IJAREEIE

e-ISSN: 2278-8875
p-ISSN: 2320-3765

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

Volume 11, Issue 2, February 2022

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.282

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 11, Issue 2, February 2022 ||

DOI:10.15662/IJAREEIE.2022.1102008

Power Flow Study of Grid Connected Bidirectional WPT Systems for EV Application

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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. 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: Dynamic charging, electric vehicle (EV), inductive power transfer (IPT), safety guidelines, stationary charging, wireless power transfer (WPT).

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 for a 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 EV today. 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

The batteries are considered fit for EVs due to their high power-to-weight ratio, high energy efficiency, good high-temperature performance, and low self-discharge.
The idea of EVs is promising to address climate change by cutting down on carbon emission.
EVs are being supported as the apparent substitute to fuel-powered cars; they are assured for a rapid growth phase with the blending outcome of longer range, lower battery cost and faster charging rate. However, the range and charging of EVs are still considerable concerns.

II. LITERATURE REVIEW

Wireless power transfer (WPT), which transmits power by an electromagnetic field across an intervening space, provides the prospect of new opportunities for electric vehicles (EVs) to enhance sustainable mobility. This review article evaluates WPT technology for EV applications from both technical and sustainability perspectives. The objectives of this review include: (1) to present the state-of-the-art technical progress and research bottlenecks in WPT development and applications in the transportation sector; (2) to characterize the demonstrations of the real-world deployment of WPT EV systems; and (3) to evaluate the sustainable performance and identify challenges and opportunities for improvement. From the technical perspective, progress on coil design, compensation topologies, and

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power electronics converters and control methods are reviewed with a focus on system performance. From the sustainability perspective, performance is defined in terms of energy, environmental, and economic metrics, and policy drivers and issues of health and safety are also examined.

Wireless power technology offers the promise of cutting the last cord, allowing users to seamlessly recharge mobile devices as easily as data are transmitted through the air. Initial work on the use of magnetically coupled resonators for this purpose has shown promising results. [4] We present new analysis that yields critical insight into the design of practical systems, including the introduction of key figures of merit that can be used to compare systems with vastly different geometries and operating conditions. A circuit model is presented along with a derivation of key system concepts, such as frequency splitting, the maximum operating distance (critical coupling), and the behavior of the system as it becomes under coupled. This theoretical model is validated against measured data and shows an excellent average coefficient of determination (R2) of 0.9875. An adaptive frequency tuning technique is demonstrated, which compensates for efficiency variations encountered when the transmitter-to-receiver distance and/or orientation are varied. The method demonstrated in this paper allows a fixed-load receiver to be moved to nearly any position and/or orientation within the range of the transmitter and still achieve a near-constant efficiency of over 70% for a range of 0–70 cm.

Efficient method for wireless power transfer would enable advances in such diverse areas as embedded computing, mobile computing, sensor networks, and micro robotics. The need to minimize energy consumption is often the main design driver in applications where devices need to operate untethered. Energy consumption often restricts or severely limits functionality in such applications.[5]

III. PROPOSED ARCHITECTURE

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 [1]. However, the energy density of the commercialized lithium-ion battery in EVs is only 90–100 Wh/kg for a finished pack [2].1 This number is so poor compared with gasoline, 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 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 [1]. 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. 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 plugin 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. Although the market demand is huge, people were just wondering whether the WPT could be realized efficiently ata reasonable cost. The research team from MIT published a paper in Science [3], in which 60 W power 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 [4]–[9]. The power transfer path can even be guided using the domino-form repeaters [10], [11]. In order to transfer power more efficiently and further, the resonant frequency is usually selected at MHz level, and air-core coils are adopted. 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

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more practical in the EV charging, ferrite as a magnetic flux guide and aluminum plate as a shield are usually adopted in the coil design [12]. 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 [13]. In fact, since the WPT is based on the nonradiative 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 [16], cordless robots in automation production lines , as well as the charging of electric vehicles [13], [14], . Recently, as the need of EV charging and also the progress in technology, the power transfer distance increases from several millimeters to a few hundred millimeters at kilowatts power level [12], [14], . 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 [14], . 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 is 250 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

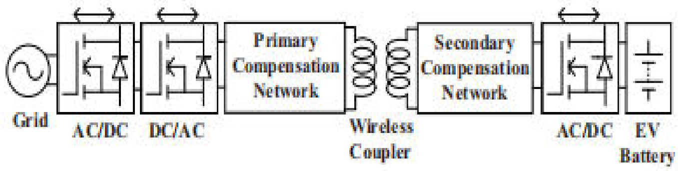

Fig. 1.Typical wireless EV charging system.

