Development of a Wireless Charging System Prototype for Electric Vehicles in Motion

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ABSTRACT: Electric vehicles (EVs), a transformative technology in the transportation sector, are emerging as a great alternative to conventionally utilized internal combustion (IC) engines, with the promising vision of decarbonizing the transportation sector. However, the integration of EVs comes with its share of challenges. Addressing these challenges requires innovative technical solutions. One such solution is the implementation of wireless charging technology for moving EVs, which has become the focus of emerging research to reduce charging time and increase the efficiency of corresponding infrastructure deployments. This paper concentrates on the development and implementation of a Wireless Charging System (WCS) for moving EVs. A prototype of the WCS is developed and presented. The study demonstrates that as the distance between the receiving coil and the transmission coil increases, the charging time of the vehicle's battery also increases. The findings shed light on the potential of wireless charging systems to revolutionize the charging process for electric vehicles, thereby contributing to the widespread adoption of EVs and the reduction of carbon emissions in the transportation sector.

***Keywords** – Electric vehicle (EV), Wireless charging system (WCS) or wireless power transfer system (WPTS), Inductive power transfer (IPT), Battery, Power electronic devices, coils.*

1. INTRODUCTION

Electric Vehicle (EV) have reaped immense popularity due to its following advantages: Clean, the accommodation of avail and design, cost- effective, connectivity, etc. [1]. Withal, EV has an overall efficiency of about 75% which is very towering compared to conventional IC engine which has an efficiency of around 5-10% [2].

An EV incorporates following components: a drive, battery and Power conversion units [2-3]. Batteries are utilized as an energy source in EV. The Battery in EV uses electrochemical reaction [4], i.e., it converts Electric energy to chemical energy, to store energy (charge) in the form of chemical in it. This process gets inverted when the vehicle is running (or battery gets discharged). Various types of batteries used in EV include lead-acid, Lithium-ion, lithium acid, nickel metal hydrate, Nickel-cadmium, Nickel-zinc, etc. [5]. These batteries have an inhibited amplitude of energy and are required to be recharged, once their energy gets exhausted so that it could further run the vehicle [6]. There are various EV charging methods developed so far [3]. Recharging of the vehicle battery has become a great challenge as it takes a lot of time to recharge a vehicle battery.

Several advances in the designs of EVs are made to optimize the energy storage capacity of the battery. Expeditious charging of vehicles has withal become a paramount part of the research. Charging methods developed so far includes recharging of EV in both stationary and moving condition also known as static [7] and dynamic charging system respectively [8]. An electric vehicle can be charged using either plugs [9] or wirelessly.

In this paper Wireless charging system (WCS) for EV has been summarized. For this, a prototype of WCS for a running vehicle has been developed. The section II of the paper, details the literature review gives a brief description of the Wireless charging system and the prototype so developed. Motivation and Problem Statement are explicated in section III. In section IV the wireless power transfer system is briefly explained. Section V includes the explication of the prototype so developed and its working. At the terminus conclusion of the study is included.

2. LITERATURE REVIEW

A profound study of past articles and papers have been studied for the prosperous development of the prototype. system. The vision of the research is supported by a literature-driven methodology carried out to determine the required technologies. The problem statement and key findings of some papers premeditated are included in Table 1.

Table 1 Literature survey

Year	***Author***	***Objective***	***Key Findings***
2013	Maini C. et al.	EV Characteristics	The paper outlines the main concept behind the growth of EV.
2013	Majid I. A. et al.	Analysis of dynamics of system	Study is done using support vector machine (SVM).
2013	Ombach G.	WCS Power optimization	Analysis is done using Qualcomm's Wireless EV charging solution.
2015	Rade M. R. and Dhamal S. S.	Batter optimization	Simulations is done in MATLAB to analyse the charging profile of battery and ultra-capacitor.
2016	Fang Y. et al.	Power converter optimization.	Analysis is based on the sensitivity indices.
2016	Xiao J. et al.	Analysis of an Inductive WCS lane for EV	Analysis is done by developing a prototype for EV. Also, the simulation of the system is done in Finite Element Analysis software to find parameter
2016	Ye Z-H. et al.	Cost and dimension reduction of EV	Analysis is based on the prototype of the system so developed by the author.

2016	Zhang X. et al.	Power optimization	Analysis of the structure is done and expression of its transmission efficiency is also deduced by developing a prototype.
2016	Kong P-Y. et al.	Charging methodologies and characteristics of plug-in hybrid EV	Shaped analysis uses a surveying technique to determine various Charging methodologies
2017	Tiwari A. and Jaga O. P.	Component study of EV	Comparative study of various component of EV is done.
2017	Noor F-U. et al.	EV technologies and components	Includes the review on various components of EV.
2017	Liu C. et al.	Structure, principle and features of coil designs for WCS	Coil topologies studied by the author are circular rectangular pad, circular pad, homogeneous pad, double-D pad, double-D quadrature pad, and bipolar pad.
2017	Tan L. et al.	Power optimization	An experimental setup is here done to analyze the power transfer efficiency.
2018	Panchal C. et al.	WCS optimization	Varieties of ferrites shapes and parameters for the selection of a particular charging system are outlined.
2018	Guo Y. et al.	Interoperability analysis of WCS	Analysis is based on stochastic approach.
2018	Liu C. et al.	WCS optimization	Simulation of direct field-circuit coupling is done to study the effects of varying parameter in the system.
2018	Zhang X. et al.	Effect of coil misalignment in WCS	Simulated model is developed and studied using Finite Element Analysis software.
2019	Wen F. et al.	Effect of WCS on the power system	For accurate analysis of voltage waveform on AC side Fast Fourier transform is done.
2019	Niculae D. et al.	Defining the use of magnetically coupled coils for charging of EV	WPTS with a parallel-series topology, is analysed using Circuit Symbolic Analysis Program. Variation of voltage with coil displacement is also studied.
2019	Dayerizadeh A. et al.	Designing, testing, control and integration approach of WCS	Hardware test is performed to study power transfer and control capabilities of an EV.

