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RECENT TRENDS IN ELECTRICAL TECHNOLOGY

EVs Wireless Power Transfer Technology

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ABSTRACT

Electrical vehicles are a recent trend in electrical technology. EVs help to reduce fossil fuel consumption and hence preventing emission of Green House Gases. The development of Electrical vehicles, electrical hybrid vehicles are in high demand due to their increased benefits and they are ecofriendly. The main barrier to this development are high price, weight, volume, driving distance, and limited investment in charging infrastructure. Shaped magnetic field in resonance (SMFIR) technology enables electric vehicles to overcome these limitations by transferring electricity wirelessly from the road surface while vehicle is in motion. This work describes the innovative SMFIR technology used in the Korean Advanced Institute of Science & Technology online electric vehicle and wireless electrical vehicle charging lane in UK.

Keywords: Electric Vehicle, Transportation, SMFIR, Battery, WPT, Eco friendly

I. INTRODUCTION

Most electric vehicles (EVs) get the electric energy needed for operation from on-board storage devices (i.e. batteries). However, current battery technology provides a very limited travel range with high costs, long charging times, and lower operating efficiencies due to battery weight. These issues must be addressed in order to increase adoption of EVs in both public and personal transportation.They has been challenging the technological limitations imposed by electric vehicle batteries by developing wireless power transmission technology that allows electric vehicles to charge during operation. This technology limits the need for remote static charging stations and replaces them with charging infrastructure embedded in the road or highway system.It allows the development of EVs with substantially smaller batteries and gives engineers greater freedom in designing the charging infrastructure and the on-board energy storage devices.It also allows the EV power management system to be more closely integrated with the electric power train. From a business perspective, this increases vehicle performance, user satisfaction, and business competitiveness, all while protecting the environment.In this paper, we introduce an overview of Shaped Magnetic Field in Resonance (SMFIR) and Dynamic Wireless Electrical Charging for Electrical Vehicles. SMFIR is a technological innovation in wireless power transmission capacity and efficiency under dynamic operation.

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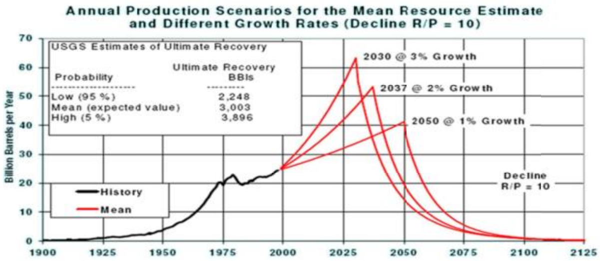

Figure 1: Annual petroleum production scenario by EIA's

II. BACKGROUND:

The world is facing a tough challenge in the perspective of climate change and the global energy supply, mainly caused by a heavy dependence on fossil fuels. In 2007, the United Nations Framework Convention on Climate Change took initiatives on providing authoritative, timely information on all aspects of technologies and socio-economic policies, including costeffective measures to control greenhouse gas (GHG) emissions. While there have been active debates with mixed opinions on the global petroleum production forecast, the U.S. Energy Information Administration (EIA) scenario, published in 2002, shows that peak oil production will be reached within a couple of decades, as depicted in Figure 1. The EIA applied a growth rate of 1-3% in the petroleum production profile with the assumption of R/P=10, which means that the amount of known resources (proven reserves) has 10 years of annual production at the current rate of production to create the three curves in Figure 1. The peak annual global production of petroleum will be at its peak between 2030 and 2050.

