A Review on Future of Smart City Wireless Charging of Electric Vehicles

[1] **K. S. Rahi**, [2] **Lokesh Sharma**, [3] **L.N. Barber**

[1] Assistant Professor, [2] Assistant Professor, [3] Assistant Professor
Mechanical Engineering Department,
G.I.T.S., Udaipur, India

Abstract : This paper presents an overview of current wireless power transfer (WPT) technologies for the application of electric vehicles (EV) wireless charging. The basic principles of each technology are introduced. Followed by classification, the advantages and limitations of each technology for EV charging are discussed. Making use of inductive charging MEDs can act as mobile charging stations, thus improving the overall energy consumption of a fleet of vehicles. The latest development, key technical issues, challenges and state-of-art researches are introduced. The research trends are also been given.

Keywords: wireless power transfer, electric vehicle, wireless charging, mobile energy disseminators

I. INTRODUCTION

With regards to the future transport arena, electric vehicles (EVs) are considered as the likely replacement of internal combustion engine driven vehicles, especially given the CO2 reduction and alternative energy perspectives. Electric cars have the potential to reduce carbon emissions, local air pollution and the reliance on imported oil. In Europe, the European commission aims to reduce road transport emissions by 70% by 2050 [2]. Taking into account the fact that road transport is expected to double by 2050, passenger cars need to reduce their emissions significantly. Advanced internal combustion engine (ICE) technologies are expected to enable emissions reduction, but are not expected to meet long term targets. Electric vehicles, especially plug-in ones (PEVS), are penetrating the market and they are currently counted as zero emissions vehicles. The growing EV market stimulates the demand for more convenient and reliable means to recharge the battery. WPT technique requires no physical contact between vehicle and charging device, therefore overcomes the inconvenience and hazards caused by traditional conductive method. The initial objective is replacing conductive charging method by the novel WPT technology, while maintaining a comparable power level and efficiency. The long-term goal is to dynamically power the moving vehicles on road. This will lead to a much reduced battery pack but extended driving range. Nissan and Chevrolet have developed wireless charging system in corporation with Evatran for their EV models, the Nissan LEAF and Chevrolet Volt.

II Charging Technologies in Electric Vehicles

There are various types of technologies for charging electric vehicles. But we can broadly classify it into two types. One is called wired charging and other is wireless charging. These two types of charging technologies are described in the following sections of the article.

1 Wired Technology

Electric vehicles are plugged for charging on the existing electrical grid infrastructure, but sometimes the electrical infrastructure is inadequate for supporting this additional energy demand of high power fast charging stations. Moreover, the presence of several concurrent charging requests could cause overload conditions in local nodes of the grid, if the charging processes of the PEVs are not properly managed and scheduled. One alternative to fast charging stations [4] is to have mobile charging systems (MCSs) with a high storage Capacity and a mobile charging system for electric vehicles is presented in . These stations can be a solution when the electrical infrastructure of the local grid is unable to support high power fast charging stations.

Smart scheduling strategies can be profitably used to manage the (PEV) charging problem [5], for based on quadratic programming for charging PEVs, these can decrease the peak load and flatten the overall load profile. The usage of Information and Communication Technology (ICT) in a smart grid environment is a proposed solution , [14]. Regarding which, the authors in [15] advocate the deployment of smart grid communication architectures by using small embedded systems in a hierarchical way or a manner that can enable the distribution grid to charge a large number of EVs without the need to carry a high workload.

2 Wireless Charging

The main disadvantages of electric wired charging are: inconvenience, poor securities, management difficulties, more land occupation, high demand for batteries, large impacts on grid, etc.The main advantages of electric wireless charging are: convenience (electric vehicles can be charged automatically, so users can automatically control the charging process via mobile phones and other devices, enhance the user experience) ; safety & reliability (no cable aging , leakage and other issues. Simply programmed to automatically charging, reduce human management, no magnetic effect); and less area (charging coil is buried directly beneath the original parking or the existing road without the need of additional land and space occupation effective use of land resources.)

2.1 Stationary Charging

Auckland University has been researching on inductive power transfer technology since early 1990s. Its IPT® technology actually employs the coupled magnetic resonance as shown in Fig.1 b. Supported by this technique, some early achievements have been made by Conductix-Wampfler, such as the 20kW charging bay for 5 golf buses in New Zealand during 1997 to 2007 and the 60kW wireless charging urban bus fleets in Genoa and

Turin, Italy in 2002 and 2003 [18]. The University owned company HaloIPT released a 3kW evaluation kits in 2010, which could achieve 85% overall efficiency through 180mm air gap. It was acquired by Qualcomm in 2011. In the same year, Qualcomm announced a pre-commercial trial in London, using similar kits but aiming to the mass consumer adoption of this technology [19].

