WIRELESS CHARGING OF ELECTRIC VEHICLES

Elena Paul[1], Nimmy Paulson[2], Rijo Bijoy[3], Benny K.K.[4]

[1,2,3]B .Tech Student, Electrical Dept., Christ College of Engineering, Irinjalakuda, Thrissur, Kerala, India
[4]Professor, Dept. of Electrical Engineering, Christ college of Engineering, Irinjalakuda, Thrissur, Kerala, India

---

Abstract - *In recent years with the rapid development of the electrical vehicle (EV) of new energy industry, higher requirements are put forward for convenience, safety and reliability of the charging of electric vehicles. Wireless power charging is done by inductive coupling. Inductive coupling can done in both stationary and dynamic conditions. By reconfiguring the transformer and altering high frequency, energy is being transferred with low energy loss and fewer demands on the primary circuit. Sufficient power for the battery can be transferred by the primary to the secondary without sufficient energy loss. Electric power is then transmitted to the chargeable battery which is electrically coupled to the secondary circuit through the air core transformer. In case of shuttle bus services, buses can be charged when it waits at bus station. It can also be implemented in rental taxi parking. Thus the battery in electric buses only needs enough charge to go to the next stop. This decreases the battery size and promotes significant cost saving in electric vehicles. This technology enables efficient opportunities in charging stations, for predefined routes and planned stops reducing down the time of charging. The dynamic charging will promote the use of electric vehicles and reduce petroleum fuel consumption. Delays in traffic signals can now be provided with longer periods of charging and even when the electric vehicle is in movement. Bad weather conditions like rain and snow do not affect the charging capabilities of electric vehicles.*

Key Words: Electrical Vehicle, Inductive Coupling, Fuel Consumption, Time of Charging

1.INTRODUCTION

Wireless charging systems can be employed in high power applications consisting of electric vehicles as well as plug in electric vehicles in stationary conditions [1]. Wireless charging system has more simplicity, reliability and user friendliness, when compared with plug in charging systems [2]. The main problem of WCS is that it can only be used when the car is parked or in stationary conditions like car parks, traffic signals, garages etc. The main challenges faced by stationary wireless charging are electromagnetic compatibility issues, low power transfer, large structure, less range and high efficiency [3].

Dynamic mode of operation is used to improve the range and sufficient volume of battery storage. So this method allows the charging of battery storage devices even when the vehicle is in motion [4]. Here the vehicles only need low volume of battery storage thus the range of transportation is able to be increased [5].

Here the dynamic WCS have to face mainly two problems such as large air gap and coil misalignment. The coil alignment and air gap distance between the source and receiver is used to determine the power transfer efficiency [3]. In small vehicles the air gap distance ranges from 150 to 300 mm and air gap distance increases for large passenger vehicles. Since the vehicle can be driven automatically in dynamic condition, alignment of required driving position on the transmission coil can be made possible.

2. PRINCIPLE OF OPERATION

AC main from the grid is converted into high frequency AC through AC/DC and DC/AC converters to enable power transfer from transmission coil to the receiving coil. Series and parallel combinations based compensation topology are used in both receiving and transmitting sides to improve the overall system efficiency [6].

Receiving coils are fixed under the vehicle to convert the oscillating magnetic field to high frequency AC. The high frequency AC is converted into a stable DC supply which can be used by the on board batteries.

To avoid any kind of health and safety issues and stable operation the power control, communications, and battery management system (BMS) are used. To reduce any harmful leakage fluxes and to improve magnetic flux distribution, magnetic planar ferrite plates are used at both transmitter and receiver sides.

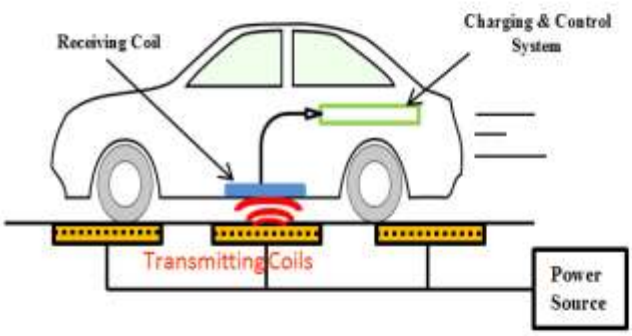

Fig.1: Schematic WEVCS

The systematic overview of wireless EV charging system is shown in Fig.1.

