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Dynamic Wireless Power Transmission System for EV

Vishakha Mahamulkar[1], Shital Jadhav[2], Ashwini Pawar[1], Deepali Wagh[3], Ajinkya Bhaware[4], Sachin Jadhav[5], Ganesh Patil[6], Kamalkishor Maniyar[6]*, Prasad Ghodke[7] and Ekta Mishra[8]

[1]Department of Electrical Engineering, Dr. D. Y. Patil Institute of Technology, Pimpri, Pune - 411018, Maharashtra, India

[2]Department of Electrical Engineering, Annasaheb Dange College of Engineering and Technology, Ashta - 416301, Maharashtra, India

[3]Department of Electrical Engineering, JSPM's Bhivarabai Sawant Institute of Technology and Research, Wagholi, Pune - 412207, Maharashtra, India

[4]Department of Electrical Engineering, Dr. Babasaheb Ambedkar Technological University, Lonere, Raigad - 402103, Maharashtra, India

[5]Department of Electrical Engineering, KES's Rajarambapu Institute of Technology, Rajaramnagar, Islampur, Sangli - 415414, Maharashtra, India

[6]Department of Mechanical Engineering, Dr. D. Y. Patil Institute of Technology, Pimpri, Pune - 411018, Maharashtra, India; kamalkishor.maniyar@dypvp.edu.in

[7]Modern Institute of Business Studies (Autonomous) Nigdi, Pune - 411044, Maharashtra, India

[8]Dr. D. Y. Patil Institute of Technology, Pimpri, Pune - 411018, Maharashtra, India

Abstract

Electric Vehicles (EVs) powered while in motion provide a safe, lightweight, and sustainable solution with an extended driving range. The system consists of immobile input coils arranged linearly beside one or more roadway paths and a second coil embedded in each EV. Only the primary coils directly beneath a moving vehicle are activated, minimizing energy waste. Each lively input coil functions as a switched resonant converter. To ensure efficient energy transfer when switching between primary coils, the stored electric energy and magnetic energy in the capacitors and coils is seamlessly transferred to the next set of capacitors and coils. This approach maximizes efficiency and reduces energy loss, making MFIPT a promising technology for future EV infrastructure. Aim: The goal of the topic is to improve a dynamic wireless power transmission that maintains a constant coupling factor, ensuring stable power transfer regardless of the relative positions of the system's components. This work explores Wireless Power Transfer (WPT) for objects moving on a platform with sequentially arranged coils. Activating a one TX coil at a time causes fluctuations in coupling and power transfer.

Major Findings: *To address this, we propose using two active TX coils. Various coil geometries and connections were analyzed through full-wave simulations and measurements, adjusting key geometric parameters. Coil connections were processed post-simulation, and results were compared. Future research directions are suggested.*

Keywords: *Converter Topologies, Multi Level Inverters (MLI), Single-phase Grid Connected Inverter, Solar-photovoltaic System*

**Author for correspondence*

1.0 Introduction

The depletion of fossil fuel supplies and the detrimental effects of internal combustion engines on the environment have drawn attention to sustainable energy solutions globally[1,2]. As a result, electric vehicle technology has been created to reduce the use of fossil fuels, which are a significant source of fuel consumption, in transportation[3,4]. As a result, hybrid electric cars, which combine an electric motor and an internal combustion engine, are now commonly available for purchase[5,6]. However, several battery-related issues, such as their size, weight, cost, charging time, and driving range, mean that the use of fully electric vehicles, including plug-in and battery electric vehicles, is still restricted[7,8]. The battery technology available now makes it difficult to overcome these obstacles. Electric vehicles that run on the roads have been proposed as a solution to these constraints[9,10].

This method eliminates the need for charging downtime and permits EVs to be wirelessly charged while traveling, allowing for smaller battery capacities[11,12]. Many studies on wireless power transfer systems for electric vehicles have been carried out in recent decades, opening the door to more sustainable and effective modes of transportation. A Moving Field Inductive Power Transfer system was previously presented[13,14]. It consisted of a secondary coil mounted in each moving vehicle and immovable primary coils aligned linearly next to one or more road tracks[15,16]. The primary coils are buried beneath the road surface, while the secondary coil is mounted on the frame of the car[17,18].