2.2 Opportunistic Charging

Opportunistic charging is a method of wireless charging in which we choose the vehicles that runs on a fixed route and stop only at fixed stations. In these type of vehicles we can plan a strategic charging so that the efficiency can be increased. the fixed route vehicles likes city buses, taxies, etc can be charged by opportunistic charging method. By the use of this method, the weight of the batteries installed in that vehicles can be reduced greatly. And also the time to charge them at different stations will become very less. Thus Predefined routes and planned stops allow for strategic charging.

2.3 Dynamic Wireless Charging

FIG.1 ELECTRIC RE-CHARGING LANE

KAIST has made great achievement on EV dynamic wireless charging in the last few years, which is called on-line electric vehicles (OLEV). The OLEV project was launched in 2009. In the same year, 3 generations of prototypes were reported with power ranger from 3 to 17kW [24]. The first demonstration, a 2.2 km tram loop, was installed in Seoul Zoo on March 2010. This 62kW wireless powered tram has a 40% smaller battery package than normal battery powered trams. At Expo 2012, an OLEV bus system was demonstrated which was able to transfer 100kW (5*20kW pick-up coils) through 20cm air gap with average efficiency of 75%. The battery package is further reduced to 1/5 [25].

Institute / corporation	Year of Installation	Location	Project Type	Vehicle Type	Power	Air Gap	Efficiency
Auckland University & Conductix-Wampfler	1997	Auckland	Public Demonstration (Stationary)	5 Golf buses	20kW	50mm	90-91%
	2002-2003	Italy		8-23 mini buses	60kW	30mm	-
Auckland University & Qualcomm Halo	2010	Auckland	Evaluation kits (Stationary)	Private vehicles	3kW	180mm	85%
	2012	UK	Public Demonstration (Stationary/ Dynamic)	-	-	-	-
ORNL	2010	US	Prototype (Dynamic)	-	4.2kW	254mm	92% (coil-to-coil)
	2012	US	Prototype (Stationary)	-	7.7kW	200mm	93% (coil-to-coil)
	2012	US	Prototype (Stationary/ Dynamic)	GEM EV	2kW	75mm	91% (coil-to-coil)
KAIST	2009	Korea	Prototype (Dynamic)	Golf Bus	3kW	10mm	80%
				Bus	6kW	170mm	72%
				SUV	17kW	170mm	71%
	2010	Korea	Public Demonstration (Dynamic)	Tram	62kW	130mm	74%
	2012	Korea		Bus	100kW	200mm	75%
MIT WiTricity & Delphi	2010	US	Commercial kits (Stationary)	Private vehicles	3.3kW	180mm	90%
Evatran	2010	US	Commercial Product (Stationary)	Private vehicles	3.3kW	100mm	90%

Table:1 Summary of Current Wireless EV Charging Projects[8]

KAIST is ready to apply its OLEV technology on over 300km/h, 180kW high speed high power rail way at the end of 2013 [5].Dynamic wireless charging is gaining more ground, since it enables power exchange between the vehicle and the grid while the vehicle is moving. Recently, the Telewatt project introduced an original approach involving the reusing of existing public lighting infrastructures for such charging, whereby a fraction of the power not consumed by lamps at night can be used for the benefit of the charging stations. The service is accessible by a smartphone application, where clients specify to the TeleWatt server their destination and their battery level, for which they receive a response of a list of available charging terminals close to this destination [6]. Hevo announced a novel dynamic charging system where manhole covers will be used as charging stations and a pilot program is scheduled to be performed in New York in 2014.

III Mobile Energy Disseminators

Similar to information dissemination, special nodes, like buses (trucks), can act as energy sources to EVs that need charging, in order to increase travel time. These vehicles, form now on called mobile energy disseminators (MEDs), use electric plug in connection or IPT in order to refill starving EVs. Buses can play the role of MEDs since they follow predefined scheduled routes and their paths cover a major part of a city, while trucks could have the role of energy chargers mainly on highways.