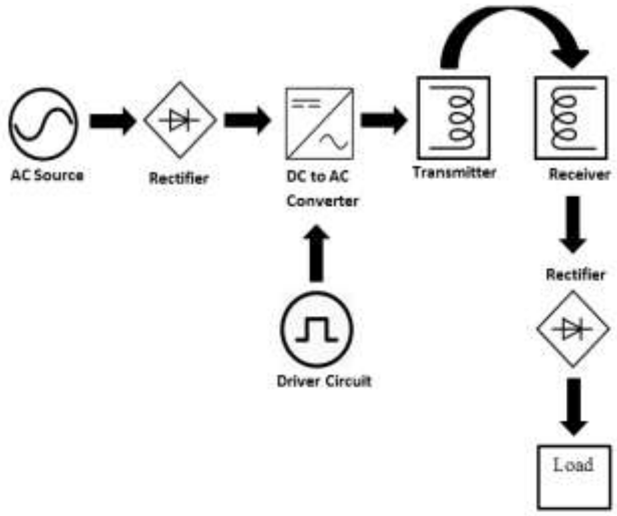

Fig.2: Block diagram of end to end system

The Fig.2 below shows the end to end system overview of the modules used in our experiment.

The main component of this system is the various ways of stepping down the incoming voltage. A conventional 220Vrms/50 Hz means is stepped down using the transformer to our required voltage and then converted to DC voltage. By using an inverter, the DC is converted to AC of our desired high frequency. The power is then transmitted through the transmitter coil to the receiver coil through inductive coupling. The receiver coil is placed at a particular distance and AC power is delivered at the end. This power is then rectified and regulated using a bridge rectifier and Zener diode circuit. Afterwards, the energy is harnessed to charge the battery. The transmitter and the receiver coils were designed to achieve maximum quality factor to maximize power transfer at the frequency of operation.

2.1 Challenges and hurdles to the deployment of WEVCS

Before the deployment of wireless electric vehicle charging system the problems linked with health and safety, finances, power range limitations, infrastructure development and maintenance should be overcome. Issues linked to Health and safety issues like EMC, fire, and electrical hazards have to be marked with the present standards. The power range constraints when compared to the plug-in charging system are another problem to the acceptance of the WEVCS system.

By DC fast charging method it is able to provide a range of 60 to 80 miles in in 20 minute time limit. Even now this technology is still in the research and development phase. Advanced network of static and dynamic wireless charging stations is required to be installed on the roads in order to overcome such issues. Due to incompatibility with the current arrangements these type of network demands for a modified infrastructure development. To avoid any significant losses due to improper handling, wear and tear, and limitations of foreign object identification, the maintenance of the structure becomes very critical since it is an expensive investment. A wide variety of experiments with simulation oriented methods are encouraged to make user friendly standards which can be made to ensure worldwide consistency so as to successfully implement WEVCS.

3. APPLICATION OF WEVCS

Wireless electric vehicle charging systems can be divided into two different incidents to channel power from the source to the battery bank and into the car based on their applications.

3.1 Static wireless electric vehicle charging system (S-WEVCS)

WEVCS creates an innovative way to provide a user-friendly environment for users and prevents any safety related problems with the plug-in charging system. Static WEVCS is able to replace easily the plug-in charging system with less driver participation and it is able to solve related safety issues such as trip and electric shock hazards. The primary coil is usually installed below the electric vehicle's front, back or center. The energy received from the electric vehicle is first converted from AC to DC by using a power converter and then it is transferred and stored in the battery bank. Power control and battery management systems are linked with a wireless communication network so as to receive any feedback from the primary side, thus it is able to overcome any safety issues. The charging time of the electric vehicle depends upon the power level of the source, size of the charging pad and air-gap distance between the two windings. In light weight vehicles the average air gap distance between the two coils is about 150–300mm. By a lever mechanism the distance between the coils can be reduced to applicable level. Static WEVCS can be implemented in parking places, car parking facilities, residential areas, commercial and industrial buildings, shopping malls etc.

