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Wireless Power Transfer Electric Vehicle

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Abstract: Wireless power transfer (WPT) using magnetic resonance is the technology which could set human free from the annoying wires. In fact, the WPT adopts the same basic theory which has already been developed for at least 30years with the term inductive power transfer. WPT technology is developing rapidly in recent years. At mill watts to kilowatts power level, the power transfer distance increases from several millimeters to several hundred millimeters with a load efficiency above 90%. The advances make the WPT very attractive to the electric vehicle (EV) charging applications in both stationary and dynamic charging scenarios. This seminar represent the technologies in the WPT area applicable to EV wireless charging. By introducing WPT in EVs, the obstacles of charging time, range, and cost can be easily mitigated. Battery technology is no longer relevant in the mass market penetration of EVs. It is hoped that researchers could be encouraged by the state-of-the-art achievements, and push forward the further development of WPT as well as the expansion of EV.

Keywords: Wireless power transfer (WPT), Electric vehicle (EV).

I. INTRODCUTION

The electrical 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 for a satisfactory distance.

Electric vehicles have received a wide range of acceptance in the recent years as an emerging technology. Its market increases dramatically with around 50,000 plug-in vehicles on the road, compared with just 3,500 in 2013 in UK. In order to charge electric vehicles there is a need to have a wire attached to the battery of the car that can be connected to the plug. The main disadvantage of this system is that the connection should be achieved manually. This method is not very convenient and might have safety risks in wet condition. 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 .Therefore a suitable solution for that is to wirelessly transfer the power to the electric vehicles. Transmission electrical power without using any physical wire is called as wireless power transfer or wireless charging.

WPT system can transfer energy through photonic light waves, electric or magnetic fields in electromagnetic waves .WPT systems can be categorized into capacitive coupling and inductive coupling. Capacitive coupling is used for low power range, while inductive coupling allows the transfer of power in the range between mill watts to kilowatts. Some of the advantages of capacitive power transfer is that using capacitor make the system simpler, have low cost, low electromagnetic radiation, and no need for magnetic flux guiding and shielding components. Although this system has many advantages but it also has some constraints that limit the performance of the system. The amount of coupling capacitance depends on the available area of the device. This can be solved by either increasing the size of the capacitor, which is not practical in some applications, or by targeting low power applications. The inductive power transfer is widely used and has many advantages such as its ability to transfer larger power than capacitive coupling. Inductive power transfer carries lower risk of electric shock because there are no exposed conductors. Moreover, inductive power transfer is waterproof since the charging connections are fully enclosed, which makes it suitable for harsh environments in general. In this paper, WPT will refer to inductive power transfer. The main disadvantages of WPT are heat and power transfer efficiency. It takes more power to inductively charge an energy storage system than charging it through normal conductive means. This is due to the higher power loss in the induction coils.

In an EV, the battery is not so easy to design because of the following requirements: high energy density, high

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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 90–100Wh/kg for a finished pack. This number is so poor compared with gasoline, which has an energy density about 12000 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 500$/kWh at the present time. Considering the vehicle initial investment, maintenance, and energy cost, the owning of a battery electric vehicle will make the consumer spend an extra 1000$/year on average compared with a gasoline-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 gasoline refueling process. The EVs cannot get ready immediately if they have run out of battery energy.

This seminar 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. LITERATURE SURVEY

In 1864, James C. Maxwell predicted the existence of radio waves by means of mathematical model. In 1884, John H. Poynting realized that the Poynting Vector would play an important role in quantifying the electromagnetic energy. In 1888, bolstered by Maxwell's theory, Heinrich Hertz first succeeded in showing experimental evidence of radio waves by his spark-gap radio transmitter. The prediction and Evidence of the radio wave in the end of 19th century was start of the wireless power transmission[1].

Nikola Tesla has been the pioneer in the field of wireless transmission of electrical power. He started efforts on wireless transmission at 1891 in his “experimental station” at Colorado. Nikola Tesla successfully lighted a small incandescent lamp by means of a resonant circuit grounded on one end. A coil outside laboratory with the lower end connected to the ground and the upper end free. The lamp is lighted by the current induced in the three turns of wire wound around the lower end of the coil. Wardenclyffe tower was designed by Tesla for trans-Atlantic wireless telephony and also for demonstrating wireless electrical power transmission[1].