2.0 Literature Summary

2.1 The Past: Centralized Inverters

Significantly, the secondary coil's length leeway is longer than that of two primary coils, guaranteeing effective and constant power transfer while the car travels the track[19,20]. This causes at least one main coil to constantly overlap with the secondary coil at any given time[21,22]. Because the secondary coil completely covers each primary coil, this arrangement ensures consistent and effective power transfer while minimizing changes in mutual coupling between the coils[23,24]. The activation smoothly switches to the following input coil unit when the moving electric vehicle's secondary coil crosses over with two input coils[25,26]. This procedure minimizes energy loss and maintains continuous power transfer by ensuring that the electric energy and magnetic energy stored in the capacitor and the input coil are effectively transferred to the succeeding coil and its matching capacitor[27,28]. This energy transfer happens quickly and without any power outages[29,30]. Through the integration of a DC-DC converter, we improve the MFIPT system in this study[31,32]. This method uses a converter that works in tandem to enable effective and dependable power conversion to obtain the four-sided AC power supply voltage from the under-road DC source[33,34].

3.0 Need of a Dynamic Wireless Power Transmission System for EV

The depletion of fossil fuels and environmental pollution from internal combustion engines have increased interest in sustainable energy options worldwide[35,36]. One way to cut down on the use of fossil fuels, especially in transportation, is through the development of electric vehicle technology[37,38]. All-electric vehicles, including plug-in and battery electric vehicles, are still not widely adopted, though, because of a number of battery-related issues, such as their size, weight, cost, lengthy charging times, and short driving range, which are problems that current battery technology finds difficult to solve[39,40]. Roadway-powered EVs, which allow wireless charging while driving, are a concept that was introduced to overcome these limitations[41,42]. This novel method improves the usefulness of EVs by reducing battery size and doing away with waiting times for charging[43,44].

4.0 Objectives

Investigating the Wireless Power Transfer (WPT) technique and promoting Electric Vehicles (EVs) as a sustainable substitute for transportation fueled by fossil fuels are the goals of this project[45,46]. Since non-renewable energy sources are running out and petrol prices are going up, switching to electric vehicles is an economical and environmentally responsible alternative[47,48]. For effective wireless energy transfer, this project seeks to create a

revolutionary dynamic wireless power transmission technology for EVs[49,50]. Installing a technology is allowed electric cars to be wirelessly charged while driving will lessen their need for charging stations. Learn about the energy transfer and system efficiency that underpin inductive wireless charging. Show the voltage, current, and charge level of the battery on an LCD panel for real-time tracking[51].

5.0 Methodology

By utilizing Faraday's Law of EI, Inductive Wireless Charging (IWC) facilitates wireless power transfer using mutual induction between the transmitter and receiver coils through a magnetic field. The transmitter coil creates an alternating magnetic field when an AC source is connected to it. This causes a current to flow through the receiver coil, producing an AC power output. After being rectified and filtered, this induced AC power is

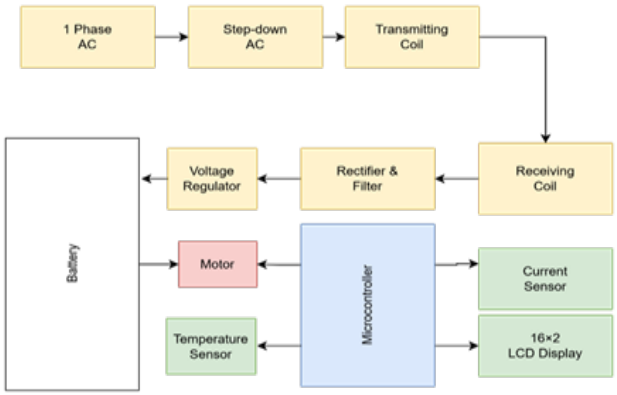


Figure 1. Block diagram of MPIT[3].

used to charge the EV energy storage system. Several variables, including as operating frequency, mutual inductance, and the separation between the transmitter and reception coils, affect power transfer efficiency. The typical frequency range for IWC is between 19 kHz and 50 kHz.

A 230V AC supply is given to the SMPS. The SMPS consists of a transformer and a converter circuit. This circuit gives us a 12V DC supply. But this DC is not constant, but a pulsating one. Led is connected in the circuit to show whether the circuit is on or off. With the help of the transmitter circuit, the frequency is increased up to 25 kHz to send to the receiver circuit. The primary