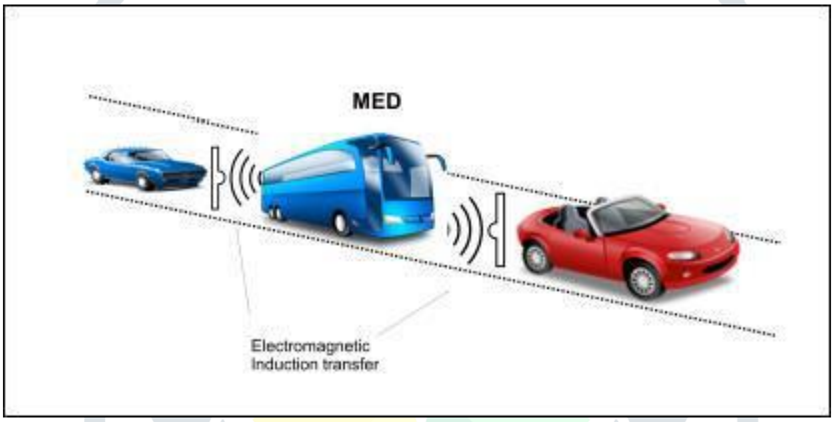

FIG.2 MOBILE ENERGY DISSEMINATOR

Buses can be fully charged when parked, before beginning their scheduled trip, and can be continuously charged along their journey by IPT stations installed at bus stops. Additional technology requirements that these vehicles may need in order to operate as energy sources, is an open issue, but it is rather more feasible in the near future, to have these features installed into large public vehicles than into passenger vehicles due to the additional cost and space requirements. Vehicles that book charging places on the same MED can create clusters and mobile charging stations will play the role of the cluster heads.

1 IVC System

In order to state its presence, each MED periodically broadcasts cooperative awareness messages (CAM). Each beacon message consists of a node identifier (Vid), node location, scheduled trip (a subset of set L), current charging capability (CC) and energy value (E=KWh). CC is the current energy that the mobile charging station can afford to dispose of to charge the vehicle without jeopardizing its own needs. These messages are disseminated by all vehicles that act as relay nodes. Each EV that needs

energy, upon receiving a CAM by an MED performs the following steps:

1) Checks MED is on his route according to their current positions and destinations

2) Checks whether the CC level is high enough in order to cover its energy needs

3) Asks for a charging place by sending a CAM which contains minimum charging time

4) Chooses to select this bus as the wireless energy transfer station

II. Books a charging place

III. Drives in front of or behind the bus for the determined time period in order to recharge Steps 3-5 constitute the negotiation phase, in which MED and EV exchange

dedicated short range messages (DSRC) in order to confirm the energy transfer. An assumption that we make is that vehicles can book their charge of battery as soon as they realize that their charge level is low and a MED meets their criteria on relative distance and available energy. The architecture of the proposed mobile energy dissemination is demonstrated in Figure.

2 LTE System

For the LTE system, we assume that vehicles are equipped with The Evolved Universal Terrestrial Radio Access Network (EUTRAN) interface, which enables the vehicles to communicate with the eNB so as to access the core components of the LTE. LTE Evolved Node B (eNB) base station transceivers are deployed alongside the road network in order to cover the area. Each bus communicates to the LTE the scheduled trip that is going to be followed, the available charging capability and energy value and charging availability, similar to the IV C system. All vehicles are assumed to be equipped with GPS. Each EV that needs energy:

1) Checks whether MED is on his route or not according to their current positions and destinations

2) Checks whether the CC level is high enough in order to cover its energy needs

1 Checks whether the MED is already fully booked

2 Books a charging place

3 Drives along the bus for the determined time in order to recharge.

The architecture of the proposed mobile energy dissemination architecture is demonstrated in Figure. The benefits of such an approach are threefold: First, it utilizesexisting cellular infrastructure. Second, the 802:11pnetwork overhead introduced by frequent communication between EV s and MEDs is offloaded.

Third, information is more up to date than that received through IV C, where many intermediate relay nodes may be needed in order to disseminate data effectively. However, vehicles are required to have two types of network interface cards. Moreover packets that pass through the LTE core potentially experience more delay. Route selection algorithms, where vehicles communicate with each other in order to exchange information are crucial in order to evaluate the performance of the method. Optimal route selection overcomes a common problem in which all vehicles are preferring the same paths, leading to over congestion. Optimal routing of vehicles that use this new technology can be formulated as a modified shortest-path problem where the weights of the road segments may vary over time, according to the existence or not of a MED travelling on the road segment.

IV Conclusion

Making use of inductive charging MEDs can act as mobile charging stations, thus improving the overall energy consumption of a fleet of vehicles. This improvement comes with a cost in time and distance travelled, but starving vehicles otherwise would have to stop or make longer re-routes in order to find a stationary station and recharge their batteries. Combining modern communications between vehicles and state of the art technologies on energy transfer, vehicles can extend their travel time without the need for large batteries or extremely costly infrastructure. Preliminary simulations show that applying some form of intelligence in how MEDs take decisions about accepting or rejecting charging requests, further improves the performance of the method.

- **References**

[1] T. R. Hawkins, B. Singh, G. Majeau-Bettez, and A. H. Strmman, "Comparative environmental life cycle assessment of conventional and electric vehicles," Journal of Industrial Ecology, vol. 17, no. 1.