William C. Brown contributed much to the modern development of microwave power transmission which dominates research and development of wireless transmission today. In the early 1960s brown invented the rectenna which directly converts microwaves to DC current. He demonstrated its ability in 1964 by powering a helicopter from the solely through microwaves.

Hidetsugu Yagi a Japanese electrical engineer also tried unsuccessfully to introduce a wireless power transmission system[1].

The research team from MIT published a paper in Science, in which 60 W powers is transferred at a 2-m distance with the so called strongly coupled magnetic resonance theory. The result surprised the academia and the WPT quickly became a hot research area. A lot of interesting works were accomplished with different kinds of innovative circuit, as well as the system analysis and control. The power transfer path can even be guided using the domino-form repeaters. In order to transfer power more efficiently and further, the resonant frequency is usually selected at MHz level, and air-core coils are adopted[2].

Recently, as the need of EV charging and also the progressing technology, the power transfer distance increases from several millimeters to a few hundred millimeters at kilowatts power level. As a proof-of-concept of a roadway inductively powered EV, the Partners for Advance Transit and Highways (PATH) program was conducted at the UC Berkeley in the late 1970s[4]. A 60 kW,35-passanger bus was tested along a 213 m long track with two powered sections. The bipolar primary track was supplied with 1200 A, 400 Hz ac current. The distance of the pickup from the primary track was 7.6 cm. The attained efficiency was around 60% due to limited semiconductor technology. During the last 15 years, researchers at Auckland University have focused on the inductive power supply of movable objects. Their recent achievement in designing pads for the stationary charging of EV is worth noting. A 766 mm × 578 mm pad that delivers 5 kW of power with over 90% efficiency for distances about 200 mm was reported. The achieved lateral and longitudinal misalignment tolerance is250 and 150 mm, respectively. The knowledge gained from the on-line electric vehicle (OLEV) project conducted at the Korea Advanced Institute of Science and Technology (KAIST) also contributes to the WPT design. Three generations of OLEV systems have been built: a light golf cart as the first generation, a bus for the second, and an SUV for the third. The accomplishment of the second and the third is noteworthy: 60 kW power transfer for the buses and 20 kW for the SUVs with efficiency of 70% and 83%, respectively; allowable vertical distance and lateral misalignment up to 160 mm and up to 200 mm, respectively. In the United States, more and more public attention was drawn to the WPT since the publication of the 2007 Science paper[5].

The Wi Tricity Corporation with technology from MIT released their WiT-3300 development kit, which achieves 90% efficiency over a180 mm gap at 3.3 kW output. Recently, a wireless charging system prototype for EV was developed at Oak Ridge National Laboratory (ORNL) in the United States. The tested efficiency is nearly 90% for 3 kW power deliveries. The research at the University of Michigan–Dearborn achieved a 200 mm distance, 8 kW WPT system with dc to dc efficiency as high as 95.7%. From the functional aspects, it could be seen that the WPT for EV is ready in both stationary and dynamic applications. However, to make it available for large-scale commercialization, there is still abundant work to be done on the performance optimization, setup of the industrial standards, making it more cost effective, and so on[6].

III. METHODLOGY

1. Wireless EV charging system

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. 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 EV charger 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.

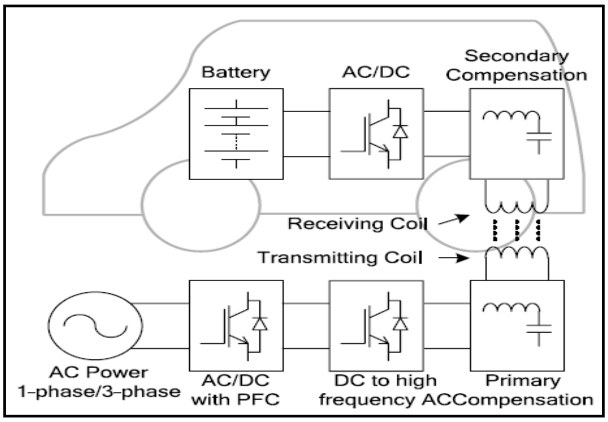

Fig..1. Typical wireless EV charging system

The maximum efficiency

$$\eta_{\max} = \frac{k^2 Q_1 Q_2}{\left(1+\sqrt{1+k^2 Q_1 Q_2}\right)^2}$$

Is achieved at $a_{\eta\max} = \left(1+k^2 Q_1 Q_2\right)^{1/2}$.

