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Efficiency Enhancement of Wireless Charging System for EV in Static and Dynamic Mode

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Contents

1 Terms

Wireless Charging Systems (WCS), Wireless Power Transmission Systems (WPTS), Resonant Inductive Coupling (RIC), Electric Vehicles (EV), Maximum Power Point Tracking(MPPT), Wireless power transfer (WPT), Proportional Integral(PI), Proportional Integral Derivative(PID), Battery Management Systems (BMS), Wireless Electric Vehicle Charging System (WEVCS)

2 Objective

To improve power transfer efficiency of wireless charging system for EVs in static and dynamic mode

3 Motivation

In recent decades, there have been significant developments and breakthroughs in technology.The use of a variety of electronics devices; such as mobile phones, laptops, tablets and home appliances has significantly increased due to consumer demands.when such electronic devices are upgraded or replaced, the chargers also need replacing even though they may still be in good working order. These unused devices end up in landfill because of improper recycling. This is known as electronic waste (E-Waste). Worldwide 20 to 50 million tonnes of E-Waste is annually generated.

On the other hand, over the last few years, fossil fuel prices have increased rapidly because of the reliance on limited hydrocarbon energy sources (such as petrol, diesel and gas) for power generation and advanced transportation systems. In order to reduce the usage of fossil fuels, electrified transportation requires the set-up of a wide variety of charging networks to create user-friendly environments and to tackle green-house and fuel price hikes.

To compete with gasolinepowered cars, EVs are required to have a long travelling range with an efficient refuel capacity. These features can only be achieved by installing a larger battery bank with continual charging facilities. However, a larger battery bank increases the overall price of EVs and requires additional charging time. Such limitations are the biggest hurdles in making EVs a reliable transportation alternative.

In order to tackle these issues, Wireless Charging Systems (WCS) are one of the up and coming technologies which have the potential to provide contactless charging facilities in all types of EVs. WCS technologies can offer safe, secure and user friendly charging techniques that are environmentally sound. WCS can provide a common charging platform for most Electric vehicles so different EVs do not require separate standardised chargers to charge their batteries.Also,this technology can reduce toxic and non-biodegradable hazardous E-waste by establishing a common charging platform for all electronic products.

But the problem or limitation associated with WCS is that they can only be utilized when the car is parked or in stationary modes such as in car parks, garages or at traffic signals. In addition, stationary WCS have some challenges such as limited power transfer, bulky structures, shorter ranges and higher efficiency levels. In order to improve: range and battery storage volume, the dynamic mode of operation of the WCS for EVs is developing in the world.

4 Introduction

In the 21st century, wireless power transmissionsystems (WPTS) are considered to be advanced technologies for numerous applications such as mobile devices, home appliances, and medical implants in the areas of low and medium voltage electronics devices, by the utilisation of two fundamental important mechanisms: inductive coupling and strong electromagnetic resonant coupling

Firstly, the inductive coupling method with resonant case was identified and used in the experiment by Nikola Tesla in 1914. This method is also known as Resonant Inductive Coupling (RIC). His idea was to transfer power over a long distance globally. Radiative transfer is suitable for transferring data and other information over the air, over a long distance, by using antennas. However, when it comes to power transfer, it is very difficult to use this method because most of the energy is lost in the air because of the omni-directional transmission. Otherwise, it requires a line of sight and an advanced tracking system at the receiver side. Inductive coupling is an immersing method to transfer power wirelessly in the power ranges between mill watts and some kilowatts. However, when it comes to efficiency, it decreases significantly with increasing distance between the primary and secondary circuit.The problem or limitation associated with WCS is that they can only be utilised when the vehicle is parked or in stationary modes such as in car parks, garages or at traffic signals . In addition, stationary WCS have some challenges such as limited power transfer, bulky structures,shorter range and higher efficiency.

In order to improve both areas (range and sufficient volume of battery storage), a dynamic mode of operation of the WCS for EVs has been researched. Inductive charging of electric vehicle at high power levels while in motion is referred to as dynamic charging. If a car was able to be charged while it was being driven, then this would solve the problem of limited range and enable vehicles to travel for potentially unlimited distances. The idea is that a coil on the bottom of a car could receive electricity from coils that are connected to an electric current that is emnedded in the road. However, before a dynamic WCS becomes more widely accepted, it has to overcome two main hurdles: a large air gap and coil misalignment. As the distance between the two coils is getting larger, the voltage at the receiver end of the transmission reduces. To compensate for the variation of the voltage, different control methods(a three-level PI controller, fuzzy and neuro fuzzy conntroller, MPPT control) are employed to improve system efficiency.

