WIRELESS CHARGING OF ELECTRIC VECHICLE USING DOUBLE SIDED LLC COMPENSATION METHOD

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Abstract

A new LLC resonant converter with two transformers in parallel for the electric vehicle battery charger is designed. The topology achieves the zero-voltage switching for main switches in the entire charging profile. In addition, the zero- current switching for output rectifier diodes is extended under charging condition. The charger provides a wide range output voltage for the battery system. In order to maintain the high efficiency under charging, the charger adopts a bidirectional switch. At low-output power condition, the charger uses one transformer to transfer the energy. Finally, the design procedure is provided and implemented in a prototype charger with the input DC link 30V and the output voltage of 36-50V. Experimental results are presented to demonstrate the system performance. The maximum power is up to 35 W and the peak efficiency is high.

KEYWORDS: *LLC resonant converter, MPPT tracking, H-bridge, resonant tank, arduino, WPT*

I. INTRODUCTION

Global warming and energy policies have become a hot topic on the international agenda in the last years. Developed countries are trying to reduce their greenhouse gas emissions. For example, the EU has committed to reduce the emissions of greenhouse gas to at least 20% below 1990 levels and to produce no less than 20% of its energy consumption from renewable sources by 2020. In photovoltaic (PV) power generation has an important role to play due to the fact that it is a green source. However, most of the PV power generation comes from grid-connected installations, where the power is fed in the electricity network. Instead, improving the tracking of the maximum power point (MPP) with new control algorithms is easier, not expensive and can be done even in plants which are already in use by updating their control algorithms, which would lead to an immediate increase in PV power generation and consequently a reduction in its price. MPPT algorithms are necessary because PV arrays have a non linear voltage-current characteristic with a unique point where the power produced is maximum. The objective of this project is firstly to review different MPPT algorithms. Then the most popular, perturb and observe (P&O), incremental conductance and fuzzy logic control (FLC) are analyzed in depth and tested according to the standard mentioned above. After that, improvements to the P&O and the InCond algorithms are suggested to succeed in the MPPT tracking under conditions of changing irradiance. To test the MPPT algorithms according to the irradiation profiles proposed in the standard, a simplified model was developed, because the simulation time required in some of the cases cannot be reached with the detailed switching model of a power converter in a normal desktop computer. The reason for that is that the computer runs out of memory after simulating only a few seconds with the complete model. Finally, the simplified model is verified by comparing its results with those obtained from a model containing a detailed model of an inverter.

II. PROPOSED SYSTEM ARCHITECTURE

There is a need for charging electric vehicles (EVs) wirelessly since it provides a more convenient, reliable, and safer charging option for EV customers. A wireless charging system using a double-sided LLC compensation topology is proven to be highly efficient. However, the large volume induced by the compensation coils is a drawback. The block diagram shown in Fig.1 consists of an output DC supply which is converted in to AC by using the H-bridge converter and then it is fed to the resonant tank. The resonant tank is used to increase the efficiency of transmission and decreases the losses. The supply is transmitted using the transformer arrangement. The same resonant tank circuit is connected in the secondary side this doesn't causes any losses but it increases the switching speed of the diode. A capacitor is connected before the load in parallel to decrease charge dissipation. Then the load is fed with the DC supply from the diode.

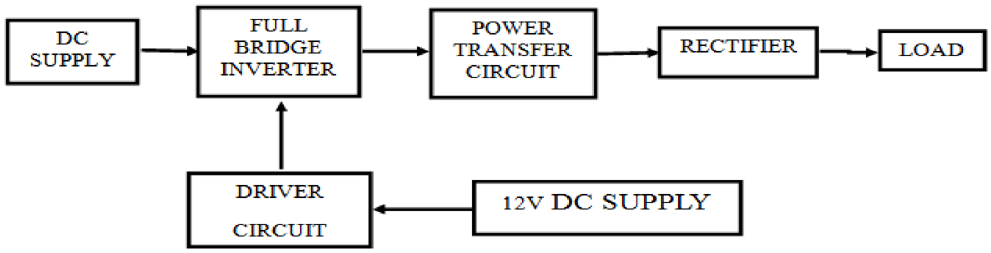

Fig.1 Block diagram of Proposed System

The Fig.2 shows the circuit diagram of the proposed system. From the conventional system the proposed system has a new technique that is the LLC compensation. This decreases the losses and increases the switching speed of the switches. The same sequence is used in the secondary side in order to stabilize the voltage and to increase the resonant frequency.

