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Design of Wireless Power Transfer Converter Systems for EV Applications Using MATLAB/ Simulink

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Abstract**:** ***Now a days wireless power Transfer Systems are used mainly to transfer the small amount of power within short distances .In recent applications it is mainly used to charge Smart Phones, Electric Toothbrushes Scanning RFID [Radio wave Frequency Identification tags are used to gather data or read the data] Tags. In medical fields WPT systems are used to charge the Bio-devices like pacemakers without any contact and transfer the energy in magnetic medium. These all applications are low power devices. For high power applications like EV charging is also possible with WPT Systems. From the past few years, researches on Electric vehicles are made more concerned and it gained popularity because it won't emit any greenhouse gases and it uses green energy. Even Electric vehicles are having many advantages there are some problems erupted when it encounter with the users. One of the main disadvantages is charging infrastructure. Because it is vulnerable to some conditions like Weather, Vandalism and Electrocution. So, WPT systems are better counterpart for charging EVs. In this paper, Overview of distinctive kinds of Wireless Power Transfer technologies has given and simple design of closed and open loop WPT systems in mat lab were given. Further, a comparison has been made in between the mat lab simulation of both open and closed loop systems and different cable systems and wireless power transfer systems.***

Index Terms**:** ***Wireless Power Transfer, Design Optimization, Electric Vehicles, shapes of Coils, Quality Factor and Coefficient of Coupling.***

I. INTRODUCTION

In the Past decade, the electric vehicles had gained more popularity because of environmental concerns whereas the present conventional vehicles are polluting environment with the high carbon emission and other main setback is the higher fuel and maintenance costs. By using Plug in Electrical Vehicles there is some possibility to reduce the fuel and maintenance cost up to 70 %. But many consumers are not satisfied with the electrical vehicles because of the battery charging problems. The charging infrastructure is vulnerable to weather conditions, Vandalism and electrocution. The charging cables can represent as a trip hazard and due to the large amount of power being transferred. Wireless Power Transfer Topologies are got more attention in past few years they can transfer the power without any contact and it allows to charge the battery with user safety and convenience and eliminating the most of the problems faced by its counter parts.

II. CLASSIFICATION OF WPS SYSTEMS

In WPT Systems there are mainly classified into two types they are i) near-field ii) far-field. Out of these, near field is non radiative and it can exchange energy over within a short distance. In this type Inductive Power Transfer Systems is more popular. It is mainly used in Induction motors. It was first used by the famous scientist and inventor Nikola Tesla in the starting of the 20th century [1]. Even though it was used in the early 20's but major contribution was done in past 3 decades by researching on this area. It has been used in applications of small power such as wireless charging of smart phones [2],[3], electric tooth brushes, biomedical implants [3],[4] and scanning RFID tags which require small amount of power to scan the data [5].In order to get more efficiency, coupled magnetic resonance is proposed. The range of power transfer is extended by resonance.it is coming under the category of near-field power transfer systems. The high power application is Charging PEV's. For Far-field technologies, they are capable to transfer the power for long distances. Though it requires the Line Of Sight transmission path and some complex tracking techniques to maintain the perfect alignment. It's mainly used in signal broadcasting and efficiency will decline when it is used in the omni-directional transfer of power due to increase of air gap. Capacitive WPT System is used to transfer energy by the alternative electric field. It has smaller Electro Magnetic Interference than the traditional electromagnetic field based technologies. The electric flux needs to travel within the capacitive plates. The main problem of this system is having small coupling capacitance and the air gap is very small. A costly dielectric material like BaTiO3 is used to increase its capacitance. These limitations are making this technology unfair for the charging of PHEV's. Magnetic Gear Technology utilises mechanical force as the energy carrying medium and it has been applied in low power medical implants such as cardio pace makers

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In recent years research is going on in WPT systems and the most approached technology is near field Systems. With this system it is possible to get better efficiency on power transfer when the air gap is smaller within a few centimetres.

III. WPT SYSTEM FOR CHARGING OF PV's

Wireless Power Transfer is using several techniques to charge the Electric vehicles based on charging time, averegae speed & power. There are two possible solutions to charge the EV's The first category of charging is static charging and the second one is charging on-route or dynamic charging.

STATIC CHARGING:

In static charging there are two different methods on charging time. Long duration of static charging time for several hours and other method is fast static charging time which is less than hour.

