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Wireless Electrical Vehicle Charging

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***Abstract:*-- In the 21st century we are now more pollution conscious than ever. The Electric Vehicles are without doubt the next big thing in automobile industry. They solve one of the most serious problems of our generation that is global warming. With zero emission they are the ideal choice for the environment friendly generation. Despite all its benefits less than 1% of the total cars in the world are electric vehicles. So why is the number of electric vehicles so less? The main and the most problem related to using an electric vehicle is the distance they can travel on a single charge. Wireless electric charge can solve the problem to a great extent. To encourage more and more people to use electric vehicles we decided to present a paper in 'Wireless Vehicle Charging'. The proposed paper shines light upon the scope of wireless charging for electric vehicles. The proposed paper explains the basic working principle of the technology used. The concept of wireless power transfer is based on mutual induction. Use of this technology can solve the main concern related to the use of electric vehicles (EVs) that is battery life. For a long time EVs were not accepted over conventional vehicles is due to the short distance the vehicles can cover in a single charge. With new and path breaking EV manufactures Tesla EVs are proven to be better choice than petrol or diesel cars. The dynamic wireless power transfer has a lot of scope to be used practically for charging EVs.**

***Keywords:*-WPT,EV, inductive charging, wireless vehicle charging**

I. INTRODUCTION

For energy, environment, and many other reasons, the electrification for transportation has been carrying out for many years. In railway systems, the electric locomotives have already been well developed for many years. A train runs on a fixed track. It is easy to get electric power from a conductor rail using pantograph sliders. However, for electric vehicles (EVs), the high flexibility makes it not easy to get power in a similar way. Instead, a high power and large capacity battery pack is usually equipped as an energy storage unit to make an EV to operate satisfactory distance. Until now, the EVs are not so attractive to consumers even with many government incentive programs. Government subsidy and tax incentives are one key to increase the market share of EVtoday. The problem for an electric vehicle is nothing else but the electricity storage technology, which requires a battery which is the bottleneck today due to its unsatisfactory energy density, limited life time and high cost.

In an EV, the battery is not so easy to design because of the following requirements: high energy density, high power density, affordable cost, long cycle life time, good safety, and reliability, should be met simultaneously. Lithium-ion batteries are recognized as the most competitive solution to be used in electric vehicles. However, the energy density of the commercialized lithium-ion battery in EVs is only 90–100 Wh/kg for a finished pack. This number is so poor compared with petrol or diesel, which has an energy density about 12 000 Wh/kg. To challenge the 300-mile range of an internal combustion engine power vehicle, a pure EV needs a large amount of batteries which are too heavy and too expensive. The lithium-ion battery cost is about 35000□/kWh at the present time. Considering the vehicle initial investment, maintenance, and energy cost, the owning of a battery electric vehicle will make the consumer spend an extra 70,000□/year on average compared with a petrol or diesel powered vehicle. Besides the cost issue, the long charging time of EV batteries also makes the EV not acceptable to many drivers. For a single charge, it takes about one half-hour to several hours depending on the power level of the attached charger, which is many times longer than the petrol refuelling process. The EVs cannot get ready immediately if they have run out of battery energy. To overcome this, what the owners would most likely do is to find any possible opportunity to plug-in and charge the battery. It really brings some trouble as people may forget to plug-in and find themselves out of battery energy later on. The charging cables on the floor may bring tripping hazards. Leakage from cracked old cable, in particular in cold zones, can bring additional hazardous conditions to the owner. Also, people may have to brave the wind, rain, ice, or snow to plug-in with the risk of an electric shock.

The wireless power transfer (WPT) technology, which can eliminate all the charging troublesome, is desirable by the EV owners. By wirelessly transferring energy to the EV, the charging becomes the easiest task. For a stationary WPT system, the drivers just need to park their car and leave. For a dynamic WPT system, which means the EV could be powered while driving; the EV is possible to run forever without a stop. Also, the battery capacity of EVs with wireless charging could be reduced to 20% or less compared to EVs with conductive charging.

