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ELECTRIC VEHICLE CHARGING BY USING WIRELESS POWER TRANSFER METHOD

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Abstract— The major drawback of the battery charging in traditional electric vehicles is the use of plug-in charging devices. The aim of this paper is to propose a wireless battery charging method, in addition to power transfer, data related to battery status, vehicle ID code, or emergency messages can be simultaneously transferred between the grid and vehicle. This work applies inductive power transfer (IPT) to complete the charging system. The proposed control system can monitor the operating status on the secondary (vehicle) side in real time and adjust charging current depending on the battery status. Furthermore, the proposed mechanism is able to make an immediate stop, if there is any contingency, such as overcharging voltage or current. This will be beneficial to efficient and safety concern during the charging process.

I. INTRODUCTION

The Traditional vehicle relies on natural resources such as diesel or gasoline through engine combustion to generate required power to keep the vehicle running on the road. However, as we all known, the by product from engineer combustion is green house gas (GHG). GHG emission is one of the main causes of globe warming. Nowadays, reduction in GHG emissions is the main topic in many countries. Some countries require the vehicle must be zero emission, thus many vehicle manufacturers to develop the electric vehicle (EV), one the most famous EV manufacturers is Tesla. However, same as a traditional vehicle, after running several hundred kilometers, an EV required refill battery recharge. Two commonly use battery recharging methods are either conductive wiring or fixed spot high frequency resonant wireless charging system. Unfortunately, neither method can fully recharge the battery within few minutes. For busy city life and some business services which required hit on the road all day long, EV might not be the best choice. In order to respond the rising trend of the use of EV, research and developed a mass and flexible battery recharge system is necessary.

One of the choices is wireless power transfer (WPT) system. Wireless power transfer technology is no physical connection between the vehicle and charging the device. Compare with the traditional conductive method, wireless power transfer can reduce the inconvenience and hazard. The initial objective of this paper is instead of using the power cord to charge EV, this paper will go for WPT technology while maintaining a comparable power level and efficiency. The ultimate target is to develop a dynamic system to power the moving vehicles on the road. It will extend the driving range. Nissan and Chevrolet have developed wireless charging system incorporation with Evertran for their EV models, the Nissan LEAF and Chevrolet Volt, the power volume of those models can only support200km to 250 km movement. It means that they need to be recharged after they are moved around 200km to 250km. Also, the charging time is at least 4 hrs. Since people rhythm of life becomes rapidly, the charging time and driving range is needed to be enhanced. Thus, wireless power transfer technology trends will be introduced. Our topic is about wireless charging system. It can be found in internet, library and Car catalog. Previous work has shown that how to select proper coils and components to maintain the high frequency suit the working conditions for charging.

The battery charging use resonance inductive coupling methodology, the charging time is too shortly, it should provide more powerful energy to operate for EV and showing the improvement of the size of the batteries and the power efficiency over a longer distance. They use a MATLAB to simulate the figure to show the actual situation. This MATLAB can tune the frequency and the size of the battery which is suitable for EV.

There are a lot of articles to discuss wireless charging system. Authors have common acceptance that the EV is useful to the world. It can reduce the GHG emissions and avoid the global warming. Thus, this dissertation will carry out the WPT system to prove the inductive coupling methodology can charge the battery continuously to increase EV driving range.

Inductive power transfer (IPT) system is designed to deliver power efficiently from a stationary primary source to one or more movable pickup units over an air gap via magnetic coupling. As many industrial and domestic applications require power transformation without physical contacts, the IPT technology is gaining global popularity and wide acceptance for numerous applications over wide power ranges.

The typical IPT technologies include induction cooking, contact-less battery charging for electric vehicles, bidirectional IPT vehicle-to-grid systems, mobile phones charging , medical implants , dynamic charging on roadway applications avionic applications , power and data transfer and some special applications .Among the recent publications, the excellent

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survey presents wireless power transfer across diverse applications using IPT and the capacitive power transfer technology by comparing the two approaches in power level, gap distance, operational frequency, and efficiency.

