

Wireless Power Transfer for Electric Vehicle Applications

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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 30 years with the term inductive power transfer (IPT). WPT technology is developing rapidly in recent years. At kilowatts power level, the transfer distance increases from several millimeters to several hundred millimeters with a grid to 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 paper reviewed 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, inductive power transfer, electric vehicle, stationary charging, dynamic charging, safety guidelines.

I. INTRODUCTION

Photo voltaics is the field of technology and research related to the devices which directly convert sunlight into electricity. The solar cell is the elementary building block of the photovoltaic technology. Solar cells are made of semiconductor materials, such as silicon. One of the properties of semiconductors that makes them most useful is that their conductivity may easily be modified by introducing impurities into their crystal lattice. For instance, in the fabrication of a photovoltaic solar cell, silicon, which has four valence electrons, is treated to increase its conductivity. On one side of the cell, the impurities, which are phosphorus atoms with five valence electrons (n-donor), donate weakly bound valence electrons to the silicon material, creating excess negative charge carriers. On the other side, atoms of boron with three valence electrons (p-donor) create a greater affinity than silicon to attract electrons. Because the p-type silicon is in intimate contact with the n-type silicon a p-n junction is established and a diffusion of electrons occurs from the region of high electron concentration (the n-type side) into the region of low electron concentration (p-type side). When the electrons diffuse across the p-n junction, they recombine with holes on the p-type side. However, the diffusion of carriers does not occur indefinitely, because the imbalance of charge

immediately on either sides of the junction originates an electric field. This electric field forms a diode that promotes current to flow in only one direction. Ohmic metal-semiconductor contacts are made to both the n-type and p-type sides of the solar cell, and the electrodes are ready to be connected to an external load.

II. WIRELESS POWER

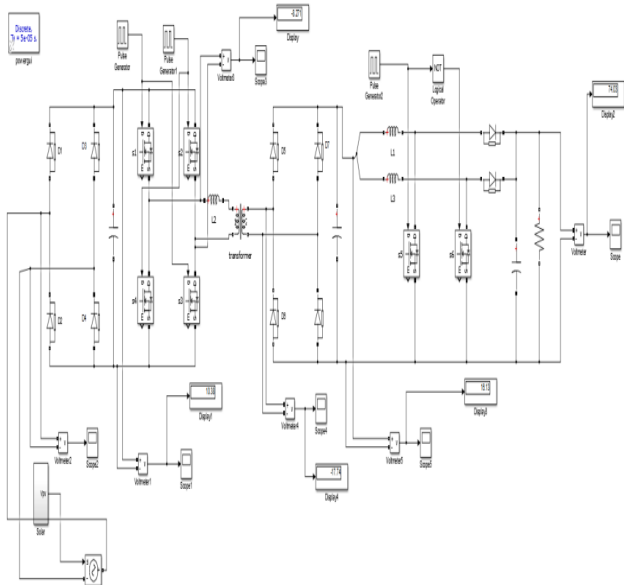
The WPT technology, which can eliminate all the charging troublesome, is desirable by the EV owners. By wirelessly transferring energy to the EV, the charging becomes the easiest task. For a stationary WPT system, the drivers just need to park their car and leave. For a dynamic WPT system, which means the EV could be powered while driving; the EV is possible to run forever without a stop. Also, the battery capacity could be reduced to 20% or more. Although the market demand is huge, people were just wondering whether the WPT could be realized efficiently at a reasonable cost. The research team from MIT published a paper in Science, in which 60W power is transferred at a 2-meter 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. Wireless power transfer involves multiple disciplines, including magnetics, power electronics, communications, mechanical and electric engineering. The study of a WPT system can be very complex due to the multidisciplinary nature and the uncertainties of the system. For example, the magnetic field is at high frequency and low density, and varies with gap distance, misalignment, and power levels. The resonance in the system is key to the high efficiency power transfer but that could be also affected by coupling between the two coils, and surrounding media (raining or dry environment). Typically, the study of WPT systems involves: (1) Analytical method, including circuit analysis and calculation of mutual inductances through analytical approaches. (2) Field analysis using numerical tools

III. WIRELESS COMMUNICATIONS

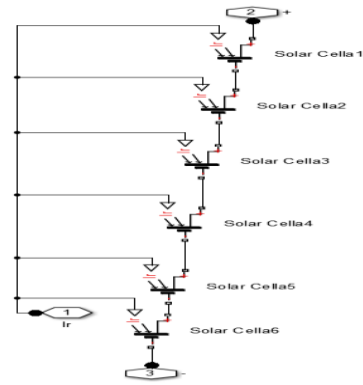
In a WPT system, it is important to exchange information between the grid side and vehicle side wirelessly to provide a feedback. Thus, the power flow could be controlled by the methods mentioned in section V. The communication

design could be classified by whether the signal is modulated on the power carrier or uses a separate frequency band. The Qi standard for wireless low power transfer modulates a 2 kHz signal onto the power carrier frequency [114]. The communication signal is transmitted through the power coils. The 2 kHz signal is very easy to process even by using the existing microcontroller in the device. In this way, the extra antennas and control chips for the communication could be saved. In EV WPT system, for the high voltage on the power coils, isolation is required for the communication control circuit which may increase the cost. For advanced information exchange, general wireless communication protocols, like Bluetooth, near field communication (NFC), and so on, could be adopted. In the EV WPT prototype from Oak Ridge National Laboratory (ORNL), the Dedicated Short Range Communications (DSRC) Link is used [95]. The DSRC is a technology based on global position system (GPS) and IEEE 802.11p wireless fidelity (Wi-Fi), which could realize the connection between vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) [115]. The FCC already allocates 75MHz band at 5.9GHz for DSRC. It is being committed to use by the U.S. department of transportation in the Intelligent Transportation System (ITS). As the IEEE and SAE standards were already published, the DSRC could provide an easier way to implement the smart grid functionalities and maximize the vehicle to grid benefits.