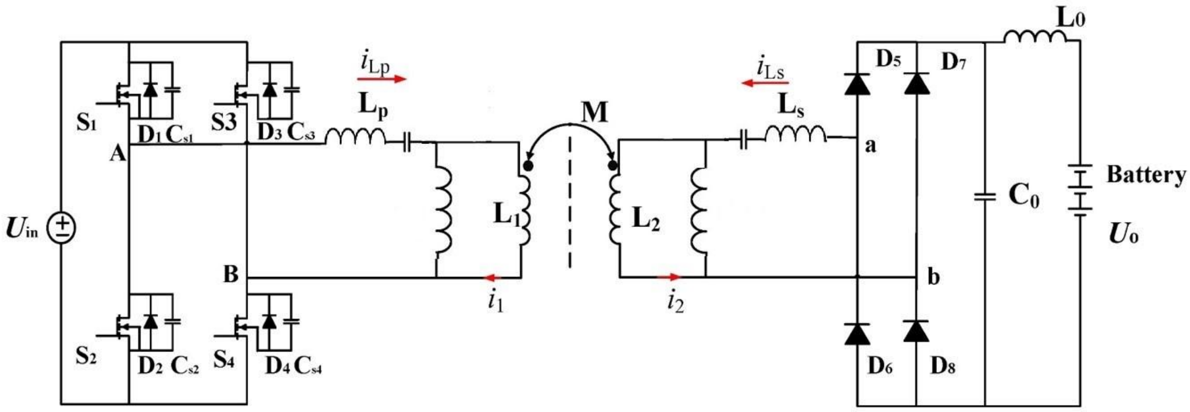

Fig.2 Circuit Diagram of the Proposed System

In order to make the system more compact, A new method to integrate the compensated coil into the main coil structure. With the proposed method, not only is the system more compact, but also the extra coupling effects resulting from the integration are either eliminated or minimized to a negligible level. Three-dimensional finite-element analysis tool MAT-LAB is employed to optimize the integrated coils, and detailed design procedures on improving system efficiency are also given in this paper. The wireless charging system with the proposed integration method is able to transfer 3.0 kW with better efficiency (overall dc to dc) at minimum air gap.

$$V=IR \qquad (1)$$

$$P=IV=I^2R \qquad (2)$$

As seen in the equations above, power loss can be derived from the electrical current squared and the resistance of a transmission line. When the voltage is increased, the current decreases and concurrently the power loss decreases exponentially; therefore high voltage transmission reduces power loss. For this reasoning electricity was generated at power stations and delivered to homes and businesses through AC power. Alternating current, unlike DC, oscillates between two voltage values at a specified frequency, and its ever changing current and voltage makes it easy to step up or down the voltage. For high voltage and long distance transmission situations all that is needed to step up or down the voltage in a transformer. The transformer made for long distance electrical transmission using AC power is possible.

III. SIMULATION DIAGRAM

The conventional circuit for simulation is shown in Fig.2 has a DC voltage source which is connected to the full bridge inverter which has 4 MOSFET switches. The full bridge inverter converts the DC supply to AC supply and feds it to the resonant tank. The resonant tank is used to increase the frequency to a very high value and transfers it wirelessly. In the resonant tank LLC compensation technology is used in order to increase the switching speed. Even the resonant tank increases the efficiency of the circuit. The same resonant circuit is in the secondary side with the same LLC compensation technique.