II. WIRELESS POWER

Wireless Power has the ability to deliver major advancements in industries and applications that are dependent on physical, contacting connectors, which can be unreliable and prone to failure.

Wireless Power is commonly known by many terms, including Inductive Power Transfer (IPT), Inductive Coupling and Resonant Power Transfer. Each these terms essentially describe the same fundamental process the transmission of energy from a power source to an electrical load, without connectors, across an air gap. The basis of a wireless power system involves essentially two coils – a transmitter and receiver coil. The transmitter coil is energized by alternating current to generate a magnetic field, which in turn induces a current in the receiver coil.

III. HOW DOES WIRELESS POWER WORK

The basics of wireless power involves the transmission of energy from a transmitter to a receiver via an oscillating magnetic field.

To achieve this, Direct Current (DC) supplied by a power source, is converted into high frequency Alternating Current (AC) by specially designed electronics built into the transmitter.

The alternating current energizes a copper wire coil in the transmitter, which generates a magnetic field. Once a second (receiver) coil is placed within proximity of the magnetic field, the field can induce an alternating current in the receiving coil.

Electronics in the receiving device then converts the alternating current back into direct current, which becomes usable power. The diagram below simplifies this process into four key steps.

IV. WIRELESS POWER TRANSFER DIAGRAM

1. The 'mains' voltage is converted in to an AC signal (Alternating Current), which is then sent to the transmitter coil via the electronic transmitter circuit.
2. The AC current flowing through the transmitter coil induces a magnetic field which can extends to the receiver coil (which lies in relative proximity)
3. The magnetic field then generates a current which flows through the coil of the receiving device.
4. The process whereby energy is transmitted between the transmitter and receiver coil is also referred to as magnetic or resonant coupling and is achieved by both coils resonating at the same frequency. Current flowing within the receiver coil is converted into direct current (DC) by the receiver circuit, which can then be used to power the device.

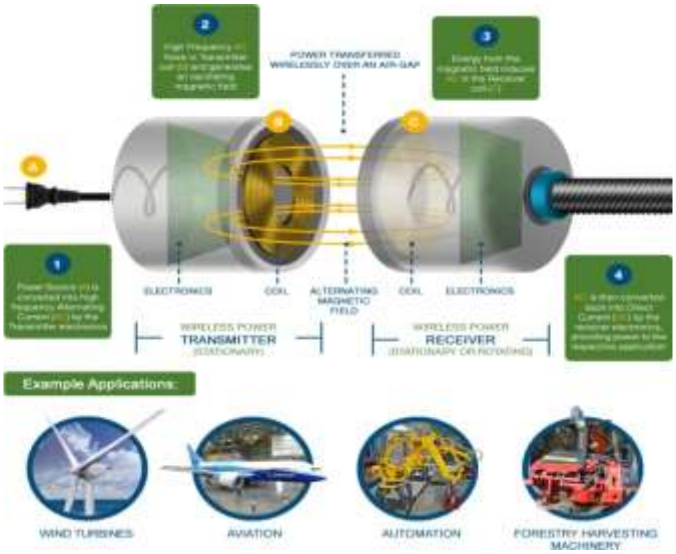


Figure 1: Wireless Power Transfer

V. BENEFITS OF WIRELESS POWER

Reduce costs associated with maintaining direct connectors
(like those in the tradtional slip ring).

- Greater convenience for the charging of everyday electronic devices
- Safe power transfer to applications that need to remain sterile or hermetically sealed
- Electronics can be fully enclosed, reducing the risk of corrosion due to elements such as oxygen and water.
- Robust and consistent power delivery to rotating, highly mobile industrial equipment
- Delivers reliable power transfer to mission critical systems in wet, dirty and moving environments.

Whatever the application, the removal of the physical connection delivers a number of benefits over traditional cable power connectors, some of which aren't always obvious. The video below highlights just some of the benefits and advantages of wireless power and offers an insight into a world where wireless power is widely integrated into industrial and mission critical environments.