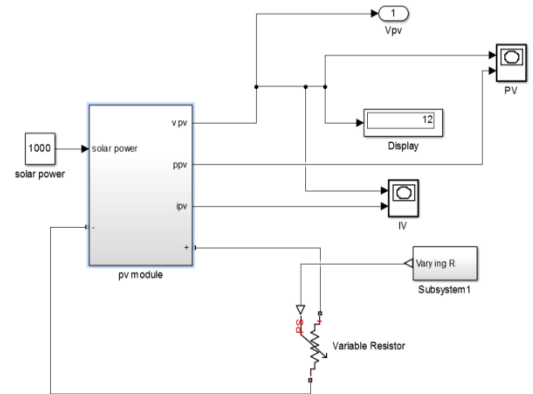
IV. SIMULATION WORK



Solar Cell

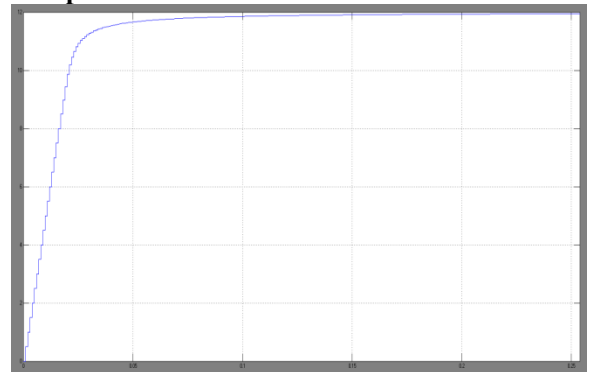


Solar Panel

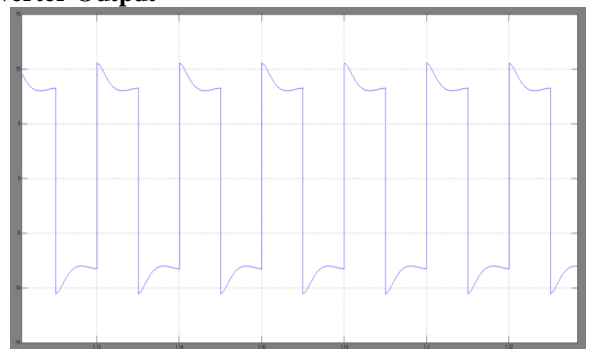


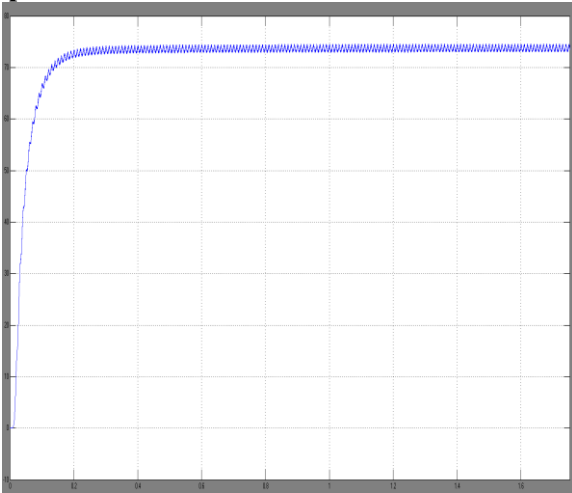
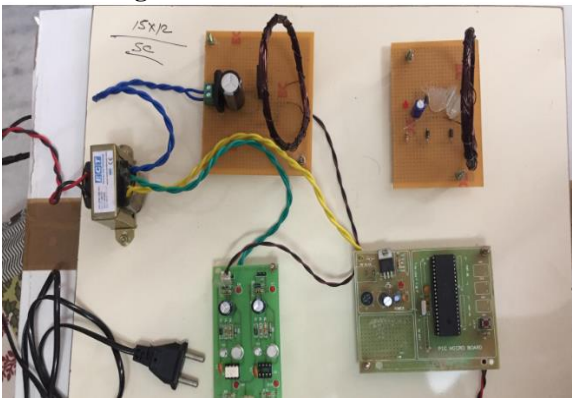
V. WAVEFORMS

Solar Input



Inverter Output



Output**Hardware Image:****VI. CONCLUSION**

This paper presented a review of wireless charging of electric vehicles. It is clear that vehicle electrification is unavoidable due to environment and energy related issues. Wireless charging will provide many benefits compared to 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.

VII. REFERENCES

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