3.2 Dynamic wireless electric vehicle charging system (D-WEVCS)

Two major obstacles suffered by the plug-in hybrid electric vehicles are cost and range. EVs are needed to be charged quite frequently or need to install a larger battery pack which leads to additional issues such cost and weight. Also frequent charging of an electric vehicle is not economical. Thus by implementing dynamic wireless electric vehicle charging system (D-WEVCS) the problems associated with range and cost of electric vehicles can be reduced. Thus D-WEVCS becomes the only answer for future of electric vehicle automation. It is also known as a "roadway powered", "on-line" or "in-motion" WEVCS. With high voltage, high frequency AC source and compensation circuits to the micro grid, the primary coils are inserted inside the road surface at a preset distance.

The secondary coil is placed below the vehicles similar to the static-WEVCS. Whenever the electric vehicles passes over the transmitting coil, the vehicle receives a magnetic field through the receiving coil and converts it into DC it is used to charge the battery bank by using the power converter and

BMS. When comparing with the current electric vehicles, here by using frequent charging facilities of electric vehicles reduces the overall battery requirement to about 20%. Necessary transmitting coil pads and power supply components need to be installed on specific locations and pre-defined routes. When comparing with the segmented scheme, the centralized scheme has lower efficiency, higher losses, higher installation and maintenance costs. However the initial infrastructure installation of this technology will be expensive. In future with the help of a self-driving vehicles, it would be able to produce perfect alignment between the transmitter and receiver coils, thus it could greatly increase the overall efficiency of the power transfer. Dynamic-WEVCS can be implemented in many electric vehicle transportation applications like light duty vehicles, bus, and rail and for fast transportation.

4. EXPERIMENTAL RESULTS

The rectified output signal is shown in fig.3, which is read from DSO oscilloscope when an AC signals as input. Fig.4 shows arduino pulse given to the optocouplers. According to the pulse the optocoupler conducts and generates gate pulse. IGBT switch will conduct if and only if there is a presence of gate signal. The gate pulse is taken across the gate and emitter pin of IGBT. Fig.5 represents the gate pulses given from the IGBTs of different links S1 andS3 or S2 and S4. The fig.6 shows the output of the transmitting coil which is in AC. The ripples are due to the inductive coil. The Fig.7 shows the rectified output at receiver coil and which is used to charge the battery.