In the maximum efficiency are also derived based on several different kinds of compensation network. The results are identical and accord with the above results. The analysis here does not specify a particular compensation form. It can be regarded as a general formula to evaluate the coil performance and estimate the highest possible power transfer efficiency.

In EV wireless charging applications, the battery is usually connected to the coil through a diode-bridge rectifier. Most of the time, there is some reactive power required. The reactive power can be provide by either the coil or the compensation network like a unit-power-factor pickup. The battery could be equivalent to a resistance Rb= Ub/Ib, where Ub and Ibis the battery voltage and current, respectively .If the battery is connected to the rectifier directly in a series-series compensation form, the equivalent ac side resistance could be calculated by Rac= 8/π2 · Rb. Thus, a battery load could be converted to a resistive load. The Rac equation is different for different battery connection style, like with or without dc/dc converter, parallel or series compensation. Most of the time, the equivalent Rac could be derived. Some typical equivalent impendence at the primary side is given in paper. By calculating the equivalent ac resistances, the above equations could also be applied to a battery load with Rectifier.

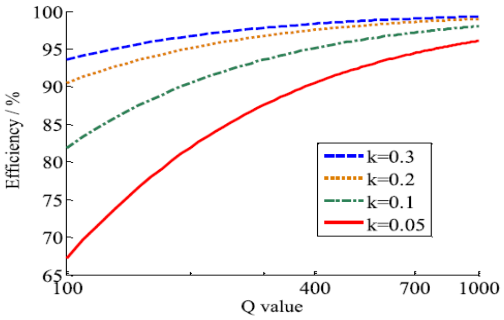

Fig..2 Theoretical maximum transfer efficiency between two coils.

For stationary EV wireless charging, the coupling between the two coils is usually around 0.2. If both the sending and receiving coils have a quality factor of 300, the theoretical maximum power transfer efficiency is about 96.7%. More efficiency calculations under different coupling and quality factors are shown in fig.2 [6]

IV. MAGNETIC COUPLER DESIGN

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 a pad or a track form. For higher efficiency, it is important to have high coupling coefficient k and quality factor Q. Generally, for a given structure, the larger the size to gap ratio of the coupler is, the higher the k is; the thicker the wire and the larger the ferrite section area is, the higher the Q is. By increasing the dimensions and materials, higher efficiency can be achieved. But this is not a good engineering approach. It is preferred to have higher k and Q with the minimum dimensions and cost. Since Q equals ωL/R, high frequency is usually adopted to increase the value of Q. The researchers at Massachusetts Institute of Technology (MIT) used a frequency at around 10 MHz and the coil Q value reached nearly 1000. In high power EV WPT applications, the frequency is also increased to have these benefits. In Bolger’s early design, the frequency is only 180 Hz. A few years later, a 400 Hz frequency EV WPT system was designed by System Control Technology. Neither 180 Hz nor 400 Hz is high enough for a loosely coupled system. Huge couplers we reemployed in the two designs. Modern WPT system uses at least 10 kHz frequency. As the technical progress of power electronics, 100 kHz could be achieved at high power level. The WiTricity Company with the technology from MIT adopts 145 kHz in their design. In the recent researches and applications, the frequency adopted in an EV WPT system is between 20 and 150 kHz to balance the efficiency and cost. At this frequency, to reduce the ac loss of copper coils, Litz wire is usually adopted. Besides the frequency, the coupling coefficient k is significantly affected by the design of the magnetic couplers, which is considered one of the most important factors in a WPT system. With similar dimensions and materials, different coupler geometry and configuration will have a significant difference of coupling coefficient. A better coupler design may lead to a 50%–100% improvement compared with some non-optimal designs[7].