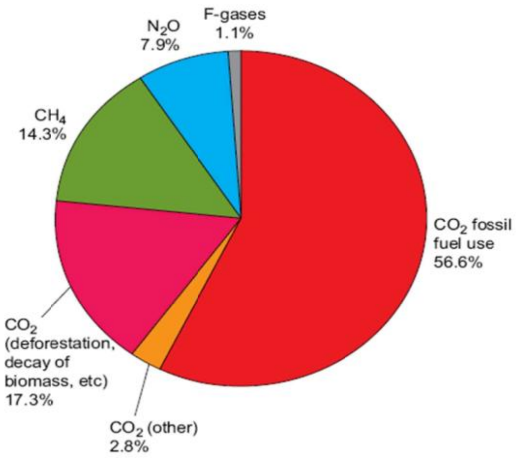

Figure 2: GHG sources distribution

According to the EIA, the energy generation and surface transportation sectors showed the biggest growth in CO2 generation during the period from 1970 to 2004, while the industrial, households and the service sectors remained at similar levels. By 2030, the CO2 growth rate on annual basis will be 1.7% per International Energy Agency (IEA), while the EIA's projection is 2.0% without any additional polices on CO2 generation reduction. Moreover the CO2 generation from the fossil fuel will increase by 40-110% by 2030 if there are no additional policies addressing the climate change [1]. Per the IPCC, transportation was responsible for about

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19% of the global energy use and 23% of energy-related CO2 emissions in 2004. With the current phase of industrial development, the projected CO2 generation in transportation will increase up to about 50% by 2030 and more than 80% by 2050.As a global effort, policy makers are developing rules and regulations including public subsidies and awareness to increase fuel economy, and thus reduce their CO2 emissions, on various transportation modes including passenger cars, light-duty vehicles, trucks, aviation and oceanic transportation. The surface transportation industry is putting emphasis on reducing global CO2 generation by improving the vehicle efficiency, developing alternative fuels and introducing new technologies, such as electric vehicles (EVs), plug-in hybrid vehicles (PHEVs) and fuel-cell vehicles (FCVs). Electric vehicles can completely achieve no tail-out emissions and EV stakeholders have put significant efforts into theintroduction of electric vehicles to public and private transportation. However,, the introduction of those new vehicle technologies aree in a limited market penetration phase compared with thee growing public's concern on the climate changes, which has been mainly caused by the lack of consumers' acceptance yet.

III. CONCEPT

Wireless Power Transfer (WPT) will help to reduce the Not having to stop for recharging will make EVs truly autonomous, and, because the vehicles can thus remain in service for more hours, fewer vehicles will be needed to meet passenger demand. Furthermore, EVs with in-motion (dynamic) wireless charging can have much smaller batteries, an option that can reduce their cost and accelerate adoption.While the concept of medium-range wireless power transfer (WPT), achieved using near-field (non-radiative) electromagnetic coupling, has existed since the pioneering work of Nikola Tesla (1891) more than a century ago, the technology to enable effective dynamic WPT for EVs is still in its nascent stage. Numerous challenges related to performance, cost, and safety need to be overcome before the vision of wirelessly powered EVs can be realized.

IV. NEAR-FIELD WIRELESS POWER TRANSFER:

Near-field WPT systems are of two types: inductive, which use magnetic field coupling between conducting coils, and capacitive, which use electric field coupling between conducting plates to transfer energy (Fig. 1). For medium-range applications (in which the distance between the transmitter and the receiver couplers is comparable to the size of the couplers, as in EV charging), inductive WPT systems have traditionally been preferred.

Classification of WPT:

1. Inductive type.
2. Capacitive type.

<u>Inductive WPT Systems:</u>

Building on work done for material handling applications during the 1990s (Green and Boys 1994), the past decade has seen tremendous progress in inductive WPT technology for stationary charging of EVs (Bosshard

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and Kolar 2016). Aftermarket stationary chargers are already available, and some EV manufacturers have announced plans to introduce built-in stationary inductive WPT systems as early as 2018.

However, for magnetic flux guidance and shielding, inductive WPT systems require ferrite cores, making them expensive and bulky. Also, to limit losses in the ferrites, the operating frequencies of these systems are kept under 100 kHz, resulting in large coils and low power transfer densities. The high cost and low power transfer density are particularly problematic for dynamic WPT, as these systems need to have very high power capability to deliver sufficient energy to the vehicle during its very brief time passing over a charging coil.

For these reasons dynamic inductive WPT is yet to become commercially viable, although a few experimental systems have been demonstrated.