DYNAMIC CHARGING:

Charging scenario when EV is on-route there are two possible solutions are available

i. EV stops at short period of time at traffic signals and bus-stops etc. is called stationary charging. In this type of charging high power is transmitted and battery volume should in smaller in size.

ii. The second on-route charging is capable of movable charging. Special road lane is used at certain speed limitations to charge slow moving EV's. Battery capacity is lower and transmitting energy is depends upon the speed i.e., high speed results the low average energy transmission.

Review of Standard WPT System:-

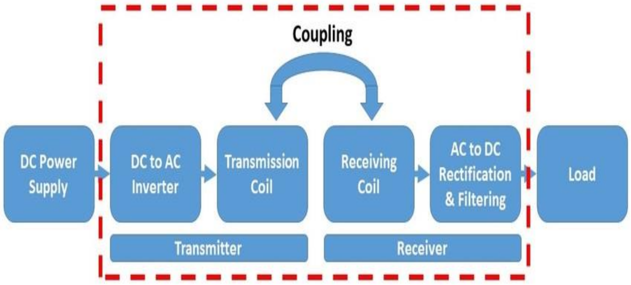

Fig 1: Block diagram of a WPT system

In wireless power system there are two main parts they are – i) the Transmitter and ii) the Receiver. The input power which is given to wpt system may given from either of AC or DC sources. In the event of AC source, the input power must be corrected or rectified. In rectifier stage it may contain a power factor correction module. The rectifier stage gives the precise power to the entire system. The subsequent stage is an inverter stage which consists of a full-bridge switching network that converts the DC waveform into high frequency square wave. The frequency should be high so that it can transmit higher amount of power with maximum efficiency and low losses. During transmission stage. The frequency in both the transmitter and receiver sides is matched to improve the efficiency of transferred power. The power that was received by the pick-up coil is transformed into DC and then fed to the load or battery.

NOMENCLATURE			
L	Inductance	V_o	Output Voltage/Secondary Coil Voltage
N	Number of Turns of Coil	P	Power
D_{in}	Inner Coil Diameter	Q	Quality Factor
D_{out}	Outer Coil Diameter	K	Coupling Factor
W	Width of Conductor	R_o	Outer Radius of Coil
P	Pitch of Coil	R_i	Inner Radius of Coil
C	Capacitance	S_w	Conductor Diameter
f	Frequency	I_o	Output Current/Secondary Coil Current
M	Mutual Inductance		

Inductance:

Self-inductance of a coil can be designed by the wheeler approximations[6]. However the formula is invalid if the coil has very less number of tuns and the pitch is low when compared to the coil diameter. The single layer helical coil inductance is given by

$$L = \frac{N^2(D_{out} - N(W+P))^2}{(16D_{out}) + 28N(W+P).} \times \frac{39.37}{10^6}$$

Capacitance:

The capacitance of a coil relies on the quantity of turns and the coil. The estimation of capacitance would hard or difficult to figure as the quantity of turns increments because of contiguous winding capacitance. As a rule, the coil capacitance can be calculated as

$$C = \frac{1}{(2\pi F)2L}$$

Mutual Inductance:

At the point when two-coils are in mutual or shared inductance, the coupling coefficient (k), decides the quality of coupling between the two coils. The coupling coefficient can extend from 0 to 1

Where 1= superbly coupled

0= not coupled

Power.

The power transmitted to the receiver is the output voltage and current product of the formulas obtained. It is given by,

$$P = \frac{\omega I I^2 M^2}{L_2}$$

The extreme amount of power that can be dispersed is mostly dependent in mutual inductance that exist between the two coils and current at primary side. The transmitted power is dependent on the operating frequency or the coupling factor. The power is directly proportional to the system frequency. A compensation topology is used to increase the range of power transmission. There are two types of compensation topologies. They are compensation capacitor in parallel or in series with the transfer coils. Guidelines were set by the society is to limit the frequency to 85 KHz by Automotive Engineers and International Electro-Technical Commission.

