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AN EFFICIENT WIRELESS POWER TRANSMISSION FOR FUTURE TRANSPORT SYSTEM

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Abstract: Wireless Power Transfer (WPT) emerges as one of the focalize technologies and engine vehicles plays a cardinal aspect in Global Warming, WPT is one of the pivotal catalyst playing a portentous role in it. This paper aims to understand the application of WPT for Electric Vehicles (EV) statistically and dynamically. This paper proposes magnetic resonance coupling technique to transfer power. The proposed concept is a technique where the EV could be charged up even if it is in motion dynamically and also could charge statically at bus stops, parking areas etc. This increases the effective driving range and reduces the size of the battery. This paper also propose ideas for billing amount and money collection from users for power consumption through power grids. `

Keywords: Electric vehicles, WPT, Resonance, Adaptive frequency tuning, Billing

1. Introduction

All the Indian cars are impelling to aforesaid by Electrical cars by the end of 2030. Gasoline vehicles exempts a lot of carbon emissions like greenhouse gases which causes environment issues such as pollution, Global Warming etc. [1], [4-7]. To make the environment pollution free, Electrical vehicles are the surrogate solution. The pros of using EVs are no gas is required, the charges of electricity are much cheaper compared to gas. The important factor to consider is the fuels used for gasoline vehicles contribute over 2% of GDP (gross domestic product) but most of the fuels are imported from other countries, hence moving to EV is worthy [4]. Also the needed electricity can be derived from renewable energy sources like solar energy, wind energy, hydro energy etc. [3] The fossil fuels are getting exhausted day by day due to enormous increase of vehicles, if these fuels get drained completely, EVs are the alternate and appropriate solutions. Government is also taking initiative to provide subsidy to electric cars for going green [8]. It also reduces the noise pollution and maintenance cost since they run on electrical motors, there is no need of using lubricants. One more benefit of EV is they use rechargeable batteries which can be recycle [2]. The major con of EV is time to charge and the battery weight, since batteries are assembled in a series manner, which makes its size and weight heavy [9]. For example, the lithium-ion battery pack used in a Tesla Roadster weighs about 453.6Kg. The driving range and speed of the EV depends on its motor and battery capacity [9]. All these difficulties can be addressed by dynamic WPT technique. Many mechanisms like Laser, RF, Microwave, Inductive Coupling and Magnetic Coupling are used to transfer power using WPT [4]. If the wavelength of the electromagnetic signal is greater than the transfer distance then they are called far field techniques and vice versa [7]. Laser, RF, Microwave WPT comes under far field techniques and Inductive coupling, Magnetic resonance coupling comes under near field techniques. In Laser WPT, laser signals are used to transfer power wirelessly. This is suitable for long range applications. In RF WPT, Microwave WPT, radio frequency signals and microwave signals are put to use respectively to transfer power wirelessly [9]. These two techniques are suitable for mid-range applications.

In inductive coupling method, electromagnetic signals induce magnetic flux between the coils which are present at non-resonance condition. Hence, this technique is also called as non-resonance coupling technique [4]. In magnetic resonance coupling method, the two coils (transmitting and receiver coils) operate at same frequency which causes resonance and an invisible transfer of power occurs due to the magnetic flux induced between the coils. The amount of power received is less than the amount of power transferred. This is due to transmission losses [6]. To reduce losses and to achieve higher efficiency, adaptive frequency tuning optimization technique is exploited for efficient WPT and charging of battery. A prototype is modelled to replicate EV with dynamic charging technique which can be implemented in real time scenario.

2. Proposed System Working Module

The WPT method proposed is magnetic resonance coupling in which two copper coils are attune to rumble at the congruent natural frequency –like two glasses that judder when a specific note is sung. The coils are stowed a few forepaw aside.

One coil is truss to an electric current, which foster a magnetic field that pretext the second coil to rumble. This magnetic resonance sequel in the invisible uproot of electric energy through the air from the first coil to the second coil. An efficient method is proposed in this paper to erect a system of wireless charging and wireless current proffering to gallop vehicles so that electrical vehicles can also hasten for longer stretch like fossil fuel vehicles.

Using magnetic resonance coupling, greater efficiency can be achieved over a higher range compared to the inductive coupling technique. Also the frequency range of inductive coupling limits to a few KHz whereas for magnetic resonance coupling, it extends up to a few MHz.

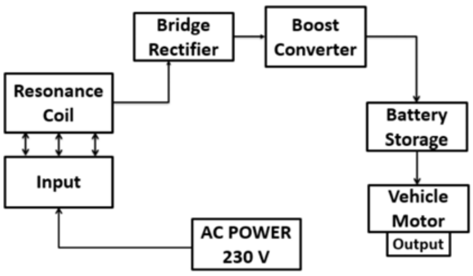

Figure. 1 Conversion unit-Hardware

Fig. 1 sketches the conversion unit from primary coil to secondary coil. A 230V AC power supply is given to the primary (transmitter) coil. According to the Ampere's law, a current carrying coil produces magnetic field around it [5]. This magnetic field is nothing but magnetic flux. When the two coils are operating at the same frequency, resonance occurs. Hence the secondary (receiver) coil is called as resonance coil.