A simple block diagram implementation of wireless charging system is shown below in figure 1:

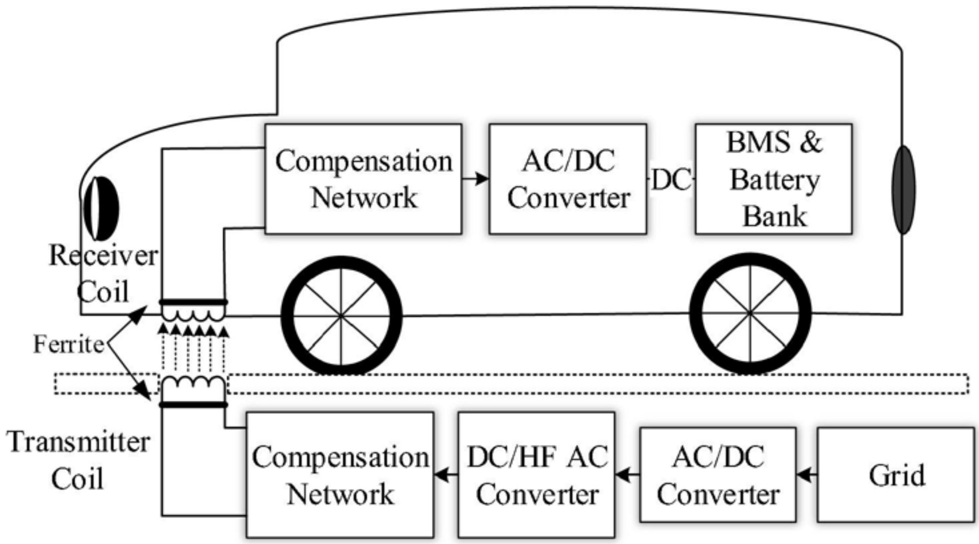

Figure 1: Schematic of Wireless Charging System

5 Literature

Wireless electric vehicle charging techniques have been popular for some time now due to their safety, convenience and efficiency. There are several ways to increase the WPT efficiency of a system. First is by the proposed Series-Series (SS) resonant compensation topology alongside the design of radio frequency feedback (Tan, 2017). This proposed model was experimented and tested with a 500W laboratory prototype and it was found that the efficiency was above 90%, an air gap was 15 cm, distance was 10cm and over an operating input voltage of 120VAC (Tan, 2017). The second method used to enhance WPT efficiency is by varying the operating frequency ranging from 81.38-90 kHz, the duty ratio and input voltage respectively (Ravikiran, 2017). The other technique employed was by finding a reference voltage in the secondary side using the simultaneous estimation of the secondary side's mutual inductance and a voltage at the primary side (Hata, 2016). In addition, the compensation topologies play a key role in the power transfer efficiency, therefore, this paper gives a detailed comparison between the SS and PS compensation topologies (Ravikiran, 2017). Simulation results show that the PS topology is good for power applications of medium range. This paper uses secondary side LCC impedance matching circuit under a rectifier load to enhance the maximum efficiency transferred (Liao, 2017).

To keep up with the pace of battery capacities, it is essential to increase the rate at which an electric vehicle battery is wirelessly charged. One of the ways of increasing battery performance is by designing the coupling factor of the coil system appropriately and ensuring that the rate of displacement is large (Klaus, 2017). Another way to increase the power transfer system of an electric vehicle is to use two extra coils in between the transmitter and the receiver coils with experimental verification with a 6.6KW circuit (Tran, 2018). This results in an efficiency of 97.08% for 3.4KW. For different challenges associated with WPT to be addressed, this paper proposed employing an 20 improved floor surface for shielding the transmitting coil area, high-frequency switches with large bandgap switches and polygon iron core (Mahmud, 2017). These components help to improve the system's efficiency.