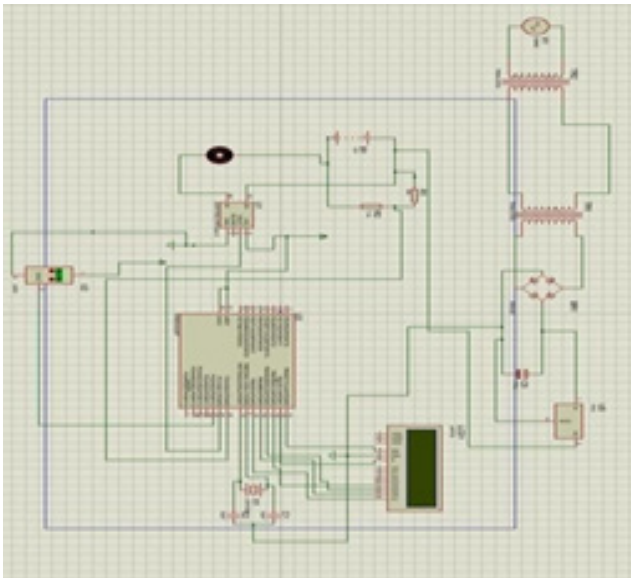


Figure 2. Project circuit diagram[5].

circuit is a stationary one attached along the road where whereas the secondary circuit is a moving one that is attached to the vehicle. This pulsating DC is sent to the receiver circuit, which further converts the pulsating DC into pure DC. The booster circuit is also used in case there is any voltage while transmission from the sending coil to the receiving coil. This constant DC is further used to charge the battery while the vehicle moves along the track where the primary coils are attached. A voltage divider circuit is used to supply 5V to the ATmega328, and 12V is given to the motor driver IC which drives the motor also, a bluetooth module is used which helps us to drive the vehicle with the help of our mobile phones. Different parameters of the battery, such as current, voltage and temperature, are shown on the LCD. In a moving vehicle scenario, multiple transmitter (TX) coils are positioned along the vehicle's path. As the vehicle advances, different TX coils sequentially couple with the receiver (Rx) coil, causing fluctuations in the coupling factor and variations in optimal power transfer conditions. To mitigate this, a long movable RX coil is typically used. Efficient power transfer requires the second TX coil to activate only after the first one is deactivated. For seamless transitions, the coupling factor should remain maximally flat, ensuring stable energy transfer. As shown in the results section, achieving this condition necessitates a Rx coil longer than twice the fixed TX coil, which reduces the coupling coefficient and complicates coil switching.

6.0 Calculations

6.1 Calculation of Coil's Self-Inductance

The Coil outer diameter, Dout = 40mm
The Coil inner diameter, Din = 10mm
Number of turns, N = 10
Self-inductance,

$$L=\frac{(a^2N^2)}{8a+11c}$$

$$L=\frac{(27^2+10^2)}{8*27+11*25}$$

L=67.16mH

6.2 Calculation of Coil's mutual inductance

$$M=\frac{\mu_0}{2\pi}\sum_{t=0}^{Nr} Rr^2 \sum_{t=0}^{Nt}\frac{2\pi Rt^2}{(Rt^2+D^2)^{\frac{3}{2}}}$$

$$M=\frac{\mu_0}{2\pi}\sum_{t=0}^{18} 20^2 \sum_{t=0}^{Nt}\frac{2\pi*20^2}{(20^2+40^2)^{\frac{3}{2}}}$$

M=501.64 pH

6.3 Calculation coefficient of coupling

$$K=\frac{M}{\sqrt{L_1L_2}}$$

K = 0.02

6.4 Resonant Frequency

$$F_r=\frac{1}{2\pi\sqrt{LC}}$$

We got equivalent capacitance is 45 μH And our inductance is 3.7μH

$$F_r=\frac{1}{2\pi\sqrt{45*10^{-6}*3.7*10^{-6}}}$$

F_r= 16.86 KHz

7.0 Conclusion

In this project, a wireless charging system for moving vehicle is implemented. Vehicle was successfully charged wirelessly while driving along the track. Various parameters of the battery were also shown on LCD. Also, with the help of Bluetooth module we were able to move the vehicle with our mobile phones. This topic presents the development of a dynamic wireless power transmission system for EV, where stationary input coils are arranged linearly along one or more roadway tracks while each EV carries a single secondary coil. The primary field excitation moves with the EV, activating only the coils directly beneath it to minimize power loss. Our implementation successfully designed a wireless charging system with real-time monitoring of battery voltage, current, and temperature using a microcontroller, with these parameters displayed on a 16×2 LCD screen. We utilized inductive coupling technology for wireless power transfer, which is effective for low-power bids and short distances amongst the transmitter and receiver coils. However, for real-world applications, where higher power levels and greater coil separation are required, Magnetic Resonant Coupling (MRC) technology is a more suitable alternative. Additionally, we conclude that while wireless charging offers convenience, it generally takes longer to charge a battery compared to conventional charging methods. In this paper, we explored various wireless charging methods. Based on our study, we carefully selected the appropriate components, software, and hardware tools to successfully design a cost-effective prototype.

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