux and imperfections in the magnetic core. Based on the current flowing and winding loss, the primary inductance Lp value is fixed in the design initially. The coupling coefficient is then fixed to determine the secondary inductance Ls. The winding losses rise as k decreases and hence, the value of L increases and vice versa. However, the effectiveness of the transmission is significantly impacted by winding design. Here, a wireless transformer is designed with a coupling factor k = 0.33, which is a widely accepted coupling factor for wireless power transfer considering the losses, coupling separation and transfer efficiency[1].

$$M = k \times \sqrt{(L_P \times L_S)} \quad (9)$$

$$V_S / V_P = k \times (N_S / N_P) = k \times (L_S / L_P) \quad (10)$$

where V_S and V_P represent the secondary and primary voltages, and N_S and N_P represent the number of secondary and number of primary turns, respectively. It is possible to determine the inductance of the secondary coil, L_S by fixing k, given the value of V_S and V_P. The WPT is giving the rated output at the same coupling separation since it is built for an output voltage of 300 V at the chosen coupling coefficient of k = 0.33. For the simulation, the load resistance is adjusted between 20 and 70. However, when the transfer distance increases, power transfer efficiency drops significantly. The value of k is changed from 0.1 to 0.5 in order to examine the impact of coupling coefficient in WPT. To ensure that the resonance condition is not compromised, the primary side’s overall inductance is kept constant while the secondary side inductance is adjusted in accordance with changes in k. The values of the compensation topology is computed using the design equations as given below:

Capacitor C_{f1};

$$C_{f1} = 1 / L_{f1} \times \omega_0^{\,2} \quad (11)$$

Primary compensation capacitor Cp;

$$C_P = 1 / (L_P - L_{f1}) \times \omega_0^{\,2} \quad (12)$$

Secondary compensation capacitor C_S;

$$C_S = 1 / L_S \times \omega_0^2 \quad (13)$$

where $\omega_0 = 2 \times \pi \times f$;

f = operating frequency = 85 kHz = 85×10^{-3} Hz
L_{f1} = primary side compensation inductance
L_P = inductance of the primary coil
L_S = inductance of the secondary coil

V. RESULTS AND DISCUSSION

When an input voltage of 130V DC is given, an output voltage of 298V was obtained and the output current obtained was 11.1A(fig 3). The total output power of the system was obtained to be 3.3KW which is in compliance with the type 1 charging standards specified by SAEJ2954 (standard for wireless power transfer for electric vehicles by SAE International).

The efficiency of the system can be computed by the equation;

$$\eta = (V_{out})^2 R_L / V_{in} \times I_{in} \quad (14)$$

From the simulation results, it is observed that the proposed system shows about 80 per cent efficiency, when the value of coupling coefficient, k = 0.33. It is noticed that the output voltage changes according to the change in the value of k and they are in a direct proportional relation. Therefore efficiency of the system also increases with the increase in the value of k. One of the major disadvantages of the series-series compensation, when used for medium or high power transfer, is that any disturbance in the resonant frequency can produce high voltages and currents in the transmission as well as receiving coils. The system is prone to frequency changes whenever there is misalignment between the transmitter and receiver, i.e. the system is sensitive to misalignment. When the same input and load conditions are given to the wireless electric vehicle charger with S-S compensation and to the LCC-S compensation, thousands of volts were produced in the transmission coil and the receiving coil of the S-S compensated system. This problem was overcome by changing the topology of the LCC-S topology.

TABLE 1: Parameters used for simulation

Parameter	Value
Input voltage, V_S	130 V
Duty ratio, D	50
Input inductor, L_{in}	8μ H
Primary coil inductance, L_P	117μ H
Secondary coil inductance, L_S	735μ H
N_P:N_S	4:10
Primary compensation inductor, L_{f1}	8μ H
Primary compensation capacitor, C_{f1}	438nF
Primary compensation capacitor, C_P	32nF
Secondary compensation capacitor, C_S	4.76nF
Load resistor, R_L	24Ω
Switching frequency, f_S	85kHZ

Figure 7 shows the secondary side receiver voltage of a series-series compensated system of the wireless power transmission electric vehicle charger with the same input and the load conditions as that of the proposed LCC-S compensated topology. For the same input and load conditions with the same operational frequency of 85KHz, the secondary coil voltage shows thousands of voltages for the series-series compensated system. This situation demands high insulation requirements which in turn increases the production cost drastically.