1. Coupler in the Stationary Charging

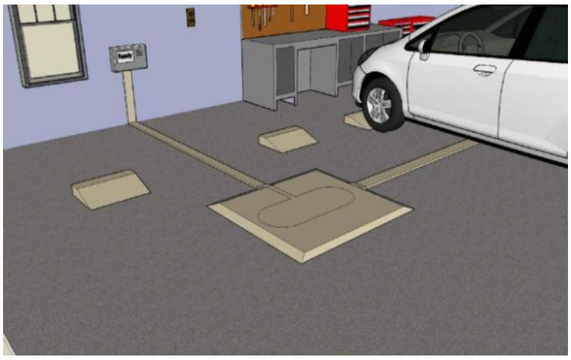

Fig.3..Stationary Charging

In a stationary charging, the coupler is usually designed in a pad form. The very early couplers are just like a simple split core transformer. Usually this kind of design could only transfer power through a very small gap. To meet the requirements for EV charging, the deformations from spilt core transformers and new magnetic coupler forms are presented for large gap power transfer. According to the magnetic flux distribution area, the coupler could be classified as the double-sided and single-sided types [6].

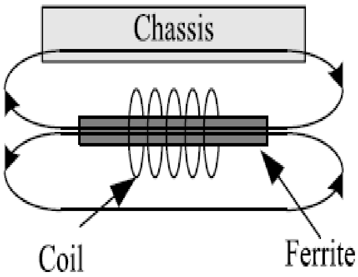

Fig 4. Main flux path of double-sided

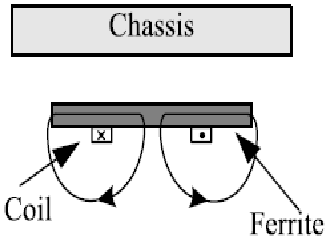

Fig.5.Main flux path of single-sided coupler

For the double-sided type, the flux goes to both sides of the coupler. A flattened solenoid inductor form is proposed in and. Because the flux goes through the ferrite like through a pipe, it is also called a flux pipe coupler. To prevent the eddy current loss in the EV chassis, an aluminum shielding is usually added which bring a loss of 1%–2%. When the shielding is added, the quality factor of a flux-pipe coupler reduces from 260 to 86. The high shielding loss makes the double-sided coupler not the optimal choice. For the single-sided coupler, most of the flux exists at only one side of the coupler. As shown in Fig.4.1.2, the main flux path flows through the ferrite in a single-sided coupler. Unlike the double-sided coupler having half of the main flux at the back, the single-sided coupler only has a leakage flux in the back. This makes the shielding effort of a single-sided type much less.

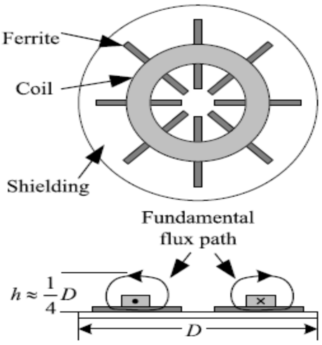

Fig.6.Two typical single-sided flux type pads Circular pad

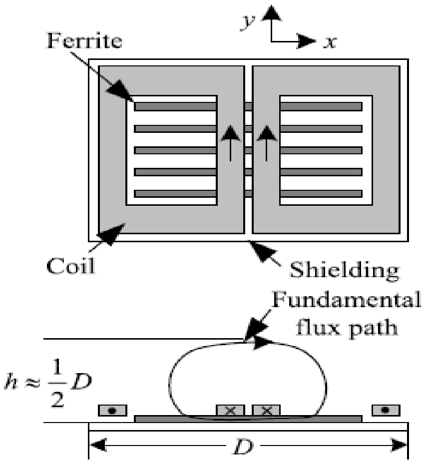

Fig.7. Two typical single-sided flux type pads DD pad

Two typical single-sided flux type pads are shown in Fig. 5.One is a circular unipolar pad. Another one is a rectangular bipolar pad proposed by University of Auckland, which is also named DD pad. Besides the mechanical support material, a single-sided pad is composed of three layers. The top layer is the coil. Below the coil, a ferrite layer is inserted for the purpose of enhancing and guiding the flux. At the bottom is a shielding layer. To transfer power, the two pads are put closed with coil to coil. With the shielding layer, most of the high-frequency alternating magnetic flux can be confined in the space between the two pads. A fundamental flux path concept was proposed in the flux pipe paper. The flux path height of a circular pad is about one-fourth of the pad's diameter. While for a DD pad, the height is about half of the pad's length. For a similar size, a DD pad has a significant improvement in the coupling. The charge zone for a DD pad could be about two times larger than a circular pad with similar material cost. The DD pad has a good tolerant in the y-direction. This makes the DD pad a potential solution for the dynamic charging when the driving direction is along with the y-axis. However, there is a null point for DD pad in the x-direction at about 34% misalignment. To increase the tolerant in x-direction, an additional quadrature coil named Q coil is proposed to work together with the DD pad, which is called DDQ pad. With a DDQ receiving pad on a DD sending pad, the charge zone is increased to five times larger than the circular configuration. As the additional Q coil in the receiver side, the DDQ over DD configuration uses almost two times copper compared with the circular one. A variant of a DDQ pad, which is called a new bipolar pad, was also proposed by University of Auckland. By increasing the size of each D pad and having some overlap between the two D coils, the new bipolar pad could have a similar performance of a DDQ pad with 25%less copper. With all the efforts, at 200 mm gap, the coupling between the primary and secondary pads could achieve0.15–0.3 with an acceptable size for an EV. Referred to Fig. 3,at this coupling level, efficiency above 90% could possibly be achieved[6].