VI. HOW EFFICIENT IS WIRELESS POWER TECHNOLOGY

The overall efficiency of a wireless power system is the most important factor in determining its performance. The efficiency of a system measures the amount of power being transferred between the power source (i.e. wall socket), and the receiving device. This, in turn, determines aspects such as charging speed and transmission distance.

Wireless power systems vary in regards to their level of efficiency based on factors such as coil configuration and design, transmission distance and coupling. A less efficient system will generate more emissions, and result in less power getting through to the receiver device.

Typically wireless charging technology for devices such as smartphones can reach upwards of 70%+ for power transfer. PowerByProxi can achieve over 90% wireless power transfer efficiency for their latest Proxi-Module platform, which transfers up to 100 watts of power.

VII. HOW IS EFFICIENCY MEASURED FOR WIRELESS POWER TRANSFER

Efficiency is measured in a general sense as the amount of power (as a percentage) that is transferred from the power source to the receiver device i.e. a wireless charging system for a smartphone with 80% efficiency means that 20% of the input power is being lost between the wall socket and the battery for the smartphone. The formula for measuring operating efficiency is:

$$\text{Efficiency} = \frac{\text{DC Power OUTPUT}}{\text{DC Power INPUT}} \times 100\%$$

VIII. REVIEW OF LITERATURE SURVEY

1) J. Dai and D. Ludois, "A survey of wireless power transfer and a critical comparison of inductive and capacitive coupling for small gap applications,"

Inductive power transfer (IPT) and capacitive power transfer (CPT) are the two most pervasive methods of wireless power transfer (WPT). IPT is the most common and is applicable to many power levels and gap distances. Conversely, CPT is only applicable for power transfer applications with inherently small gap distances due to constraints on the developed voltage. Despite limitations on gap distance, CPT has been shown to be viable in kilowatt power level applications. This paper provides a critical comparison of IPT and CPT for small gap applications, wherein the theoretical and empirical limitations of each approach are established. A survey of empirical WPT data across diverse applications in the last decade using IPT and CPT technology graphically compares the two approaches in power level, gap distance, operational frequency, and efficiency, among other aspects. The coupler volumetric power density constrained to small gap sizes is analytically established through theoretical physical limitations of IPT and CPT. Finally, guidelines for selecting IPT or CPT in small gap systems are presented.

2) C. H. Ou, H. Liang, and W. Zhuang, "Investigating wireless charging and mobility of electric vehicles on electricity market".

To avoid inconvenient vehicle stops at charging stations, on-road wireless charging of electric vehicles (EVs) is a promising application in the future smart grid. In this paper, we study a critical yet open problem for this application, i.e., the impact of wireless charging and mobility of EVs on the wholesale electricity market based on locational marginal price (LMP), which is mainly determined by the EV mobility patterns.

To capture the dynamics in vehicle traffic flow and state of charge of EV batteries, we model the EV mobility as a queuing network based on the statistics obtained via traffic information systems. Then, the load on each power system bus with respect to EV wireless charging is obtained using the stationary distribution of the queuing network. An economic dispatch problem is formulated to incorporate the EV wireless charging demand, and the LMP of each power system bus is obtained. Furthermore, a pricing mechanism based on the LMP variations of power system buses is investigated to enhance the social welfare. The performance of our proposed analytical model is verified by a realistic road traffic simulator (SUMO) based on a 3-bus test system and an IEEE 30-bus test system, respectively.

Simulation results indicate that our proposed analytical model can accurately provide an estimation of the LMP variations due to EV wireless charging.

3) C. S. Wang, O. H. Stielau, and G. A. Covic, "Design considerations for a contactless electric vehicle battery charger,"

This overviews theoretical and practical design issues related to inductive power transfer systems and verifies the developed theory using a practical electric vehicle battery charger. The design focuses on the necessary approaches to ensure power transfer over the complete operating range of the system. As such, a new approach to the design of the primary resonant circuit is proposed, whereby deviations from design expectations due to phase or frequency shift are minimized. Of particular interest are systems that are neither loosely nor tightly coupled. The developed solution depends on the selected primary and secondary resonant topologies, the magnetic coupling coefficient, and the secondary quality factor.