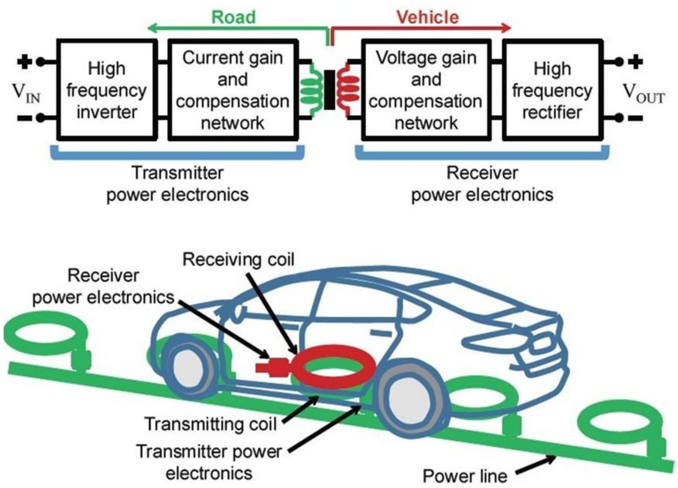

Fig. Inductive WPT System

Capacitive WPT Systems

Capacitive WPT systems have potential advantages over the inductive systems because of the relatively directed nature of electric fields, which reduces the need for electromagnetic field shielding. Also, because capacitive WPT systems do not use ferrites, they can be operated at higher frequencies, allowing them to be smaller and less expensive. Capacitive WPT could thus make dynamic EV charging a reality.But because of the very small capacitance between the road and vehicle plates, effective power transfer can occur only at very high frequencies, making the design of these systems extremely challenging. With the recent availability of wide-bandgap (gallium nitride [GaN] and silicon carbide [SiC]) power semiconductor devices that enable higher-frequency operation, high-power medium-range capacitive WPT systems are becoming viable .Two major challenges associated with capacitive WPT for EV charging are achieving high-power transfer density at high efficiencies while meeting electromagnetic safety requirements, and maintaining effective power transfer even as the couplers' relative position changes. These challenges have been a focus of my group's recent efforts.

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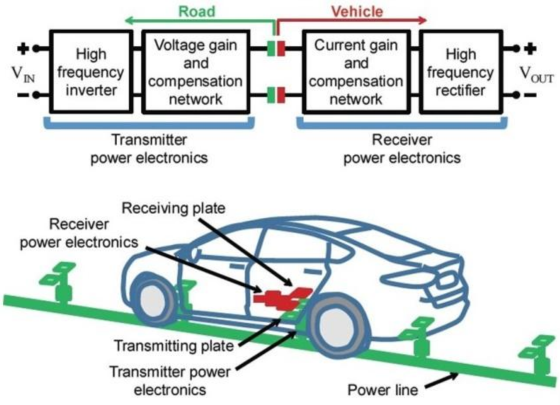

Fig. Capacitive WPT System

Brief introduction SMFIR system

SMFIR technology enables the electric vehicle to be charged while the vehicle is in motion. The power cable installed under the road surface can generate a 20 kHz electromagnetic field as depicted in the Figure when the cable gets 20 kHz AC electricity from the power inverter which is controlled under constant current output

The power converter gets the electricity from the grid with the typical industrial power of 33-phase 380 or 440V. For the bus application, the power capacity of the power inverter has been selected with a 100 – 200 kW range, and can be scaled-up depending on the required electric load of different applications.. The pick-up coil sets attached under the vehicle’s bottom-floor are tuned to a 20 kHz resonant frequency and are designed to have maximized exposure to the generated magnetic field, which has an optimized field shape for the same purpose. In this way, the transmission efficiency can be maximized while reducing the magnetic field leakage outside of design-intended space.The design objective is to obtain the maximum power transmission efficiency with thee pre-determined level of required power capacity by optimizing the paired power supply and collection system design with the alternate current magnetic field shapes at 20 kHz of resonant magnetic power transmission. The shaped magnetic field concept and the coverage of the magnetic field by pick-up devices are also shown in a schematic manner in Figure. This system is called as a dual type power supply system due to its magnetic shape.

