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A Comprehensive Study of Wireless Charging Lane for Electric Vehicles

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***Abstract*: -- In this paper, a brief study of wireless charging lane is presented. Electrical vehicle dynamic charging by wireless power transfer is becoming prevalent. This new power supply mode allows running cars to be charged with electricity at any time on the road. This charging is done on the basis of inductive coupling theory. Various types of wireless transfer methods are compared. Problems arising in the wireless power transmission are also discussed and optimal design for wireless charging for power maximization is also presented.**

***Keywords:*—Wireless power transfer; Electric vehicles; dynamic charging**

I. INTRODUCTION

In the present scenario carbon emission due to conventional IC engine vehicles has increased drastically. The electric vehicles(EV) have captured the attention of many developed and developing countries since they reduce carbon emission and effectively global warming. However, the traditional cable charging has some constraints such as EVs have to be parked and it takes at least two hours to completely charge the vehicle. In this paper, charging of EV by wireless power transfer (WPT) is presented. Constraints of cables charging such as position and time are overcome by WPT [3]. With the precipitous development of WPT technology, dynamic charging for moving electric vehicles became a reality. With the inductive coupling effect EVs can be charged without interruption [1]. In many practical applications, multiple receiver and/or multiple transmitter configuration are of interest. Based on the basics mentioned above this paper aims to present theories regarding wireless charging on the way.

II. THEORETICAL BACKGROUND

The wireless power system structure consists of supply, ac-dc converter, resonant tank with air core transformer, load matching converter. The charger system is designed with low voltage input [2]. As indicated in Fig.1, the output voltage of the supply is converted to a high frequency square wave, followed by a series resonant network connection; the resonant network consists of a series capacitor and the sending coil. On the receiving side, the receiving coil and a series connected capacitor forms the secondary resonant tank, which is connected to a full bridge rectifier with large output capacitance. An impedance matching converter, in which case is a boost converter, is connected between the rectifier and battery load. As a dc-dc converter with continuous input power, the boost converter is especially useful in load interfacing/shaping applications such as PV power and power factor correction (PFC), in which the boost converter can change the steady-state port impedance to the rectifier output such that the rectifier could see different impedance during operation. The power flow into the battery can be properly controlled by adjusting the impedance of the load matching converter.

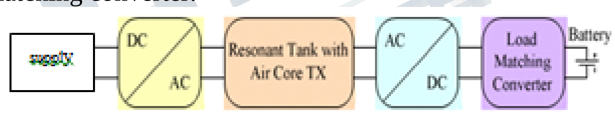

Fig 1: Wireless power charger system structure

III. INDUCTIVE COUPLING THEORY

WPT is presented based on the inductive coupling theory. In this technique, the sinusoidal current flows through a primary coil to generate a varying magnetic field, and the secondary coil in this field can collect the energy through inductive coupling [1].

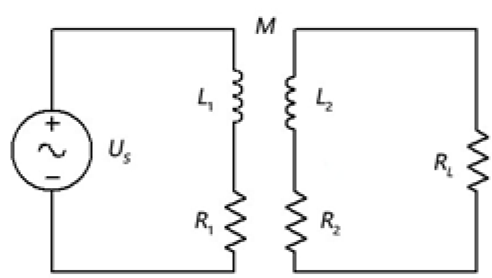

Fig. 2: Coupling equivalent circuit

Fig. 2 shows the magnetic coupling equivalent circuit. The voltage of power is US. The angular frequency is ω0. R1 and R2 represent the equivalent resistance of primary coil and secondary coil while the equivalent inductances are L1 and

L2, respectively. The mutual inductance between the primary coil and secondary coil is M and the load is RL. It can be derived that,

$$\eta = \frac{(\omega_0 M)^2 R_L}{R_1 (R_2 + R_L) + (R_2 + R_L)(\omega_0 M)^2} \quad \text{.... (1)}$$

WPT efficiency is given in (1) and the relationship between the self-inductance and mutual inductance is shown in (2). As can be observed in the equation, the energy transfer efficiency is related to the coupling coefficient. Thus, coupling coefficient can be applied to evaluate the coupling performance

$$k = \frac{M}{\sqrt{L_1 L_2}} \quad \text{.... (2)}$$

IV. WIRELESS CHARGING LANE

Fig 3 shows the basic structure of EV dynamic charging system. By connected with the primary coil, high-frequency electric source provides power for the entire system. The primary coil is laid under the road. The coupling coil (secondary coil) is set with vehicle chassis. The electric power is transferred wirelessly. Compensative capacitors are used in both primary and secondary sides to reduce impedance and increase efficiency [3].