The magnetic flux produced by the primary coil links with the secondary. According to the Faraday's law, the change in magnetic flux linking the coils produce an electromotive force proportional to the rate of flux linkage [5]. This causes a transfer of energy between the coils. Usually DC current is used to charge the battery. So, to convert AC to DC a bridge rectifier is used. To boost up the current received from the bridge rectifier, boost converter is used. The need of boost converter is the proclivity of an inductor to oppose changes in current by generating and demolishing the magnetic field. Usually in a boost converter, the output voltage is always greater than the input voltage which in turn is stored in the battery.

Engines of gasoline vehicles are replaced by motors and gasoline tanks are replaced by batteries in EVs. Motor performs the same work as that of engine.

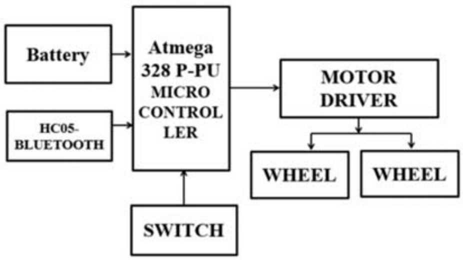

Figure. 2 Vehicle Hardware Unit

Fig. 2 displays the prototype of EV. The prototype uses the HC05 Bluetooth module to transmit the signals for the manual movement of the vehicle. It transmits data serially with a data rate of 3mbps and an operating frequency of 2.4GHz. It greatly suits for wireless communication since it can be used either in master or slave configuration. L2938D motor driver is used to control the geared motors that are attached to the wheels. The role of a motor driver is to take a low current control signal and convert it into a high current control signal which drives a motor. It is not possible to lay power tracks in the all the areas, in that case the power stored in the battery is used to drive the vehicle. Hence a battery is used in the prototype. At mega 328 P-PU microcontroller is used to control all the above modules.

The transmitter coils are placed under the road in a series manner to resemble as power track. The receiver coil is placed under the EV, a few feet part on the chassis and shielded such that environmental conditions doesn't pay for degradation of WPT as well as the circuits of secondary coil. While designing the coils, certain parameters like shape, size, electrical parameters and weight must be considered.

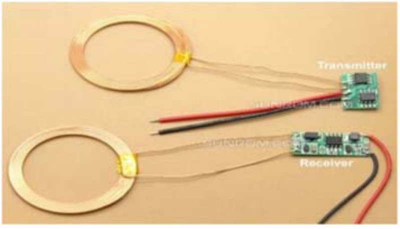

Figure. 3 Transmitter and Receiver Unit

Fig. 3 represents the transmitter and receiver coils used in the prototype. The transmitter coil can provide input voltage from 6V-2Amps to 12V-2Amps. The receiver coil can receive output voltage in two types, either a variable voltage based on distance or a fixed voltage. Variable voltage ranges from 0.5V to 12V whereas the fixed voltage that can be provided is 5V.

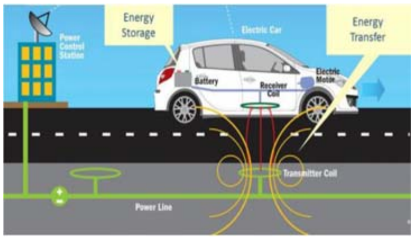

Figure. 4 Working of WPT [16]

Fig. 4 represents the working of the WPT using magnetic resonance coupling. The magnetic flux travels in different directions which lead to the power loss. This can be overcome by adopting optimization techniques which are discussed in the below sections. The coils must be made of materials that can provide insulation and can withstand the temperature, pressure etc.

3. Optimization Technique

The optimization technique adopted for maximum power transfer in the prototype is frequency tuning. It deals with the coupling coefficients and critical coupling points. The fraction of flux produced by the primary coil, which links with the secondary coil is called coupling coefficient. There are two types of coupling coefficients, self-coupling coefficient denoted by *K* and mutual coupling coefficient denoted by *M*. As the name indicates self-coupling coefficient relates to the flux linkage of single coil whereas the mutual coupling coefficient indicates the mutual flux linkage between the coils.

Based on the strength of *M* between the coils, there are three operating regions such as

1.Strongly coupled, 2.Critically coupled and 3.Weakly coupled.

If the coils are strongly coupled then the frequency at which maximum power transfer occurs splits into two. To avoid this frequency splitting, frequency tuning technique is used. The point at which frequency splitting ends is called as critical coupling point. The power transferred to the load decays exponentially with increase of coil separation distance beyond this point.