2. Coupler in the Dynamic Charging

Fig.8. Dynamic Charging

The dynamic charging, also called the OLEVs or 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 Fig pickup coil is running along with the track, continues 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.

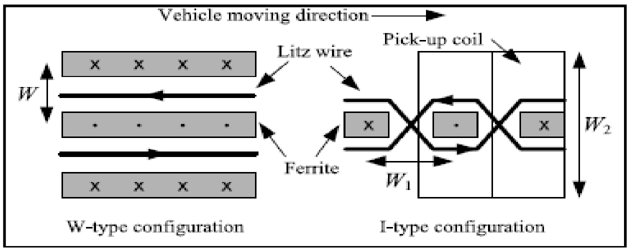

Fig.9. Top view of W-shape and I-shape track configuration

The differences between the W-type and I-type are shown in Fig. 6.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. The excitation of each segment can be controlled by the switches' ON-OFF state. The electromagnetic field above the inactive segments is reduced significantly. However, there is always a high-frequency current flowing through the common supply cables, which lowers the system efficiency. The published systems efficiency is about 70%–80%, which is much lower than the efficiency achieved in the stationary charging [7].

When each segment is short enough, the track becomes like a pad in the stationary charging, which is the other kind of the primary magnetic coupler. Each pad can be driven by an independent power converter. Thus, the primary pads can be selectively excited without a high-frequency common current. Also, the energized primary pad is covered by the vehicle. The electromagnetic field is shielded to have a minimum impact to the surrounding environment. The efficiency and EMI performance could be as good as that in a stationary charging application. However, the cost to build a power converter for each pad is unaffordable. It is desired to use only one converter to drive a few pads, and the current in each pad can be controlled. A double-coupled method was proposed with each pad configured with an intermediary coupler and a bidirectional switch. The intermediary couplers are coupled to one primary coil at the converter side. The intermediary coupler performs like a high-frequency current source. By controlling the ON-OFF time of the switch, the current in each pad can be controlled. However, even the corresponding pad is shutdown by the switches; the high-frequency current is always circulating in all the intermediary couplers, which may lower the efficiency. A reflexive field containment idea by North Carolina State University was also proposed. Three pads are driven from only one power converter. By carefully designing the primary and pickup parameters, the reflexive field of the pickup pad could enhance the current in the primary pad. The current in each primary pad is sensitive to the coupling condition and could be automatically built up when the pickup pad is coupled. The current decreases very quickly when the pickup pad moves away. The relation between the primary pad current and coupling coefficient is carefully designed. For dynamic charging, the EV runs freely on the road which makes the coupling varies in a wide range. To make this method more practical, the system characteristics under coupling variation caused by the lateral misalignment, vehicle forward movement and vehicle types should be studied further [8].

V. POWER ELECTRONICSCONVERTER AND POWERCONTROL

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 to dc current. Depending on whether a secondary side control is needed, an additional converter may be employed. The primary side converter may be 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. A typical wireless power circuit schematic is shown in Fig. 8. In the primary side, the full bridge converter outputs a high-frequency square voltage. By adopting the LC compensation network, a constant high frequency current can be maintained in L1. An additional capacitor C1s is introduced here to compensated part of the reactive power on L1. Thus, the power rating on L f 1could be reduced. The system design flexibility could also be improved. At the secondary side, the parallel compensation is adopted. With a constant primary coil current and parallel secondary side compensation, the output is like a current source. At a certain coupling, the current in L3 is almost constant. By changing the duty ratio of switch S5, the output power can be controlled [9].