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. The WiTricity Corporation with technology from MIT released their WiT3300 development kit, which achieves 90% efficiency over a 180 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 delivery . 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. 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

IV. CONCLUSIONS

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

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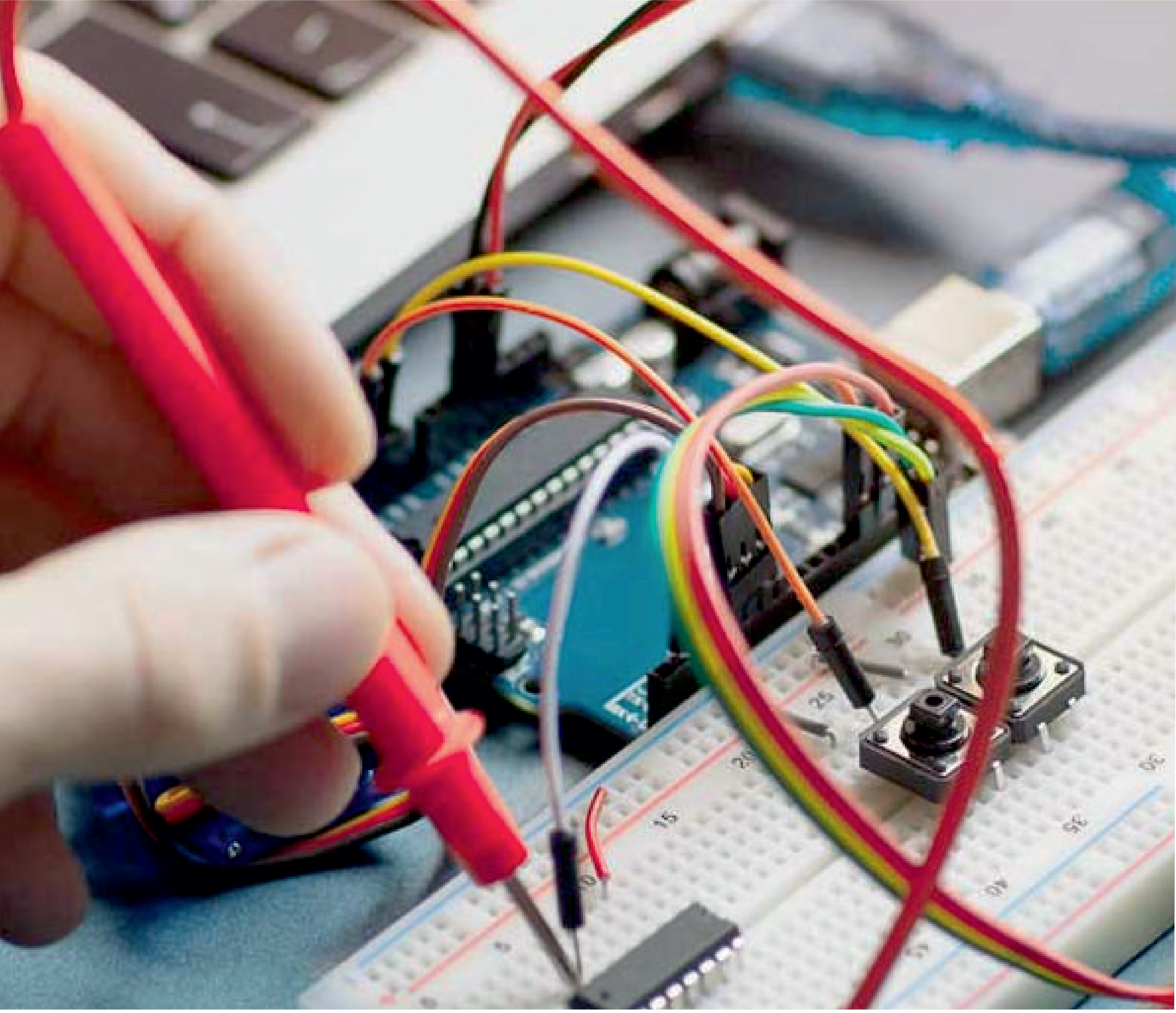
provide the foundation for mass market penetration for EV regardless of battery technology. With technology development, wireless charging of EV can be brought to fruition. Further studies in topology, control, inverter design, and human safety are still needed in the near term.