[2] H. de Wilde and P. Kroon, "Policy options to reduce passenger cars CO_2 emissions after 2020," 2013.

[3] S. Lukic and Z. Pantic, "Cutting the cord: Static and dynamic inductive wireless charging of electric vehicles," in Electrification Magazine, IEEE 2013, vol. 1, no. 1. pp. 57-64.

[4] N. Machiels, N. Leemput, F. Geth, J. Van Roy, J. Buscher, and J. Driesen, "Design criteria for electric vehicle fast charge infrastructure based on flemish mobility behavior," 2013.

[5] G. Putrus, P. Suwanapingkarl, D. Johnston, E. Bentley, and M. Narayana, "Impact of electric vehicles on power distribution networks," in Vehicle Power and Propulsion Conference, 2009. VPPC '09. IEEE, 2009.

[6] A. R. Mario, A. A. Fadi, M. Gagnaire, and Y. Lascaux, "Telewatt: An innovative electric vehicle charging infrastructure over public lighting systems," in Proceedings of the 2nd International Conference on Connected Vehicles and Expo (ICCVE), Las Vegas, USA, December, 2013.

[7] G. Jung, B. Song, S. Shin, S. Lee, J. Shin, Y. Kim, C. Lee, and S. Jung, "Wireless charging system for on-line electric bus(oleb) with seriesconnected road-embedded segment," in Environment and Electrical Engineering (EEEIC), 2013 12th International Conference on, 2013.

[8] L. A. Maglaras, F. V. Topalis, and A. L. Maglaras, "Cooperative approaches for dymanic wireless charging of electric vehicles in a smart city," in Energy Conference ENERGYCON), 2014 IEEE International, May 2014, pp. 1365–1369.

TABLE I. K. Boriboonsomsin, M. J. Barth, W. Zhu, and A. Vu, "Eco-routing navigation system based on multisource historical and real-time traffic information," 2012.

Fig. 1. S. Deilami, A. Masoum, P. Moses, and M. A. S. Masoum, "Realtime coordination of plug-in electric vehicle charging in smart grids to minimize power losses and improve voltage profile," Smart Grid, IEEE Transactions on, 2011.

[9] K. Mets, T. Verschueren, W. Haerick, C. Develder, and F. De Turck, "Optimizing smart energy control strategies for plug-in hybrid electric vehicle charging," in Network Operations and Management Symposium Workshops (NOMS Wksps), 2010 IEEE/IFIP, 2010.

[10] S. Bohn, M. Agsten, O. Waldhorst, A. Mitschele-Thiel, D. Westermann, and P. Bretschneider, "An ict architecture for managed charging of electric vehicles in smart grid environments," in Journal of Engineering, 2013.

[11] D. Promiti, "Coordinating rendezvous points for inductive power transfer between electric vehicles to increase effective driving distance," in Proceedings of the 2nd International Conference on Connected Vehicles and Expo (ICCVE), Las Vegas, USA, December, 2013.

[12] C. Donna, M. K. Kara, and K. Moby, "The electric vehicle charging station location problem: A parking-based assignment method for seattle," in Proceedings of the 92nd Annual Meeting of the Transportation Research Board, 2013.

[13] I. Frade, A. Ribeiro, G. Goncalves, and A. Antunes, "Optimal location of charging stations for electric vehicles in a neighborhood in lisbon, portugal,"in Transportation Research Record: Journal of the TransportationResearch Board, No. 2252: 91-98, 2011.

[14] M. R. Sarker, H. Pandzic, and M. A. Ortega-Vazquez, "Electric vehiclebattery swapping station: Business case and optimization model."

[15] M. Neaimeh, G. Hill, Y. Hubner, and P. Blythe, "Routing systems to extend the driving range of electric vehicles," Intelligent Transport Systems, IET, vol. 7, no. 3, pp. 327–336, 2013.

[16] L. A. Maglaras and D. Katsaros, "Distributed clustering in vehicular networks," in Wireless and Mobile Computing, Networking and Communications (WiMob), 2012 IEEE 8th International Conference on, Oct 2012.

[17] N. Lagraa, M. B. Yagoubi, S. Benkouider et al., "Localization technique in vanets using clustering (lvc)," IJCSI, 2010.

[18] M. Segata, F. Dressler, R. Lo Cigno, and M. Gerla, "A simulation tool for automated platooning in mixed highway scenarios," in Proceedings of the 18th annual international conference on Mobile computing and networking. ACM, 2012, pp. 389–392.

[19] L. A. Maglaras, J. Jiang, F. V. Topalis, and A. L. Maglaras, "Mobile energy disseminators increase electrical vehicles range in smart city," in Hybrid and Electric Vehicle Conference, IET,November-2014