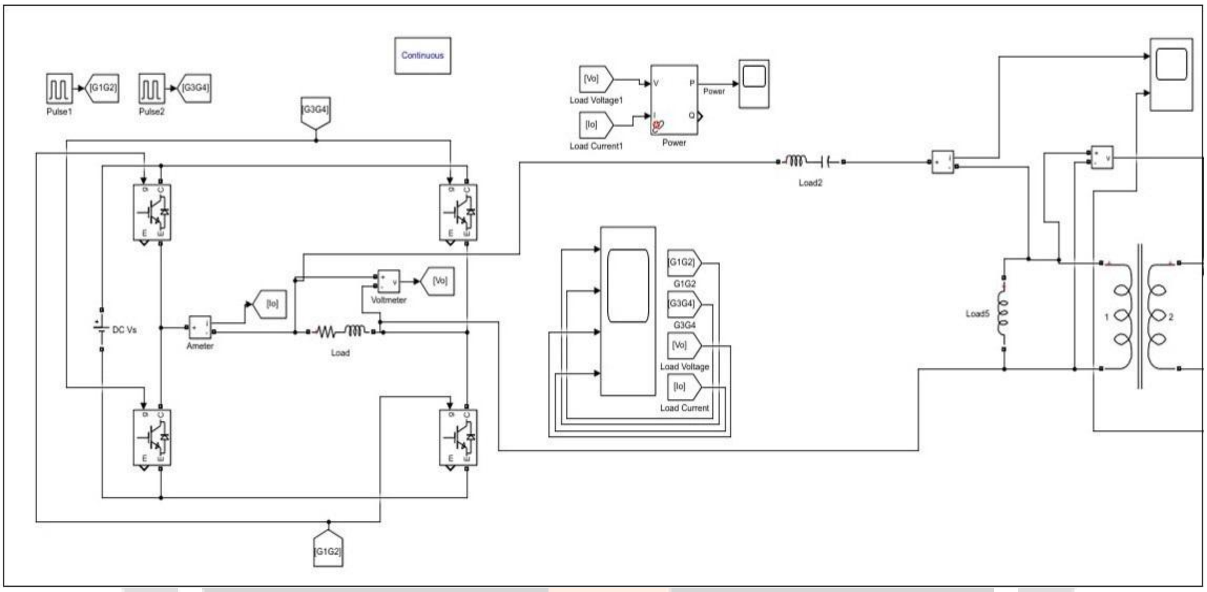

Fig.3 Simulation of Primary Side

The primary side of the simulation is shown in the Fig.3. In the primary side a H-Bridge inverter is used to convert DC-AC it consist of four MOSFET switches which are connected parallel. The pulse generator is used to fed the pulse to the MOSFET to convert the DC-AC. Alternating wave is generated and fed to the switches in order to generate or convert a pulsating DC to a AC supply. The pulse generator is a simple microcontroller which is working according to the program fed to it. It controls and gives a AC supply from the primary side. Then the MOSFET is connected to the resonant arrangement that is the LLC compensation method which is used to increase the resonant frequency to decrease the losses while wirelessly transferring energy. Then the supply is given to the primary coil.

The secondary side of the simulation is shown in the Fig.4. The secondary side begins with the secondary coil which receives the flux from the primary coil. Then the secondary side is connected to the resonant tank which is a LLC compensation, the LLC compensation is similar to that of the primary side and so it is called as double sided LLC compensation. Then the supply is connected to the H-bridge rectifier connection. This is used to convert the AC supply to the DC supply.