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IV. COEFFICIENT OF COUPLING

The power transmitted is corresponding to the square of the mutual inductance between the two coils. Mutual inductance is the main factor in the formula that cannot be amplified by making the electronic modifications. Hence, the plan has of the system must be such that it enhances the mutual inductance between the two coils. The coupling between the two coils is related to the mutual inductance given by the formula.

$$K = \frac{M}{\sqrt{L1L2}}$$

Coupling relies on the separation between the coils which are in vertical axis. If there is any misalignment between the coils in the horizontal axis will also reduce the mutual inductance of the coils. Large variation in the coupling is isn't alluring in wpt systems as regular changes in current may harm the power electronic segments. In resonant power system, the coupling factor is in between the range of 0.1 to 0.4. This low coupling coefficient is because of the large leakage flux between the two coils due to the large distance. At times, it has also analysed that a high value of coupling is not suitable for WPT systems [7]. By making the value of k large can in turn reduce the value of supply current and reduce the losses associated with it.

V. LEAKAGE FLUX

Leakage flux is that which is passing through air gap and has not been captured by the secondary coil. If coupling between the two coils decreases, the leakage flux increases. The greatest variables that redues the coupling between the two coils are the vertical distance and misalignment of the coils. The leakage flux is related to the coupling as follows

$$(1-k) \propto \varphi_{Leakage}$$

Rules are set by the the international commission on Non-Ionizing Radiation Protection a maximum of 27µT is the magnetic field exposure limit for humans.

VI. RESULTS AND ANALYIS

This section deals with the simulation results of the both open loop WPT system and closed loop WPT systems. Simulation is carried out in matlab 2016.a Simulink software.

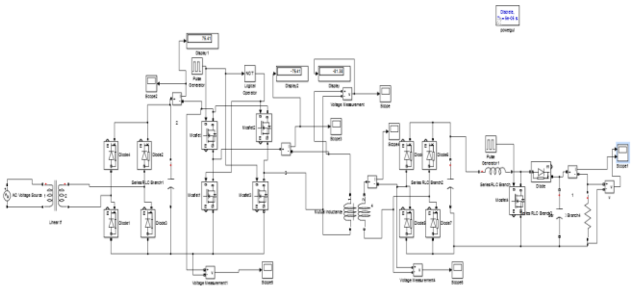

Fig.2: Open loop WPT system

AC input of 158v RMS is fed to the rectifier circuit and the filter capacitor produces an output of 99v is with a ripple voltage of about 3%. Fig 2 shows the output of the rectifier in the transmitter side.

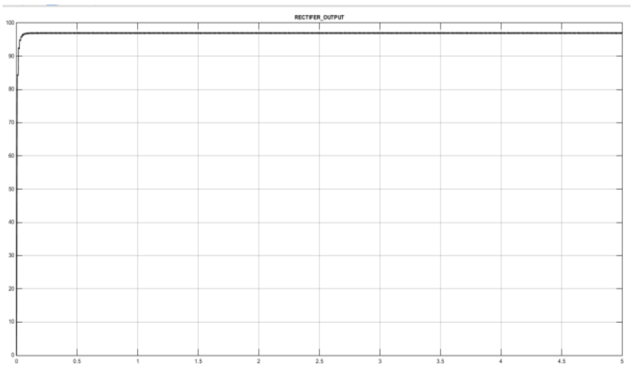

Fig. 3 : Output of the rectifier in transmitter side

Available output from this rectifier output is fed to the single phase inverter in which the switches are operated in the frequency of 50 KHz using the pulse generator as shown in the circuit. The output of the inverter is ±85 volts that are nothing but the transmitter side voltage.

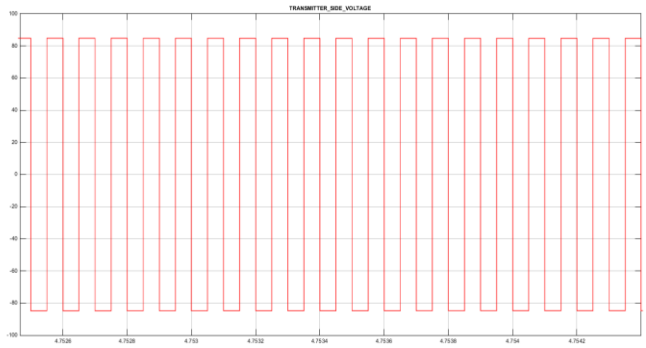

Fig 4: Transmitter side voltage

The output of the inverter is ±85 volts that are nothing but the transmitter side voltage. It is shown in the fig 3. The power transmission takes place to transmit the transmitter voltage to recievers side by mutual inductance.