Subsequently, a wireless power charging system requires a constant current flow and output voltage alongside a maximum efficiency. This leads to the design of a control based maximum efficiency tracking system that controls the transmitter current based on the information the receiver receives via Bluetooth (Yeo, 2017). This gives a constant output voltage and constant current flow with increased efficiency in the WPT system. A fixed voltage source and fixed current load are modeled, analyzed and verified experimentally to increase the wireless power charging system's efficiency (Zhang, 2017). The voltage on the receiving coil in a wireless power transfer depends on the distance between two coils. This paper implements a proportional integral controller at the receiver side of the wireless power transfer to eliminate the variation of voltage for a varied distance between the two coils (Yeo, 2017). [1]

6 Methodology

6.1 For static mode

1. The different resonant circuit will be modeled . Simulation results will be carried out showing the effect of parameters such as inductor, capacitor, load and coupling coefficient on efficiency.
2. 3D modeling of transmitting and receiving coil using ANSYS Maxwell.
3. Design of system circuit in ANSYS Simplorer.
4. Design of complete system of a magnetic resonance WPT in Maxwell.
5. Comparing Magnetic Induction Power Transfer with Magnetic Resonance Method.

6.2 For dynamic mode

1. Design of three-level cascaded PI controller to eliminate the variation of voltage because of varied spacing existing between both coils.
2. Design of fuzzy logic and neuro-fuzzy controller.
3. Design of three-level cascaded MPPT controller. The design of dynamic mode controllers will be done using Matlab Simulink.

7 Operating Theory

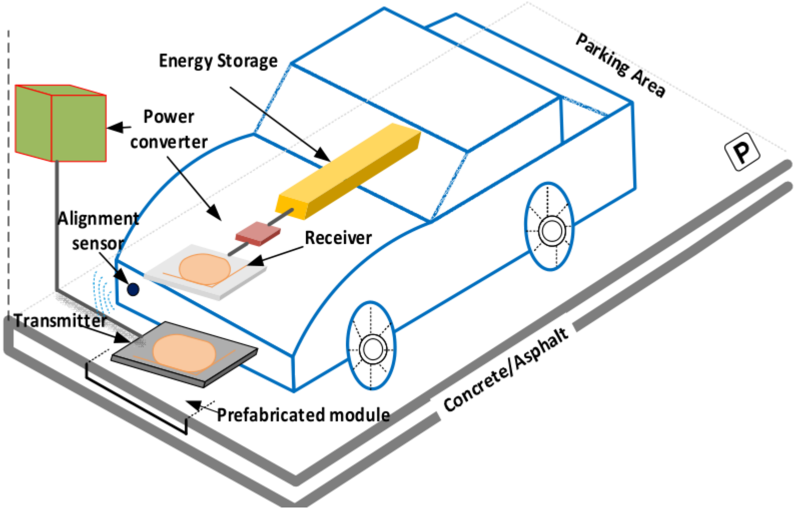

Figure 2: Wireless Charging model of EV

Figure 2 shows the basic arrangement of WEVCS. The primary coil is installed underneath in the road or ground with additional power converters and circuitry. The receiver coil, or secondary coil, is normally installed underneath of the EVs front, back or center. The receiving energy is converted from AC to DC using the power converter and is transferred to the battery bank. In order to avoid any safety issues, power control and battery management systems (BMS) are fitted with a wireless communication network to receive any feedback from the primary side. The charging time depends on the source power level, charging pad sizes, and air gap distance between the two windings. The average distance between lightweight duty vehicles is approximately 150 mm - 300 mm. Static WEVCS can be installed in parking areas, car parks, homes, commercial buildings, shopping centres. [2]

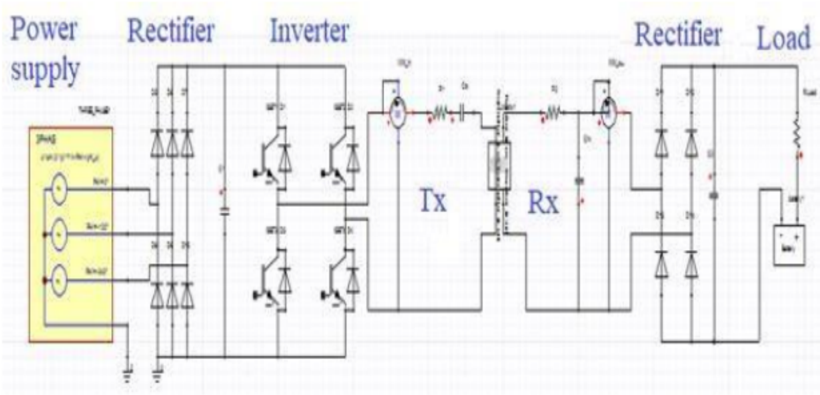

Figure 3: circuit diagram of electric wireless system

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