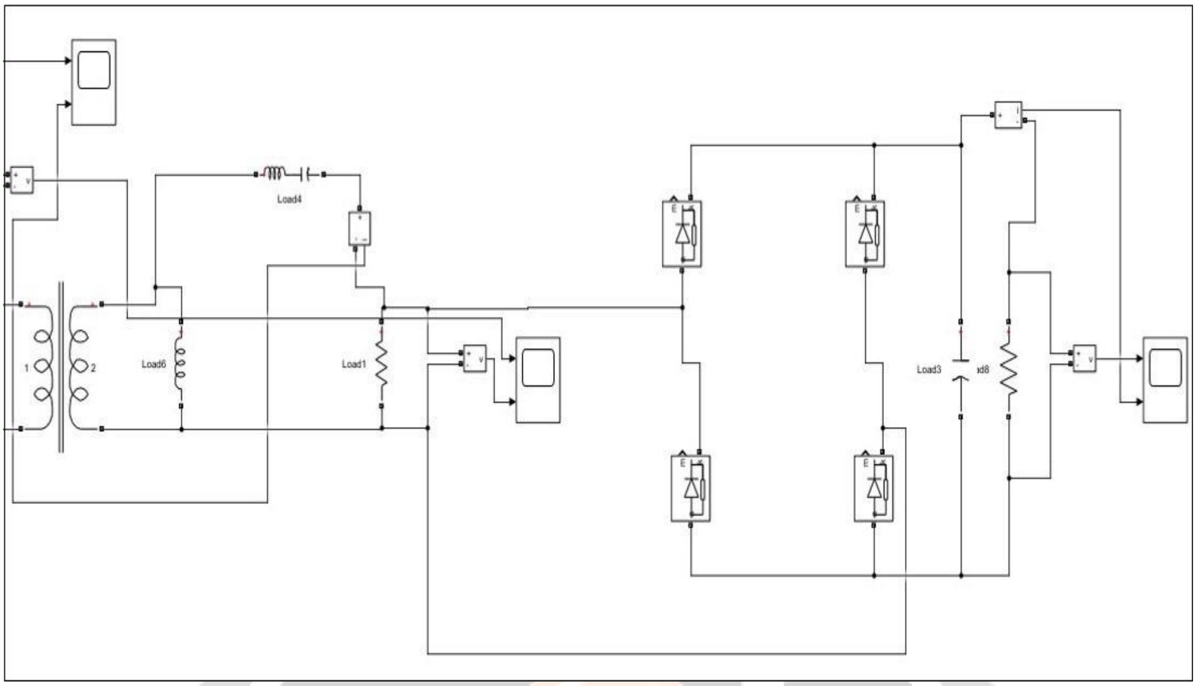

Fig.4 Simulation of Secondary Side

A capacitor is connected in parallel to dissipate the stored charges. The load is connected at the end which is a electrical vehicle. The output of the resonant tank in secondary side is given to the H-Bridge inverter which converts AC to DC supply. The output of the converter is given to the electric vehicle that is the load. The full bridge inverter or the H-bridge inverter in the primary side contains 4 MOSFET switches which are driven alternately with the help of the pulse generator. The pulse generator generates an alternate pulse to convert the DC to AC supply. The resonant tank is connected next to the full bridge converter to increase the efficiency and the switching speed this is shown in the Fig.3. The same circuit is repeated in the secondary with small changes. The H-bridge inverter is changed to a H-bridge converter. It converts the AC supply to DC supply and it is fed to the load the simulation of the secondary side is shown in Fig.4.

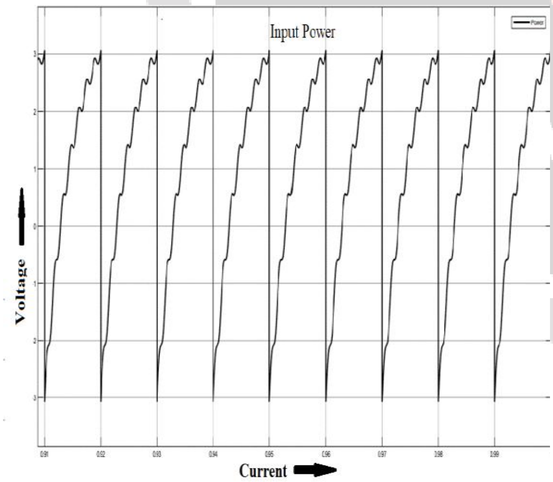

Fig.5 Input Power in Primary Side

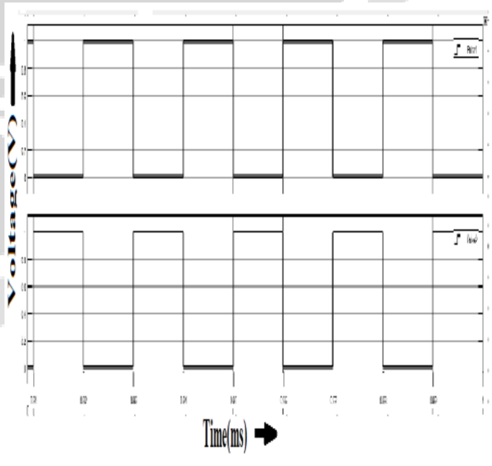

Fig.6 Gate pulse for MOSFET switches

The Fig.5 shows the input power that is given to the primary side of the circuit. The power is calculated theoretically with the formula shown in Equation 1. **T**he Fig.6 represents gate pulses for MOSFET switches. The pulse generator is connected across the MOSFET switch for triggering the gate pulse, which is given with the amplitude 1, period is 0.02 milliseconds, pulse width is 50% of period and phase delay is zero seconds. In the output from the H-Bridge inverter a RL load is connected. The resistance R=1 Ohms and Inductance H = 5e-3. Both voltage and current measurement device connected across the load for monitoring purpose.

Output from the H-Bridge is fed with a Linear Transformer. The transformer is used for isolation. In the secondary side of the transformer one more LC load is connected. Also full bridge rectifier fed with the secondary transformer. The output from secondary is DC voltage. Load is connected with the Dc voltage. The load is resistance load. A voltage measuring device is connected across the R load. Hence, the voltage can be monitored using scope. The pulses that are given to the MOSFET to convert the DC to AC are generated by the pulse generator to fed the MOSFET. These pulses are generated with the help of the Arduino microcontroller. The arduino serves the driver circuit and controls the MOSFET alternately to convert the DC supply to the AC voltage.