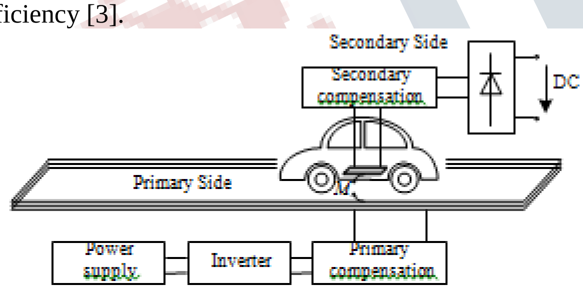

Fig.3: Roadway-powered electric vehicle system

Wireless charging systems are properly shielded so that no animals or humans will be harmed. A coil in the road will only emit power when it is in wireless communication with a receiver coil above it, and the latter will absorb nearly all of it. The bit that is lost is mostly absorbed by the metal body of the car itself.

V. TYPES OF WPT

Wireless Power Transfer (WPT) based on a resonant magnetic coupling represents a promising solution for wirelessly providing power to electronic devices. There are two configurations one of which consists of just two resonators, a transmitting resonator connected to a source and a receiving resonator connected to the load. And the other one just one resonator, two transmitting resonators connected to a source and two receiving resonators connected to the load.

A. Two transmitter one receiver

A three-port network consisting of three magnetically coupled LC resonators is considered. It is assumed that a load ZL1 = RL1 + jXL1 is connected at port 1, while a voltage generator is connected at port 2 and port 3. The inductance and the capacitance of the i-th resonator are denoted with Li and Ci [4].

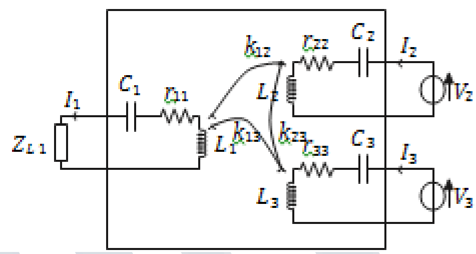

Fig.4: two transmitters one receiver WPT link

B. One transmitter two receiver

We consider a WREL system transmitting power by inductive coupling from a single transmitter to two receivers. As illustrated in Fig. 1, the structure can be schematized by means of three coupled inductors: Li with i ¼ 1, 2, 3. We assume that a generator is present at port 1, while at port 2 and 3 we have the loads R2 and R3, respectively. We also assume that a compensating capacitor Ci in series configuration with each inductor is present [5].

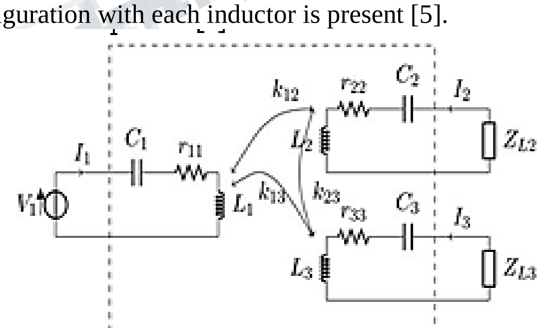

Fig.5: One transmitter two receiver WPT link

VI. PROBLEMS ARISING IN WPT

WPT is theoretically possible, but until relatively recently induction charging required close proximity. The electric buses in have to lower a charging plate to within an inch of the ground. Sending a charge over a larger gap has been more difficult and less efficient [6]. Another major issue is biological safety problems caused by high frequency electromagnetic leakage. According to the research, WPT efficiency cannot reach 100%. The lost electric energy is consumed in the form of heat energy and the other part is lost in space. In the radio frequency environment, the plant body will generate genetic variation and other phenomenon, the animals heart disease can occur.

VII. OPTIMAL DESIGN FOR POWER MAXIMIZATION

According to the literatures, the optimal design which gives the maximum power transfer condition is of two transmitters and one receiver configuration as discussed in section V [4].

VIII. CONCLUSION

In this paper simple wireless charging system is presented. The efficiency of inductive coupling depends upon the mutual inductance between the coils. A wireless charging lane system is presented in brief, the types of wireless power transfer are also discussed with basic circuitry. Problems arising in WPT are reviewed and optimal design is discussed.

IX. ACKNOWLEDGMENT

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