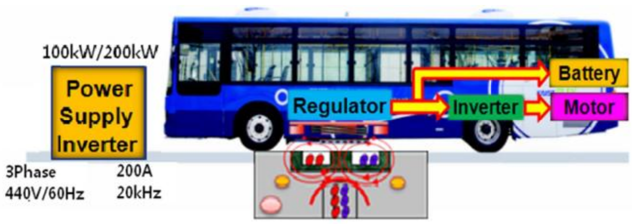

Fig. Schematic diagram of SMFIR technology system

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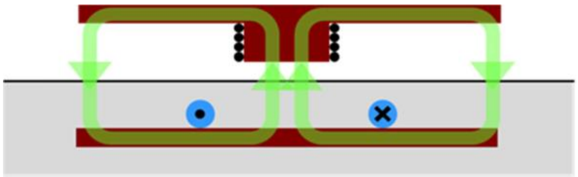

Fig. Schematic of shaped magnetic field

Brief introduction to Dynamic Wireless Power transfer

Wireless power transfer (WPT) is emerging as a practical means for electric vehicle (EV) charging. Of the most common approaches to WPT, inductive coupling, and capacitive coupling, capacitive power transfer (CPT) is proposed to charge an EV at a kilowatt scale power level. CPT implementation replaces copper coils and permeable focusing/shielding materials of inductive approaches with foil surfaces, making CPT a cost effective and structurally simple system to implement while maintaining efficient power transfer capability. High capacitive coupling is achieved through a conformal (flexible and compressive) transmitter bumper that molds and contours itself to the vehicle. This minimizes the air gap and confines the field during charging. Here, a conformal surface demonstrates 3-5 times more coupling capacitance than its rigid counterpart of equal area.

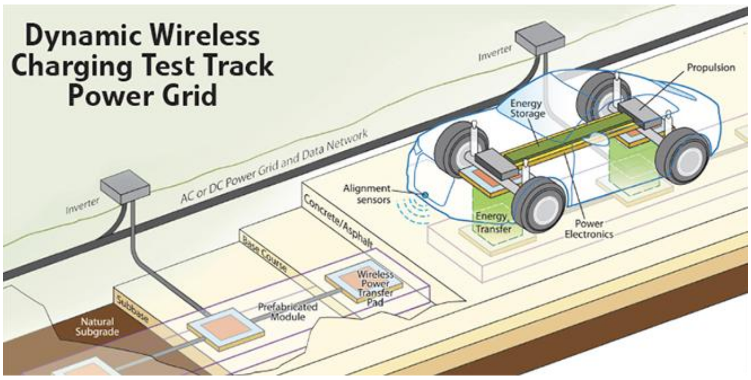

Fig. Schematic diagram of Dynamic WPT system

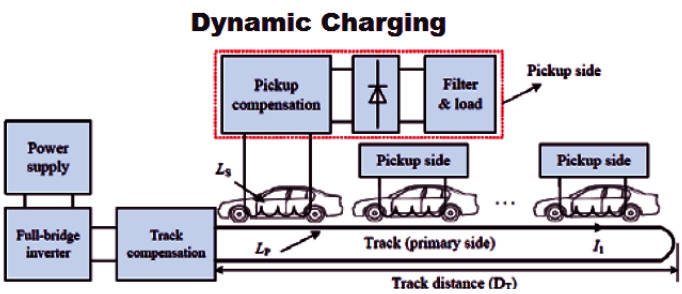

Fig. Schematic of Dynamic WPT system

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Future implementation of SMFIR technology

This technology is implemented in Wireless Charging in Korean Buses. This technology has been implemented in 12km lane in Republic of Korea.

Future implementation of DynamicWPT.

To overcome the losses in SMFIR technology and for Efficient Car charging, the Dynamic WPT system is being tested in UK.

V. CONCLUSION

In this paper, the principle of the SMFIR (Shaped Magnetic Field in Resonance) technology has been introduced so that the electric vehicle or OLEV can be dynamically charged from the road surface while the vehicle is in motion. The vehicle system architecture and power supply infra-structure design process and its examples are described and discussed.

For the practical application of SMFIR technology in future urban transportation, the demonstrative test beds are described with the design process while achieving the required performance parameters. With the technology innovation, the fixed design variables, or design constraints, in launching electric vehicles such as the battery energy storage capacity, charging station location, and operating charging distance and time, etc. have been moved to the design variable domain.

Thus, in the view of design strategy for future urban transportation systems, SMFIR technology can provide a greater deal of design flexibility in the charging facility and electric vehicle launch motivated by the CO2 reduction effort.

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