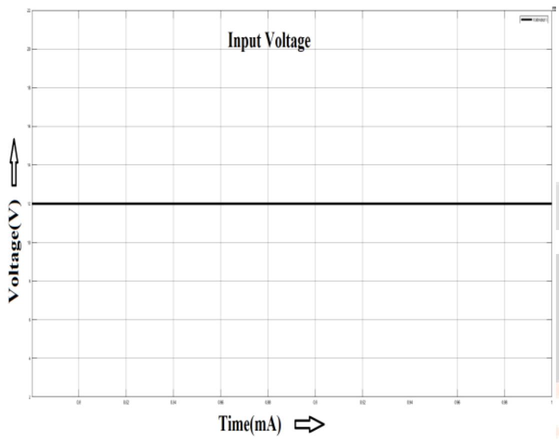

Fig.7 Input Voltage

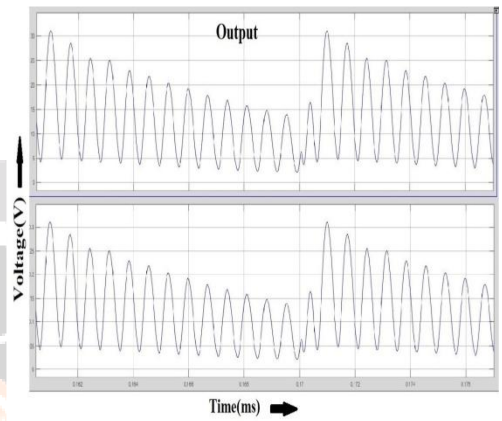

Fig.8 Output voltage

The input voltage of the circuit is shown in Fig.7. A 12V supply is connected as the input of the system. It is a DC supply the input may be a pure DC or pulsating DC. The input is fed to the H-Bridge inverter in order to convert it to AC. The output voltage is shown in the Fig.8. The output of the converter is fed to the load that is the electric vehicle. The output voltage is measured using the voltmeter and it is measured using graph. The output voltage is measured by connection a scope in the output side (i,e) the load. Actually the voltage should be pure DC, but it is pulsating DC it can be converted to pure DC by adding filters in the load. The ripples are due to the switching of the diodes. The total time cycle is 0.2ms.

The System connected with a dc source of 200V. A voltage measurement device is connected across the dc source shown in Figure 3.5 in order to monitor the voltage via scope. This source fed with a H-Bridge converter. The bridge inverter converts the DC source into Ac source. The Pulses given to the switches are generated form the pulse generator. The pulse generators one has a amplitude of 1 and the period for a single cycle is 1/50 sec. The width of the pulse is 50%, there is no phase delay in the generator. The pulse generator two has a amplitude of 1 and the period for a single cycle is 1/50 secs. The width of the pulse is maintained at 50% as of the original. The phase delay is 10e-3.

IV. HARDWARE IMPLEMENTATION

In the hardware implementation process the components are fused together and the main aim of the project is obtained. The components are connected with the help of the soldering iron, the components are fixed on the printed circuit board. All the components are selected according to their specifications recommended for the wireless power transfer. The major use of the arduino is to provide the gate pulses to the MOSFET, since MOSFET requires a gate pulse to convert the DC to AC. The arduino is connected to the PC and the required program to provide gate pulse alternately is added. The gate pulses should be provided alternately to convert the pulsating DC to AC supply.

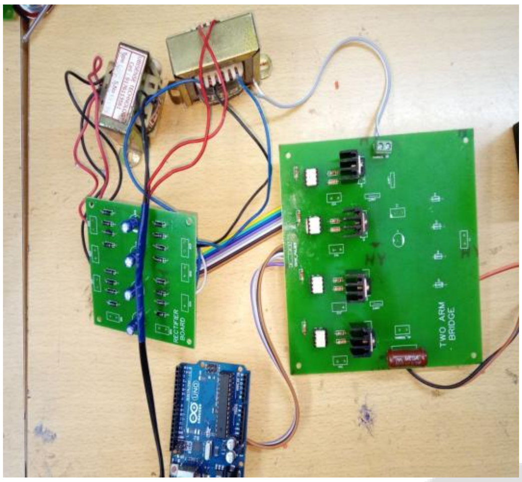

Fig.9 Hardware Circuit (Primary Side)