When the WPT is used in the EV charging, the MHz frequency operation is hard to meet the power and efficiency criteria. It is inefficient to convert a few to a few hundred kilowatts power at MHz frequency level using state-of-the-art power electronics devices. Moreover, air-core coils are too sensitive to the surrounding ferromagnetic objects. When an air-core coil is attached to a car, the magnetic flux will go inside the chassis causing high eddy current loss as well as a significant change in the coil parameters. To make it more practical in the EV charging, ferrite as a magnetic flux guide and aluminium plate as a shield are usually adopted in the coil design. With the lowered frequency to less than 100 kHz, and the use of ferrite, the WPT system is no different from the inductive power transfer (IPT) technology which has been developed for many years. In fact, since the WPT is based on the nonradioactive and near-field electromagnetic, there is no difference with the traditional IPT which is based on magnetic field coupling between the transmitting and receiving coils. The IPT system has already been proposed and applied to various applications, such as underwater vehicles, mining systems, cordless robots in automation production lines, as well as the charging of electric vehicles.

This paper starts with the basic WPT theory, and then gives a brief overview of the main parts in a WPT system, including the magnetic coupler, compensation network, power electronics converter, study methodology, and its control, and some other issues like the safety considerations. By introducing the latest achievements in the WPT area, we hope the WPT in EV applications could gain a widespread acceptance in both theoretical and practical terms. Also, we hope more researchers could have an interest and make more brilliant contributions in the developing of WPT technology.

II. FUNDAMENTAL THEORY

A typical wireless EV charging system is shown in Fig. 1. It includes several stages to charge an EV wirelessly. First, the utility ac power is converted to a dc power source by an ac to dc converter with power factor correction.

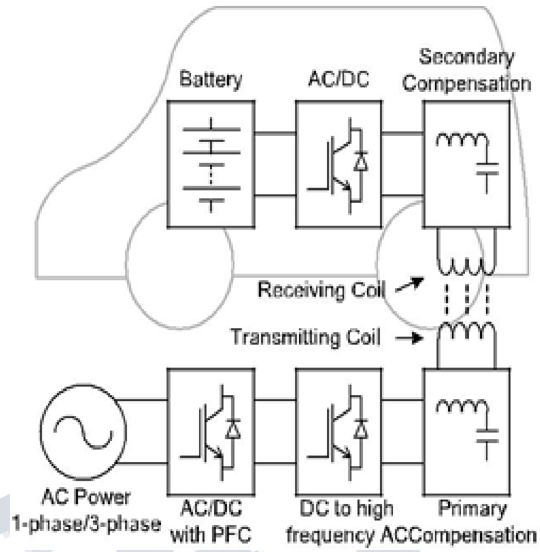

Fig. 1. Typical wireless EV charging system

Then, the dc power is converted to a high-frequency ac to drive the transmitting coil through a compensation network. Considering the insulation failure of the primary side coil, a high-frequency isolated transformer may be inserted between the dc-ac inverter and primary side coil for extra safety and protection. The high-frequency current in the transmitting coil generates an alternating magnetic field, which induces an AC voltage on the receiving coil. By resonating with the secondary, compensation network, the transferred power and efficiency are significantly improved. At last, the ac power is rectified to charge the battery. Fig. 1 shows that a wireless EVcharger consists of the following main parts:

1) The detached (or separated, loosely coupled) transmitting and receiving coils. Usually, the coils are built with ferrite and shielding structure, in the later sections, the term magnetic coupler is used to represent the entirety, including coil, ferrite, and shielding;

2) The compensation network;

3) The power electronics converters.

III. MAGNETICCOUPLERDESIGN

To transfer power wirelessly, there are at least two magnetic couplers in a WPT system. One is at the sending side, named primary coupler. The other is at the receiving side, named pickup coupler. Depending on the application scenarios, the magnetic coupler in a WPT for an EV could be either apad or a track form. For higher efficiency, it is important to have high coupling coefficient and quality factor. Generally, for a given structure, the larger the size to gap ratio of the coupler is, the higher thekis; the thicker the wireand the larger the ferrite section area is, the higher theQis. By increasing the dimensions and materials, higher efficiency can be achieved. But this is not a good engineering approach.