REFERENCES

[1] S. J. Gerssen-Gondelach and A. P. C. Faaij, "Performance of batteries for electric vehicles on short and longer term," *J. Power Sour.*, vol. 212, pp. 111–129, Aug. 2012.
[2] V. Etacheri, R. Marom, R. Elazari, G. Salitra, and D. Aurbach, "Challenges in the development of advanced Li-ion batteries: A review," *Energy Environ. Sci.*, vol. 4, no. 9, pp. 3243–3262, 2011.
[3] A. K. A. Kurs, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljacic, "Wireless power transfer via strongly coupled magnetic resonances," *Science*, vol. 317, no. 5834, pp. 83–86, 2007.
[4] A. P. Sample, D. A. Meyer, and J. R. Smith, "Analysis, experimental results, and range adaptation of magnetically coupled resonators for wireless power transfer," *IEEE Trans. Ind. Electron.*, vol. 58, no. 2, pp. 544–554, Feb. 2011.
[5] B. L. Cannon, J. F. Hoburg, D. D. Stancil, and S. C. Goldstein, "Magnetic resonant coupling as a potential means for wireless power transfer to multiple small receivers," *IEEE Trans. Power Electron.*, vol. 24, no. 7, pp. 1819–1825, Jul. 2009.
[6] A. Kurs, R. Moffatt, and M. Soljacic, "Simultaneous mid-range power transfer to multiple devices," *Appl. Phys. Lett.*, vol. 96, no. 4, pp. 044102-1–044102-3, 2010.
[7] C. Sanghoon, K. Yong-Hae, S.-Y. Kang, L. Myung-Lae, L. Jong-Moo, and T. Zyung, "Circuit-model-based analysis of a wireless energytransfer system via coupled magnetic resonances," *IEEE Trans. Ind. Electron.*, vol. 58, no. 7, pp. 2906–2914, Jul. 2011.
[8] C. Kainan and Z. Zhengming, "Analysis of the double-layer printed spiral coil for wireless power transfer," *IEEE J. Emerg. Sel. Topics Power Electron.*, vol. 1, no. 2, pp. 114–121, Jul. 2013.
[9] Z. Yiming, Z. Zhengming, and C. Kainan, "Frequency decrease analysis of resonant wireless power transfer," *IEEE Trans. Power Electron.*, vol. 29, no. 3, pp. 1058–1063, Mar. 2014.
[10] L. C. Kwan, W. X. Zhong, and S. Y. R. Hui, "Effects of magnetic coupling of nonadjacent resonators on wireless power domino-resonator systems," *IEEE Trans. Power Electron.*, vol. 27, no. 4, pp. 1905–1916, Apr. 2012.
[11] W. X. Zhong, L. C. Kwan, and S. Y. Hui, "Wireless power dominoresonator systems with noncoaxial axes and circular structures," *IEEE Trans. Power Electron.*, vol. 27, no. 11, pp. 4750–4762, Nov. 2012.
[12] Y. Nagatsuka, N. Ehara, Y. Kaneko, S. Abe, and T. Yasuda, "Compact contactless power transfer system for electric vehicles," in *Proc. IPEC*, Jun. 2010, pp. 807–813.
[13] J. G. Bolger, F. A. Kirsten, and L. S. Ng, "Inductive power coupling for an electric highway system," in *Proc. 28th IEEE Veh. Technol. Conf.*, Mar. 1978, pp. 137–144.
[14] M. Eghtesadi, "Inductive power transfer to an electric vehicleanalytical model," in *Proc. IEEE 40th Veh. Technol. Conf.*, May 1990, pp. 100–104.
[15] A. W. Green and J. T. Boys, "10 kHz inductively coupled power transfer-concept and control," in *Proc. 5th Int. Conf. Power Electron. Variable-Speed Drives*, Oct. 1994, pp. 694–699.
[16] K. W. Klontz, D. M. Divan, D. W. Novotny, and R. D. Lorenz, "Contactless power delivery system for mining applications," *IEEE Trans. Ind. Appl.*, vol. 31, no. 1, pp. 27–35, Jan./Feb. 1995.
[17] J. M. Barnard, J. A. Ferreira, and J. D. Van Wyk, "Sliding transformers for linear contactless power delivery," *IEEE Trans. Ind. Electron.*, vol. 44, no. 6, pp. 774–779, Dec. 1997.
[18] N. H. Kutkut and K. W. Klontz, "Design considerations for power converters supplying the SAE J-1773 electric vehicle inductive coupler," in*Proc. 12th Annu. APEC and Expo.*, vol. 2. Feb. 1997, pp. 841–847.
[19] D. A. G. Pedder, A. D. Brown, and J. A. Skinner, "A contactless electrical energy transmission system," *IEEE Trans. Ind. Electron.*, vol. 46, no. 1, pp. 23–30, Feb. 1999.
[20] H. Abe, H. Sakamoto, and K. Harada, "A noncontact charger using a resonant converter with parallel capacitor of the secondary coil," *IEEE Trans. Ind. Electron.*, vol. 36, no. 2, pp. 444–451, Mar./Apr. 2000.
[21] J. T. Boys, G. A. Covic, and A. W. Green, "Stability and control of inductively coupled power transfer systems," *Proc. IEE Electr. Power Appl.*, vol. 147, no. 1, pp. 37–43, Jan. 2000.
[22] A. P. Hu, J. T. Boys, and G. A. Covic, "ZVS frequency analysis of a current-fed resonant converter," in *Proc. 7th IEEE Int. Power Electron. Congr.*, Oct. 2000, pp. 217–221.
[23] W. Chwei-Sen, G. A. Covic, and O. H. Stielau, "Power transfer capability and bifurcation phenomena of loosely coupled inductive power transfer systems," *IEEE Trans. Ind. Electron.*, vol. 51, no. 1, pp. 148–157, Feb. 2004.



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