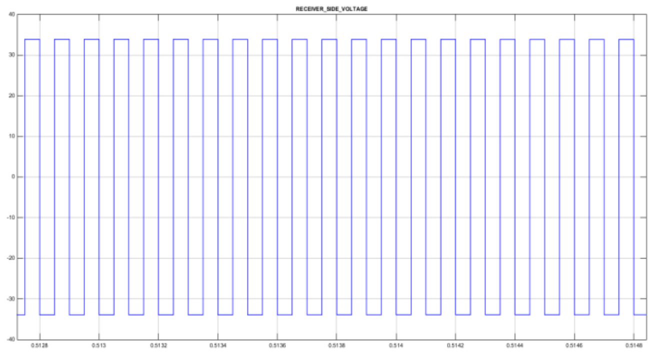

Fig 5 : Reciever side voltage

In fig 4 it shows the receiver side voltage and it is ±32 volts and the secondary coil is fed to the rectifier (Receiver side) and output of the rectifier is fed to boost converter. The final output of the open loop is shown in given below figures.

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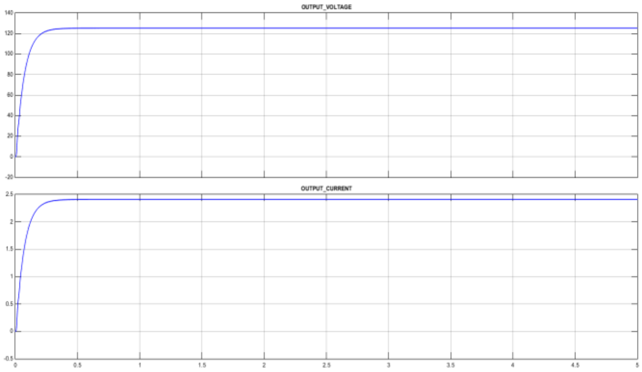

Fig 6: Output Voltage and Current

Further, the impact of input variation is observed in the simulation result to understand the significance of a controller. There are few issues that are observed in the open loop system. If input is increased the output values are also increasing. The input contribution to the chopper is thought to differ when the separation between the two coils are fluctuated and varied.

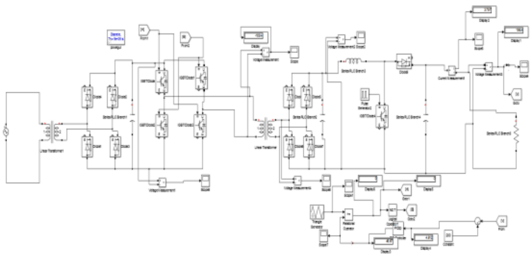

Fig 7 : Closed Loop WPT System

To conquer this issue a closed loop system is designed using P-I Controller feedback to the inverter switches as shown in figure 6. The auto tuning technique available in Simulink is used to acquire the controller pi parameters.

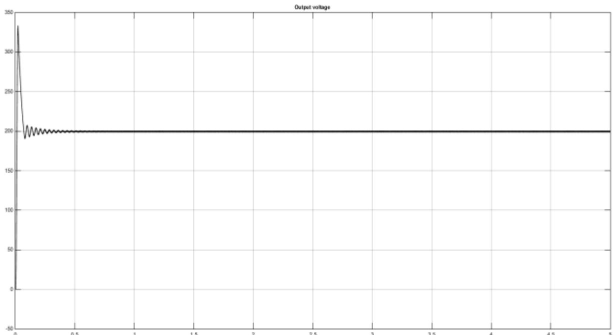

Fig 8 : Output Voltage Of Closed Loop WPT System

It is observed that while using the controller, the output overshoots and settles to the constant voltage of about 200v and settling time is about 5ms.

VI. CONCLUSION

The main objective of this project is to transmit the power wirelessly without any contact within a short distance through magnetic medium. It is conceivable/possible to operate some electric vehicles and other equipment etc. In this paper we had simulated both open and closed loop systems and closed loop system is efficient charging system to transmit the desired output voltage. A closed loop system using Pi controller is feedback to transmitter side inverter switches and the distance between the coils is in between 10 to 20 cms. This project is going to implement in hardware design in future.

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