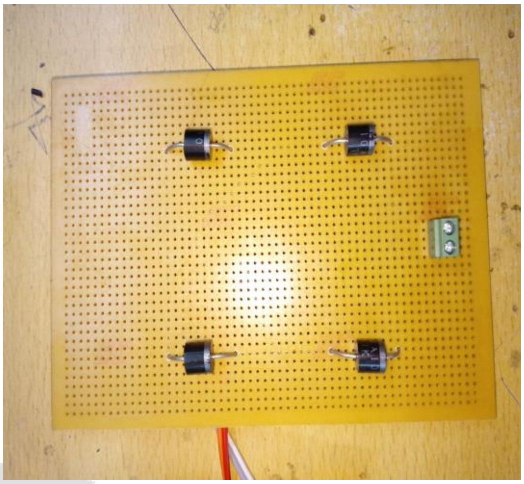

Fig.10 Hardware Circuit (Secondary Side)

The primary side consist of inverter, arduino, pulse generator, power supply is shown in Fig.9. At first the supply is provided to the H- bridge circuit, rectifier circuit and arduino. The rectifier circuit is used to convert DC-AC for the MOSFET switches and feds the MOSFET through the rectifier. The arduino is used as a pulse generator which is used to give alternate ON and OFF time for the MOSFET's. The transformer is used to regulate the supply given to the MOSFET and the output of the H-Bridge inverter is given to the transmitter coil. The Fig.10 shows the secondary side of the circuit which contains a Resonant tank, Diode, and Load. The secondary resonant tank is used to decrease the frequency when compared to the primary side. Resonant tank contains two inductor and one capacitor. Then the circuit board contains a rectifier circuit. The diode is fused to that rectifier circuit which is used to convert the AC-DC. But by using this rectifier circuit, only pulsating DC is obtained. Then a capacitor is used as a filter to reduce the noise or pulse produced in rectifier circuit. Then the supply is fed to the battery. Battery is used to store the dc voltage.

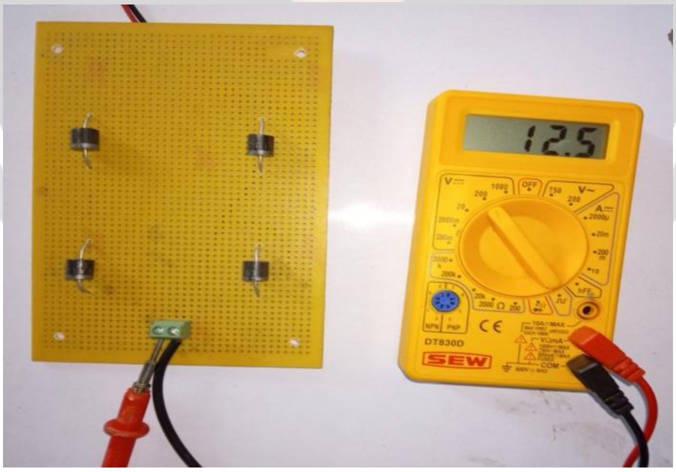

Fig.11 Output Voltage

The output of the Hardware implementation of electric vehicle charger using the wireless power transfer circuit is obtained it is shown in the Fig.11. The output voltage that obtained is in and around 12.5V which is enough to charge a battery. The output voltage is connected to the load and the battery is charged wirelessly using the circuit.

V. CONCLUSION

Wireless Power Transfer (WPT) technology is widely used in powering biomedical implants, tooth brush, cell phones, laptops, and even plugin hybrid electric vehicles and electric vehicles .The power level ranges from several milli watts to tens of kilowatts. The inductive-based wireless charging for PHEVS and EVS is highly acknowledged since it provides a more convenient, reliable, and safer charging option compared to conductive charging. The research in this field is of a great variety, such as coil design, power electronics converters and control method, issues. among them, coil design and compensation topologies are two main research areas.Thus the hardware model of the wireless power transfer can be used in the electric car charger. It can efficiently transmit energy wirelessly using the LLC compensation technology which helps in effective increase in the efficiency of the circuit. It can be implemented in the improvising technology for charging the electric car easily without complications, since electric cars are being increasing in number.

VI. FUTURE SCOPE

The future scope of this project can be kept to very high level, because electric cars are increasing in number and its necessary for the future. They may be shortage of fossil fuels in the future, at that time the electric car serves as a great replacement. If the wireless charging is improvised and more efficiency can be obtained then it hits to a newer history in development of car science.

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