The coupling coefficient and critical coupling point equals at certain distance that is referred as maximum power transferrable distance.

If the operating frequency is equal to either electrical resonance or magnetic resonance frequency which are defined in the Eq. (1) and Eq. (2), the maximum power transfer occurs.

$$f_m = \frac{w_0}{2\pi\sqrt{1+k}}$$

$$f_e = \frac{w_0}{2\pi\sqrt{1-k}}$$

Where f_m = magnetic resonance frequency
f_e=electric resonance frequency

K=coupling coefficient

The equations show that electrical resonance and magnetic resonance frequencies depend on the coupling point. The power transfer efficiency can be calculated by the ratio of output power to the input power. In the prototype, the coupling coefficient value is assumed as 0.216 at which the tuned resonance frequency occurs. At this tuned frequency, WPT attains maximum efficiency.

4. Billing of WPT for EV

Basically two methods are available to measure the power consumption.

4.1 Based on real energy flow

Standard charging rates are expressed in KWh. Price will be fixed per KWh and that must be paid by the customer

4.2 Based on time

Depending on the charging time period, billing will be done. However this is not much suitable because different vehicles have different battery capacities hence the power consumption varies. If the EVs are implemented in real time, some methods must be installed for billing money to the power consumed by the vehicle. Few of them are

4.3 Cash

This payment method looks alike with the method being used at petrol stations. The holder of EV pays for the power consumed using cash. This method is inefficient since the cost of power used for charging is smaller compared to the costs of collecting, depositing and selling the power.

4.4 Fuel Card

In this billing method, the holder of EV pays for the power consumed by using fuel card. It also looks alike with the methods being used at the petrol stations.

4.5 Pay through mobile

Now-a-days many payment apps are available in the internet, using them money can be paid through mobile. It is an easy and user friendly method since the usage of mobile in all aspects is rapidly increasing day by day.

4.6 Household electricity bill

This technique is a suitable one for the holders of EV because many of the users may already have a household electricity account. The power consumption for charging is added to the household electricity bill. This requires the public charging points to have both the values of power consumed and validate information of user to be sent to the power supplier.

4.7 Segregate EV electricity bill

This method requires installation of two segregate meters in home. One for household power consumption and the other for charging of EV. The holder will receive a segregate bill for the power consumption of the EV. In all the above methods, money can be paid either in prepaid or post-paid manner.

5. Implementation and Results

WPT for future vehicular system dynamically is going to be the biggest demand soon. To forecast the real time implementation scenario, a prototype has been designed. It consists of arduino controller, motor driver unit, HC-05 Bluetooth module, LCD, primary and secondary coils, battery, etc. To show the EV movement using WPT dynamically, it requires a series of coils to be placed in road tracks which increases the cost of the prototype. So, the modelled prototype is operated with the help of HC-05 Bluetooth module to transmit the commands.

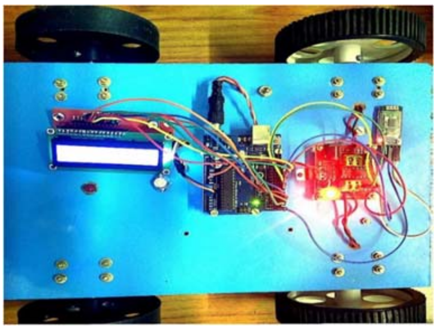

Fig. 5 The top view of the prototype modelled.

A LCD display interfaced with battery of the EV is casted to show the status of charging or discharging. If the primary and the secondary coils are in the near field, the WPT takes place due to magnetic flux density erected between coils and charging of battery is observed in LCD. L239d motor driver is used to control geared motors attached to the wheels. It gives commands to the wheels of the prototype. Fig. 6 displays the back view of the prototype with secondary coils. The magnetic flux travels in different directions which lead to the power loss. These Power loses can be reduced by using the optimization technique viz., adaptive frequency tuning through which an efficiency of 81% is attained.

Figure. 6 Back view of the Prototype

6. Conclusion and Future Work

The dynamic wireless charging system for electrical vehicles, which is the future of transportation all over the globe is erected. Prototype equipped with wireless charging system is been modelled and optimization technique is adopted for increasing the efficiency of the system. Open source hardware and software viz., arduino helps in cost efficiency of electrical transportation system. An electrical robotic system which functions with battery and DC motor resembles the electrical vehicles. The battery can be charged using wireless power system dynamically whenever the vehicle gets near to the transmitter coil deployed on the road track. Boost converters and adaptive frequency tuning optimization technique gives hand for increasing the efficiency of wireless power transmission. Also, billing methods for consumption of dynamic WPT by EV is been discussed. For future enhancement, vehicle model can have anti-collision methods to avoid accidents, real-time GPS connectivity and RFID based refuelling system with solar panels for activating the primary coils.

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