Based on the above-defined objectives and key findings it is found that technically one of the main hurdles faced in the designing the charging infrastructure is the space between the transmission and receiving coil. To define this impact more appropriately a prototype of an

EV and its charging infrastructure use to charge a moving EV is developed and the results so obtained are defined in this paper.

3. MOTIVATION AND PROBLEM STATEMENT

Vision: The key idea abaft the development of this paper is to obtain an Expeditious - charging system for Electric Vehicle. For this, the wireless charging system is found to be one of the most appropriate charging methods with the ability to charge both running and stationary EV.

State of art: The wireless charging system can make use of various techniques such as inductive-coupling, capacitive-coupling, and magnetic gear. This paper has explored the idea of Inductive-coupling Wireless charging technology.

Identification of challenges: To charge a stationary EV, the vehicle is required to be parked at the charging station for some time. In this duration, the vehicle remains unused which leads to unwanted delays in the journey. Predicated on this concept the paper focuses on the implementation of the inductively-coupled wireless charging system for a running EV. Inductive-coupling requires two coils, one inside the road and other inside the vehicle. For proper coupling of coils, the coupling co-efficient or distance between two coils is required to be set, as poor the coupling co-efficient worst is the charging efficiency.

Visual Roadmap: Firstly, a prototype for the inductively-coupled wireless charging system for a running EV is developed. For the prosperous development of the prototype and to understand an appropriate analogy a profound study of all the writings and papers has been done. To apprehend the impact of coupling co-efficient on the recharging of the vehicle battery the distance between the two coils is continuously increased and the charging time is then monitored and recorded.

4. WIRELESS CHARGING SYSTEM

Wireless charging technology is one the oldest charging technology that is utilized for charging purpose or running of various electrical equipment such as charging for mobile phones, induction challahs, etc. WCS has led to the truncation of avail of heftily ponderous plugs in the system [10-11]. This charging technology can be utilized for both high and low power transfer applications and has a very simple design [12]. After the prelude of wireless charging system of EVs, four different designs for transfer of power wirelessly have been considered which includes [13-14]:

- Inductive wireless power transfer (IWPT)
- Capacitive wireless power transfer (CWPT)
- Magnetic gear wireless power transfer (MGWPT)
- Resonant inductive power transfer (RIPT)

In this paper, we have only focused on Inductive wireless power transfer (IWPT) technology.

4.1. Inductive WCS

Inductive WCS works on the principle of electromagnetic induction and utilizes an inductive coil for power transfer between the road and the vehicle [15]. It one of the best WC technologies with high efficiency, reliability and low-cost design [16]. Here the WCS consists of two main parts that are, transmission part and receiver part. In both these parts, coils are separately connected [17]. At the transmitter that is present inside the Road, coils are connected to the grid with the help of power electronic devices such as AC/DC and DC/AC converters. The receiver coil is present at the chassis of the vehicle which is connected along with battery with the help of power electronic devices [18].

5. PROTOTYPE LAYOUT AND METHODOLOGY

The paper intends to define innovative needs to capacitate the integration of EV into the energy system and to define their appropriate structure.

5.1. Inside the Road

Inside the road, a li-ion battery of (three batteries each of 4V) is connected which supplies to the system. This DC power then goes through the MOSFET to get converted to the AC supply. This AC voltage is than step-up to 80V with the help of a transformer which is then alimented to the coil presents along with the road. Road consists of five rings made with the help of a copper wire. Each ring has 80 turns. This copper coil interacts with the copper coil present in the vehicle by the principle of induction, power energy from the coils present inside the road is transferred to the coil present in the bottom of the vehicle [19].

Fig 1. Connection inside the road

5.2. Inside the Vehicle

The vehicle consists of a secondary coil of 150 turns which receives AC power from the road when aligned properly [20] and converts it to DC with the help of a p-n junction diode and the capacitor present in the vehicle and stores it in the battery of the vehicle. In the vehicle also same 12V Li-ion battery is present. With the help of a voltmeter, the charging of the vehicle can be easily monitored.

Fig 2. Bottom view of the Vehicle

Fig 3. Top view of the Vehicle

Table 2. Distance versus charging time

Distance (D) (in meters)	Charging Time (T) (in min)
2 meters	221 min
4 meters	418 min
5 meters	593 min
7 meters	846 min

From the table 2. it is optically discerned that as the space between the receiving coil and the transmission coil, D is increased the charging time, T of the 12 Volt battery also increases.

6. CONCLUSION

This paper presented a literature review on Electric Vehicles technologies and explained the issues marked by various researchers. The shaped apparition is converted in to realistic baseline scenario by focussing on the development of novel EV charging infrastructure. Based on the key findings of researchers a prototype for the wireless charging of a running EV is developed in this paper. It is observed that as the space between the receiving coil and the transmission coil is increased the charging time of the 12 Volt battery also increases. From this, it can be concluded that the coupling coefficient of the coils gets affected as we increase the space between the coils. The presented work confirms that electric vehicles could govern the mobility market.

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