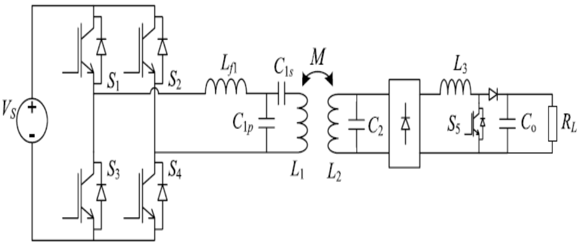

Fig.10.Circuit schematic of a typical WPT configuration

Many different control methods were proposed to control the transferred power. Depending on where the control action is applied, the control method could be classified as primary side control, secondary side control and dual-side control. In most case, the primary side and dual-side control is only suitable for power transfer from one primary pad to one pickup pad. This secondary side control could be used in the scenario where multiple pickup pads are powered from one primary pad or track.

The control at the primary side can be realized by changing the frequency, duty cycle and the phase between the two legs. Since the characteristic of a resonant converter is related to the operating frequency, a frequency control at the primary side is adopted in some designs.

When adjusting the frequency, it should be noted that the bifurcation phenomenon in the loosely coupled systems. The power versus frequency is not always a monotonic function. Also, the frequency control method takes up a wider radio frequency bandwidth, which may increases the risk of electromagnetic interference. When the switching frequency is fixed, the control can be carried out by duty cycle or phase shift. The problem of duty cycle or phase shift control is that there is a high circulating current in the converter. Also, the ZVS or ZCS switching condition may be lost. To ensure ZVS, an alternative way to control the system output power is to adjust the input dc voltage VS. An asymmetrical voltage cancellation method, which uses an alternative way to change the duty cycle, was proposed to increase the ZVS region. A discrete energy injection method, which could achieve ZCS and lower the switching frequency at light load condition, was proposed in [10].

At the secondary side, as shown in Fig. 8, with parallel compensation, a boost converter is inserted after the rectifier for the control. Correspondingly, with series compensation, a buck converter can be used. When the control is after the rectifier, an additional dc inductor, as well as a diode on the current flow path, should be introduced. The University of Auckland proposed a control method at the ac side before the rectifier. By doing so, the dc inductor and additional diodes could be saved. Because of the resonating in the ac side, ZVS and ZCS could be achieved. The detailed designs for series compensation as well as a LC compensation network are presented in. The dual-side control is a combination of both primary and secondary side control. The system complexity and cost may increase, but the efficiency can be optimized by a dual-side control.

VI. ADVANTAGES AND DISADVANTAGES:

A. ADVANTAGES:

1. Vehicle to Grid Benefits

As the ongoing develop of EV, the vehicle to grid (V2G) concept, which studies the interaction between mass EV charging and the power grid, is also a hot research topic in smart grid and EV areas. It is recognized that if the EV charging procedure could be optimized, it could have many benefits for the grid. The EV could balance the loads by valley filling and peak shaving. The batteries in the EVs are like an energy bank, thus some unstable new energy power supply, like wind power, could be connected to the grid more easily. When the secondary rectifier diodes are replaced by active switches, a bidirectional WPT function is realized. The bidirectional WPT could provide advanced performance in V2G applications. Studies show that by introducing WPT technology, the drivers are more willing to connect their EV into the grid, which could maximize the V2G benefits[11].

2.No Gas Required

Electric cars are entirely charged by the electricity you provide, meaning you don’t need to buy any gas ever again. Driving fuel based cars can burn a hole in your pocket as prices of fuel have gone all time high. With electric cars, this cost can be avoided as an average American spends $2000 – $4000 on gas each year. Though electricity isn’t free, an electric car is far cheaper to run.

3.No Emissions

Electric cars are 100 percent eco-friendly as they run on electrically powered engines. It does not emit toxic gases or smoke in the environment as it runs on clean energy source. They are even better than hybrid cars as hybrids running on gas produce emissions. You’ll be contributing to a healthy and green climate.

4. Low Maintenance

Electric cars runs on electrically powered engines and hence there is no need to lubricate the engines. Other expensive engine work is a thing of past. Therefore, the maintenance cost of these cars has come down. You don’t need to send it to service station often as you do a normal gasoline powered car.