It is preferred to have higherkandQwith the minimumdimensions and cost.

The dynamic charging, also called the OLEVsor roadway powered electric vehicles, is a way to charge the EV while driving. It is believed that the dynamic charging can solve the EVs' range anxiety, which is the main reason limits the market penetration of EVs. In a dynamic charging system, the magnetic components are composed of a primary side magnetic coupler, which is usually buried under the road, and a secondary side pickup coil, which is mounted under an EV chassis. There are mainly two kinds of primary magnetic coupler in the dynamic charging. The first kind is a long track coupler. When an EV with a pickup coil is running along with the track, continuous power can be transferred. The track can be as simple as just two wires, or an adoption of ferrites with U-type or W-type to increase the coupling and power transfer distance. Further, a narrow-width track design with an I-type ferrite was proposed by KAIST. The differences between the W-type and I-type are shown in Fig. 2 For W-type configuration, the distribution area of the ferrite W determines the power transfer distance, as well as the lateral displacement. The total width of W-type should be about four times the gap between the track and the pickup coil. For I-type configuration, the magnetic pole alternates along with the road. The pole distance W1 is optimized to achieve better coupling at the required distance. The width of pickup coil W2 is designed to meet the lateral misalignment requirement. The relation between track width and transfer distance is decoupled and the track can be built at a very narrow form. The width for U-type and W-type is 140 and 80 cm, respectively. For I-type, it could be reduced to only 10 cm with a similar power transfer distance and misalignment capacity. 35 kW power was transferred at a 200 mm gap and 240 mm displacement using the I-type configuration. With the narrowed design, the construction cost could be reduced. Also, the track is far away from the road side, the electromagnetic field strength exposed to pedestrians can also be reduced.

The problem of the track design is that the pickup coil only covers a small portion of the track, which makes the coupling coefficient very small. The poor coupling brings efficiency and electromagnetic interference (EMI) issues. To reduce the EMI issue, the track is built by segments with a single power converter and a set of switches to power the track.

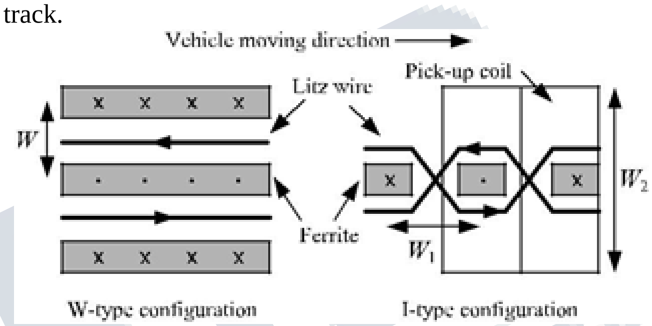

Fig. 2 Top view of W-shape and I-shape track configuration.

IV.POWER ELECTRONICS CONVERTER AND POWER CONTROL

In a WPT system, the function of the primary side power electronics converter is to generate a high-frequency current in the sending coil. To increase the switching frequency and efficiency, usually a resonant topology is adopted. At the secondary side, a rectifier is adopted to convert the high-frequency ac current todc current. Depending on whether a secondary side control is needed, an additional converter may be employed. The primary side converter maybe a voltage or a current source converter. As a bulky inductor is needed for the current source converter, the most common choice at the primary side is a full bridge voltage source resonant converter.

V. COMPENSATION NETWORK

In a WPT system, the pads are loosely coupled with a large leakage inductance. It is required to use a compensation network to reduce the VA rating in the coil and power supply. In early inductive charging designs, the compensation is set on primary or secondary side only. When the coupling coefficient is reduced to less than 0.3 in the EVWPT, compensation at both the primary and secondary side is recommended to have a more flexible and advanced characteristics. To compensate a leakage inductance, the simplest way is to add a capacitor at each side.