4) Q. Xu, D. Hu, B. Duan, and J. He, "A fully implantable stimulator with wireless power and data transmission for experimental investigation of epidural spinal cord stimulation,"

Epidural spinal cord stimulation (ESCS) combined with partial weight-bearing therapy (PWBT) has been shown to facilitate recovery of functional walking for individuals after spinal cord injury (SCI).

The investigation of neural mechanisms of recovery from SCI under this treatment has been conducted broadly in rodent models, yet a suitable ESCS system is still unavailable. This paper describes a practical, programmable, and fully implantable stimulator for laboratory research on rats to explore fundamental neurophysiological principles for functional recovery after SCI. The ESCS system is composed of a personal digital assistant (PDA), an external controller, an implantable pulse generator (IPG), lead extension, and stimulating electrodes. The stimulation parameters can be programmed and adjusted through a graphical user interface on the PDA. The external controller is placed on the rat back and communicates with the PDA via radio-frequency (RF) telemetry. An RF carrier from the class-E power amplifier in the external controller provides both data and power for the IPG through an inductive link. The IPG is built around a microcontroller unit to generate voltage-regulated pulses delivered to the bipolar electrode for ESCS in rats. The encapsulated IPG measures 22 mm × 23 mm × 7 mm with a mass of ∼ 3.78 g. This fully implantable batteryless stimulator provided a simplified and efficient method to carry out chronic experiments in untethered animals for medical electro-neurological research.

5) T. Bieler, M. Perrottet, V. Nguyen, and Y. Perriard, "Wireless power and data transmission,"

The wireless charging and data transmission systems developed by major car manufacturers rely heavily on additional transmission equipment. This paper presents a newly developed wireless power and bidirectional data transmission scheme without adding any radio frequency (RF) devices. The battery charge status and vehicle related information can be transmitted bidirectionally in the wireless manner by the compensation capacitor between two isolated units. Based on the function, this system can quickly inform the user when an emergency event occurs during power transmission. An inverter is used on the primary side of the system, and the generated AC power is transmitted to the load at the secondary side through mutual inductance; the secondary side of the system adjusts the load current to transmit data back.

The primary side uses the zero voltage switching (ZVS) method to receive data, and the trimming of the current curve to transmit commands; the secondary side of the system receives commands and uses carrier cycles for decoding. Experimental verification shows applicability of the proposed system.

IX. PROPOSED SYSTEM:

A wireless vehicle charger with the capacity of simultaneous data/power transmission is proposed. The grid (primary) side is operated on the utility power source of single phase. The vehicle (secondary) side is to accept the power transferred from the primary side. In addition to receiving power, the secondary side will simultaneously transfer digitalized date back to the primary side via the same conduction coils.

To depict the idea, consider the simplified schematic diagram of the proposed system. First, the ac grid voltage is rectified via a rectifier at the primary side, in which, a fly back converter, tuned to the operating frequency of power transfer is used. Q1 at the primary side has optimal efficiency to deliver power based on the principle of zvs. Q2 at the secondary side has two functions, i.e., control of output current and transmit the modulated signal. At the primary unit, the parameter tuning of the lc circuit is essential. Although such tuning depends on the load, it is not necessary to adapt the resonant system because the coupling factor is low.

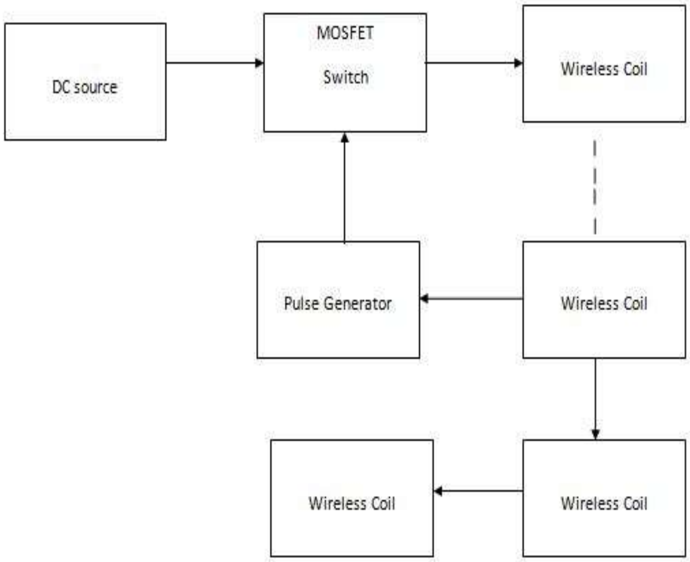
1) Advantages:

- ❖ Achieve steady-state compensation.
- ❖ Improves the security during energy charge.

2) Applications:

- Grid applications.
- EV Charging.

3) BLOCK DIAGRAM



X. MOSFET with Working MOSFET as a Switch

The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) transistor is a semiconductor device which is widely used for switching and amplifying electronic signals in the electronic devices. The MOSFET is a core of integrated circuit and it can be designed and fabricated in a single chip because of these very small sizes. The MOSFET is a four terminal device with source(S), gate (G), drain (D) and body (B) terminals. The body of the MOSFET is frequently connected to the source terminal so making it a three terminal device like field effect transistor.

The MOSFET is very far the most common transistor and can be used in both analog and digital circuits.

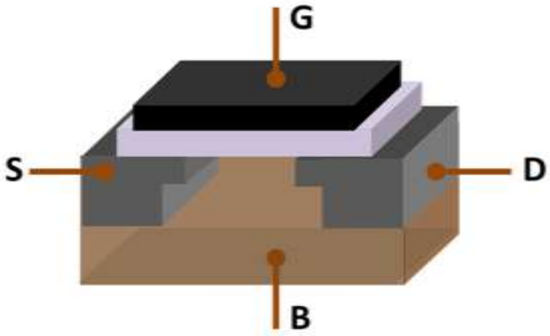


Figure 2 : MOSFET Switch

The MOSFET works by electronically varying the width of a channel along which charge carriers flow (electrons or holes). The charge carriers enter the channel at source and exit via the drain. The width of the channel is controlled by the voltage on an electrode is called gate which is located between source and drain. It is insulated from the channel near an extremely thin layer of metal oxide. The MOS capacity present in the device is the main part

XI. INDUCTOR

An inductor is a passive electronic component which is capable of storing electrical energy in the form of magnetic energy. Basically, it uses a conductor that is wound into a coil, and when electricity flows into the coil from the left to the right, this will generate a magnetic field in the clockwise direction.

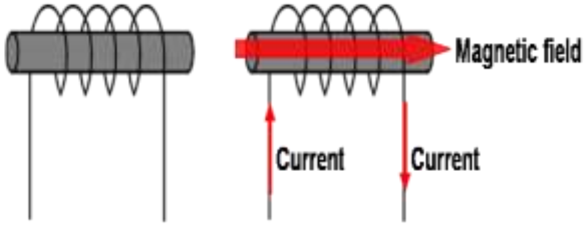


Figure 3: Magnetic coil

Presented below is the equation that represents the inductance of an inductor. The more turns with which the conductor is wound around the core, the stronger the magnetic field that is generated. A strong magnetic field is also generated by increasing the cross-sectional area of the inductor or by changing the core of the inductor.

$$L = \frac{\mu \cdot k \cdot N^2 \cdot S}{l}$$

Where L: Inductance (H)
μ: Magnetic permeability (H/m)
k: Nagaoka coefficient
N: Number of turns of coil
S: Cross-sectional area of coil (m^2)
l : Length of coil in axial direction (m)

Let's now assume that an AC current is flowing through the inductor. "AC" (alternating current) refers to a current whose level and direction change cyclically over time. When current is about to flow to the inductor, the magnetic field generated by that current cuts across the other windings, giving rise to an induced voltage and thus preventing any changes in the current level. If the current is about to rise suddenly, an electromotive force is generated in the opposite direction to the current--that is, in the direction in which the current is reduced--thus preventing any increase in the current. Conversely, if the current is about to drop, an electromotive force is generated in the direction in which the current is increased.