5.Reduced Noise Pollution:

Electric cars put curb on noise pollution as they are much quieter. Electric motors are capable of providing smooth drive with higher acceleration over longer distances.

B. DISADVANTAGES:

1. Safety Concerns

WPT avoids the electrocution danger from 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.

A safe region should always be defined for a wireless charging EV. We should ensure that the magnetic flux density should meet the safety guidelines when people are in normal positions, such as standing outside a car or sitting inside a car. Fortunately, a car is usually made of steel, which is a very good shielding material.

The guideline published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) is the most referenced standard to ensure the human safety. There are two versions of ICNIRP standards. The first one was published at 1998. In ICNIRP 1998, there are two reference levels for occupational and general public exposures, respectively. At frequency 0.8–150 kHz, which covers most of the EV WPT frequency, the limit for general public exposure is 6.25 μT. For occupational exposure, it is a little different. At frequency0.82–65 kHz, the limit is 30.7 μT. While at 0.065–1 MHz, the limit is 2/ f .fis the frequency measured in MHz. Under the ICNIRP

1998 guideline, the safety evaluation for a 5 kW stationary EV WPT system was conducted. The average magnetic field exposed to a 1500 mm height body was4.36 μT. For a 35 kW dynamic EV WPT system, the magnetic flux density at 1 m from the center of the road is 2.8 μT. Both the stationary and dynamic WPT system design could meet the ICNIRP 1998 safety guidelines. A good thing for EV WPT is that, after another 10 years of experience on the health affection of time-varying electromagnetic, ICNIRP revised the guideline at 2010 and increased the reference level significantly. For occupational exposure, the reference level is relaxed to 100 μT. For general public, the value changes from6.25 to 27 μT. The increase in the reference level is because the former guideline is too conservative. There is another standard about the electromagnetic field safety issues, IEEE Std.C95.1-2005, presented by the IEEE International Committee on Electromagnetic Safety. In IEEE Std. C95.1-2005, the maximum permissible exposure of head and torso is 205 μT for general public, and 615 μT for occupation. The maximum permissible exposure for the limbs is even higher, which is 1130 μT for both the general public and occupation. Compared with the IEEE Std. the ICNIRP 2010 standard is still conservative. According to ICNIRP 2010, the exposure safety boundaries of our 8 kW EV WPT system for both occupation and general, public people are shown in Fig. 11.

Together with the chassis, the safety zone is quite satisfactory. On the premise of safety higher power WPT system could be developed according to the ICNIRP 2010. Besides the safety issue, the emission limit for Industrial, Scientific, and Medical (ISM) equipment is also regulated by Federal Communications Commission (FCC) in Title 47of 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 EV WPT. When the WPT operates at a non-ISM frequency, the field strength limit should be subjected to §18.305. The Society of Automotive Engineers (SAE) has already formed a committee, J2954, to look into many issues related to EV WPT systems. Among one of their goals will be safety standards. It is projected that a SAE standard on EV WPT systems will be released in June2014 by this committee. More standards and regulations from different regions are summarized in a paper from Qualcomm Incorporated.[12].

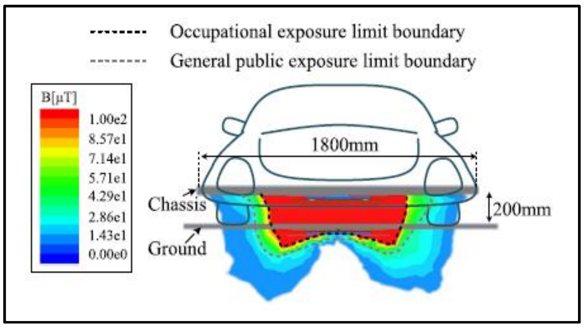

Fig.11.Exposure limit boundary for an 8 kW WPT system

2. Cost

An importance factor that affects the future of WPT is its cost. Actually, from Fig. 8 we see the WPT has only a little difference with a wired charger. The extra cost in a WPT is mainly brought by the magnetic coupler. For our 8 kW stationary WPT 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. 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 [13].

VII. CONCLUSION

1. This seminar presented the wireless charging of electric vehicles.
2. It is clear that vehicle electrification is unavoidable because of environment and energy related issues.
3. Wireless charging will provide many benefits as compared with wired charging.
4. 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.
5. Further studies in topology, control, inverter design, and human safety are still needed in the near term

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