Simulation results show that the proposed topology gives an output of about 300V when an input of 130V is given. 3.1kW output power was obtained which complies with the power standards of class 1 type wireless charging. As indicated about the CSI design, the transmitter inductance value is adjusted by taking the primary-side converter's input inductor into account. Eliminating reverse current flow, increasing wireless power transfer effectiveness, and achieving a higher and flexible coupling separation are the main objectives of this tuning. This proposed design aims to reduce power loss due to misalignment, which will add flexibility to the charging mechanism, along with enhanced coupling separation and higher transfer efficiency. Rectangular-shaped WPT coils will play a significant role in tolerating misalignment for medium-powered EVs like e-cars. Misalignment tolerance has a significant impact on EV charging applications in the real world. Here, the suggested concept can be put into practice for EVs with medium power, such e-cars. The primary benefit of these vehicles is their physical stability provided by their four-tyre design. According to the findings of the analysis, the suggested design offers good efficiency even for the worst-case misalignment.

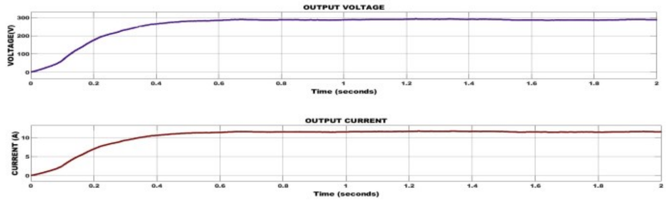

Fig 3: Output voltage and output current

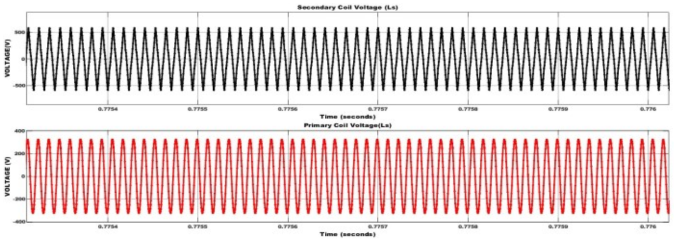

Fig 4: Coil voltages

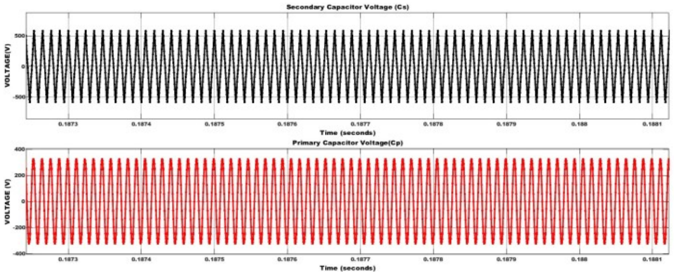

Fig 5: Compensation capacitor voltages

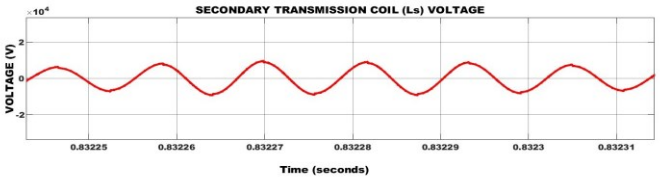

Fig 6: The secondary coil voltage of the series-series compensated topology

VI. CONCLUSION

In the transportation industry, wireless EV charging is quickly becoming the technology that defines an era. For EV charging, a variety of WPT techniques were devised, each with advantages and disadvantages of its own. The entire idea of electric vehicle transportation can only be realised truly and totally with the integration of renewable energy sources. However, standard topologies cannot be efficiently used to integrate renewable energy and achieve flexible charging distance as well as better transfer efficiency.

The analysis, design, and software implementation of a wireless charger for medium powered electric vehicles are presented in this project. The simulation results show that the proposed magnetic resonant wireless electric vehicle charger is a simple structure which gives a boosted DC output for DC input voltage. Since the performance in the simulation is promising, a prototype should be implemented to examine the design's viability and to confirm the simulation's findings. The system can be expanded to charge high-power electric vehicles if it proves to be practical. Future development can also construct a very effective vehicle-to-grid system by switching the converter circuit to a bidirectional mode.

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