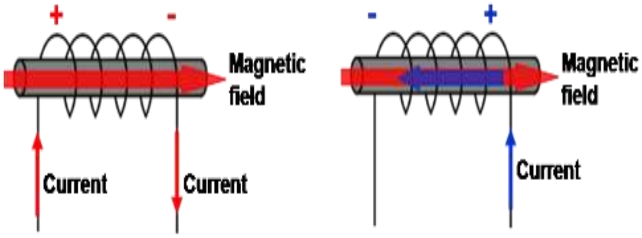


Figure 4 : current flow to flow to the inductor

These effects of the induced voltage are produced even when the direction in which the current is flowing is reversed. Before overcoming the induced voltage that is attempting to block the current, the direction of the current is reversed so that there is no flow of current.

The current level remains unchanged when DC (direct current) flows to the inductor so no induced voltage is produced, and it is possible to consider that a shorted state results. In other words, the inductor is a component that allows DC, but not AC, to flow through it.

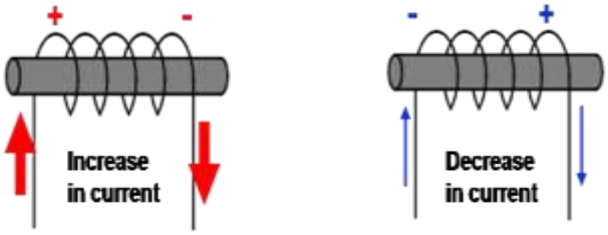


Figure 5 : Increase and decrease the current

- The inductor stores electrical energy in the form of magnetic energy.
- The inductor does not allow AC to flow through it, but does allow DC to flow through it.

The properties of inductors are utilized in a variety of different applications. There are many and varied types of inductors in existence, and in the next lesson the applications for which inductors are best suited will be described.

XII. SIMULATION RESULT

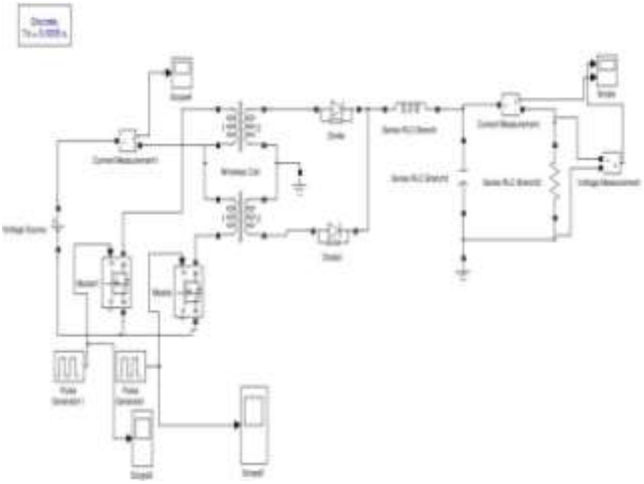


Figure 6: Wireless Charging and Power Transfer

Figure 7: Output MATLAB Simulation for Wireless Charging and Power Transfer

XIII. CONCLUSION

This work proposes a prototype simultaneous wireless power/data transfer for electric vehicle charging solutions. The proposed system possesses the following advantages: 1) The design is practical. The controller at the primary side can control and adjust the output current to achieve steady-state compensation at the secondary side via wireless communication. 2) The proposed system improves the security during energy charge. When an emergency contingency appears at the secondary side, the system can inform the primary side with the highest priority channel within 1/120 sec. 3) The contactless charging and discharging technology is to be used for energy exchange between car batteries and apartment complex's energy storage tank (V2G and G2V). The excessive energy stored in the vehicle battery could be transferred to the apartment complex's energy storage tank, and vice versa, via contactless energy transfer technique. In addition to power transfer, data related to battery status, vehicle status or ID code, etc can be simultaneously transferred between the grid and vehicle in a compact scheme in real time. Experimental verification has been successfully conducted to verify applicability of the proposed design.

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