A. Safety Concerns

WPT avoids the electrocution danger rom the traditional contact charging method. But, when charging an EV battery wirelessly, there is a high-frequency magnetic field existing between the transmitting and receiving coils. The magnetic flux coupled between the two coils is the foundation for WPT, which cannot be shielded. The large air-gap between the two coils causes a high leakage field. The frequency and amplitude of the leakage magnetic field should be elaborately controlled to meet the safety regulations.

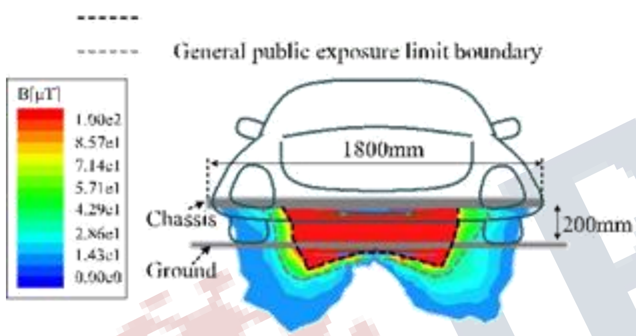

Fig.3 Exposure limit boundary for an 8 kW WPT system.

B. Besides the safety issue, the emission limit for Industrial, Scientific, and Medical (ISM) equipment is also regulated by Federal Communications Commission (FCC) in Title 47 of the Code of Federal Regulations (CFR 47) in part 18 in United States. According to FCC part 18, ISM equipment operating in a specified ISM frequency band is permitted unlimited radiated energy. However, the lowest ISM frequency is at 6.78 MHz, which is too high for EVWPT. The Society of Automotive Engineers (SAE) has already formed a committee, J2954, to look into many issues related to EVWPT systems. Among one of their goals will be safety standards. It is projected that a SAE standard on EVWPT systems will be released in June 2014 by this committee. More standards and regulations from different regions are summarized in a paper from Qualcomm Incorporated .

C. Cost

An importance factor that affects the future of WPT is its cost. The extra cost in a WPT is mainly brought by the magnetic coupler. For our 8 kW station-aryWPT design, the material cost of the two magnetic couplers is about $400. This will be the rough cost increase of an 8 kW wireless charger compared with a wired charger, which is quite acceptable if considering all the convenience brought by the WPT and long-term operation cost savings and reduction of battery size. For the dynamic WPT design, the infrastructure cost including converter and track for 1km one-way road is controlled to $0.4 million [57]. The investment of electrification is much lower with the construction cost of the road itself. With the road electrification, the EV on-board batteries could be reduced to 20%. The savings on the batteries might be much more than the investment on the infrastructure. Studies also show that with only 1% electrification of the urban road, most of the vehicles could meet a 300-mile range easily. The road electrification time is coming.

VI. CONCLUSION AND FUTURE SCOPE

This paper presented a review of wireless charging of electric vehicles. It is clear that vehicle electrification is unavoidable because of environment and energy related issues. Wireless charging will provide many benefits as compared with wired charging. In particular, when the roads are electrified with wireless charging capability, it will provide the foundation for mass market penetration for EV regardless of battery technology. With technology development, wireless charging of EV can be brought to fruition. Further studies in topology, control, inverter design, and human safety are still needed in the near term.

Wireless transmission of energy is a technique thatholds a strong potential. It promises to change the face of the technologies in transmission of power. Its applications can be huge. For the next generation roads in smart city. In future there are possibilities that power can be transferred over large distances without affecting the environment.Another important issue being use of batteries can be reduced; replacement and recharging batteries would not be required. Use of wireless technology also saves on the resources spent on wire. Laying a wireless network would be much simpler than struggling with wire in difficult terrains. The technology technique in future.also promises to be eco friendly in comparison to today's technologies. Hence all in all wireless transmission of energy could be the key power transmission.

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