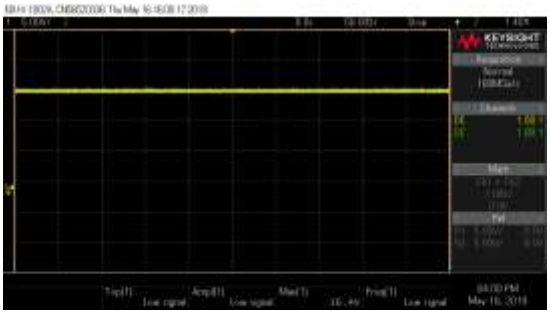

Fig.3: Rectified Output Signal

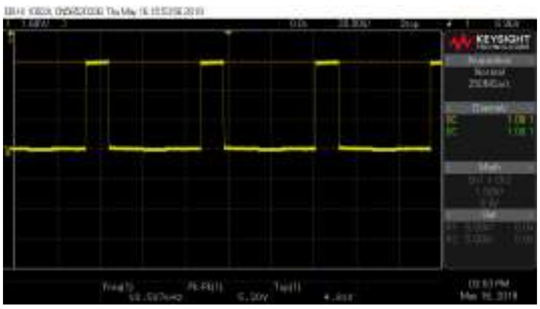

Fig.4: Arduino Pulse to Optocouplers

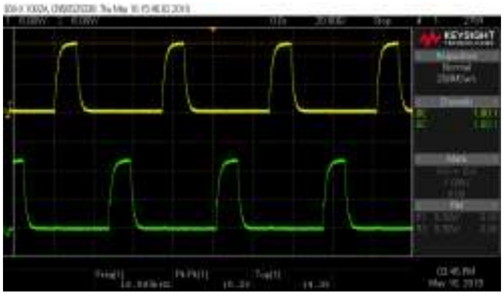

Fig.5: Gate Pulse From IGBTs

Fig.6: Output of Transimitting Coil

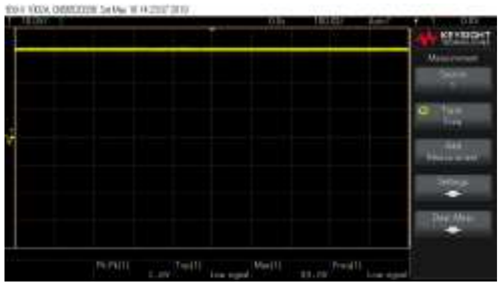

Fig.7: Rectified Output from Receiver

Fig.8: Hardware Prototype

The fig.8 is the hardware prototype of the proposed project. The mobile phone is successfully charged using this prototype. The minimum ground clearance from the road is shown in Fig.9 as per project prototype and Fig.10 shows the maximum ground clearance and above it will cause to decrease the efficiency and wireless transmission will not take place.

Fig.9: Minimum Ground Clearance

Fig.10: Maximum Ground Clearance

5. CONCLUSION

Here we have found out an innovative technology to charge electric vehicles wirelessly through inductive coupling. In this prototype, when we gave an input voltage of 30V DC we were able to get an output voltage of 5V with 700mA at a distance of 20mm.

We can improve the efficiency by following methods,

- By a lever mechanism we can adjust the distances between receiving and transmitting coils which will increase the power transmission between the coils.
- By increasing the frequency level to MHz range.
- By making the system to magnetic resonance coupling.
- Increasing the no of turns of the coils by proper coil design.

The prototype we made is of lower efficiency because the power input given to the prototype is used for meeting the constant loss as well as magnetic leakage. But we are sure that as the power rating of the prototype increases the overall efficiency of the system also get improved as better, since the power required for the constant loss and the magnetic leakage will almost remain the same.

ACKNOWLEDGEMENT

Management, teaching and non-teaching staff of Christ College of Engineering and our parents and friends who supported us to make this work a grant success.

REFERENCES

[1] K.A. Kalwar, M. Aamir, S. Mekhilef, Inductively coupled power transfer (ICPT) for electric vehicle charging – a review, Renew. Sustain. Energy Rev. 47 (2015) 462–475.

[2] H. Barth, M. Jung, M. Braun, B. Schmülling, U. Reker, "Concept Evaluation of an Inductive Charging System for Electric Vehicles", Presented at the 3rd European Conference SmartGrids and E-Mobility, Munchen, Germany, 2011.

[3] M. SangCheol, K. Bong-Chul, C. Shin-Young, A. Chi-Hyung, M. Gun-Woo, Analysis and design of a wireless power transfer system with an intermediate coil for high efficiency, Indust. Electr., IEEE Trans. 61 (2014) 5861–5870.

[4] S. Lukic, Z. Pantic, Cutting the cord: static and dynamic inductive wireless charging of electric vehicles, Electr. Magazine, IEEE 1 (2013) 57–64.

[5] M. Fuller, Wireless charging in California: range, recharge, and vehicle electrification, Trans. Res. Part C: Emerg. Technol. 67 (2016) 343–356.

[6] J.L. Villa, J. Sallan, J.F.S. Osorio, A. Llombart, High-misalignment tolerant compensation topology For ICPT Systems, IEEE Trans. Indust. Electr. 59 (2012) 945–951.

AUTHORS

Ms. Elena Paul
B. Tech Student, Electrical Dept.
Christ College of Engineering, Irinjalakuda,Thrissur, Kerala, India

Ms. Nimmy Paulson
B. Tech Student, Electrical Dept.
Christ College of Engineering, Irinjalakuda,Thrissur, Kerala, India

Mr. Rijo Bijoy
B. Tech Student, Electrical Dept.
Christ College of Engineering, Irinjalakuda,Thrissur, Kerala, India

Prof. Benny K.K.
Professor, Electrical Dept.
Christ College of Engineering, Irinjalakuda,Thrissur, Kerala, India