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Loosely Coupled Inductive Power Transfer for Electrical Tractions

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Abstract - *Inductively Coupled Power Transfer (ICPT) systems are designed for efficient delivery of power from a stationary primary source to movable secondary loads over air gaps via magnetic coupling. The fundamental principle of this system is identical to closely coupled electromechanical devices like transformers and induction motor. Wired vehicle chargers are presently used so that corrosion of connectors is very serious problem. Frequent replacement and maintenance of the chargers requires proper operation. Vehicles with different battery voltages need modified chargers in order to suit the battery voltages which will affect the charger efficiency. Design for a practical electric vehicle charger which is suitable for any power vehicles such as two wheelers, four wheelers, heavy motor is proposed in this work. These Loosely Coupled Power Transfer (LCPT) wireless chargers have no contact problem as well as a cost efficient charger. Without changing the charger, the LCPT chargers can charge different vehicles with different battery so that the efficiency does not affect. By adjusting the number of turns of the pickup coil that is secondary coil during the manufacture of the vehicles, the efficiency can be varied. This concept of Loosely Coupled Power Transfer can also be used in traction system by neglecting the battery.*

***Key Words*: Loosely Coupled Power Transfer.**

1. INTRODUCTION

Loosely coupled power transfer (LCPT) systems are designed to deliver power effectively from a stationary primary source to movable secondary loads .The core used here is air and power delivered by magnetic coupling. The fundamental principle of this system is identical to closely coupled electromechanical devices such as transformers and induction motors. Loosely coupled power transfer, as the name indicates the primary and secondary systems coils is loosely coupled ie, there is no solid core for coupling primary and secondary. Simply, loosely coupled indicates air core between primary and secondary system coil. Modern power electronics have revealed many applications such as wireless power supply for professional tools, wireless battery charging across large air gaps for electric vehicles, compact electronic devices, mobile phones, and medical implants. Also include material handling systems and public transport vehicles where the secondary systems are electrically isolated and movable. Since, in all situations, the system would be installed in a vehicle made of steel, and also in order to ensure security for both the passengers and the electronic equipment from harmful effects originated by the magnetic field shielding should be required. But this paper doesn't deals with scope of shielding , although different shielding have been studied using a finite element program and it is found that the use of combined ferrite-aluminum plates provides the required shielding without significantly affecting the magnetic parameters. But this paper gives a proof that, the calculations made without considering the shielding would be valid. The obtained algorithm is applied to the design of a 230-kW 35-cm air-gap LCPT battery charger for a public use of transportation. In this method, the designed parameters are coil shape and dimensions, air gap, maximum operating frequency, primary voltage, load voltage and power. Even after applying for the mentioned parameters, there are infinite possible outputs.

1.1 OVERVIEW

Most of the former wireless power solutions focused on tight coupling, with induction coil solutions working at relatively low frequencies from 100 kHz through 315 kHz and this is the basis of the Wireless Power Consortium and Power Matters Alliance (PMA) standards. The Alliance for Wireless Power (A4WP) standard known as Rezence makes use of high-frequency that is 6.78 MHz operation that allows resonance to be used to enhance the generation and transmission of magnetic fields for wireless power transmission. This use of high-frequency operation is the footing for the loosely-coupled power transfer, highly-resonant approach to wireless power transfer. In all formats, power management and control between the source and device is set using digital communications. In the Wireless Power Consortium (WPC) Qi standard and the Power Matters Alliance (PMA) standards, the digital information is encoded on the power carrier.

2. PROPOSED SYSTEM

We propose a new significant system to transfer power that is loosely coupled power transfer. The wireless transmission using inductive coupling is used to transfer power with an advanced loosely coupled technique. With electrodynamic induction, electric current flowing through a primary coil creates a magnetic field which acts on a secondary coil producing a current within it.

2.1BLOCK DIAGRAM

The circuit consists of mainly two sections primary and secondary sections.

PRIMARY SECTION:

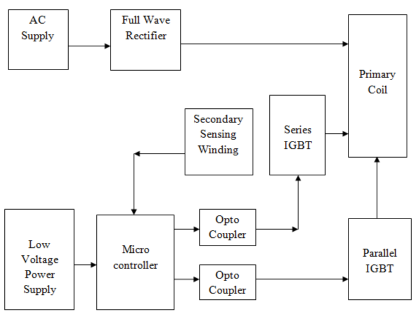


Figure 1: Block Diagram of Primary Section

AC Power Supply:

A line voltage of 230V, 50Hz Alternating Current (AC) power is used to operate the primary section. A low voltage power supply is used to provide the power required for the microcontroller and IGBT to perform exactly. A low voltage power supply of 5v for the microcontroller and 12v for Insulated Gate Bipolar Transistor is designed.

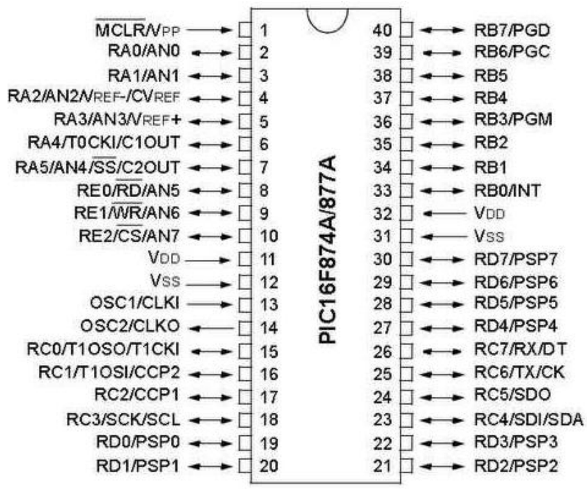
Full Wave Rectifier:

A high frequency full wave rectifier is used here. The function of full wave rectifier is to rectify the line voltage of 250V.The output of this section will be approximately 325V.Then this rectified voltage is applied to the primary coil.

Microcontroller (PIC16F877X):

PIC16F877X has a high-performance RISC CPU with only 35 single word instructions to study. It consists of all single cycle instructions except for program branches which are two cycle. The Pinout of PIC16F877X is compatible to the PIC16C73B/74B/76/77.It has an Interrupt capability of up to 14 sources and eight level deep hardware stack. There are three addressing modes namely direct, indirect and relative addressing modes. This microcontroller contains large operating voltage range of 2v-5.5v.

Pinout of PIC16F4A/877A:



OPTO COUPLER:

An Opto-isolator is also known as an Optocoupler, photo coupler, or optical isolator. It is a device that converts electrical signals between two isolated circuits by using light. Opto-couplers prevent high voltages from affecting the system. The Opto-isolators can withstand an input-to-output voltage of up to 10 kV and voltage transients with speeds up to 10 kV/μs. The implementation of an Optocoupler consists of an LED that produces infra-red light signals and a semiconductor photo-sensitive device which is used to notice the emitted infra-red beam. Both the LED and photo-sensitive device are contained in a light-tight body or package with metal legs for the electrical connections.

SWITCHING ELEMENT:

The Insulated Gate Bipolar Transistor also called an IGBT for short which is of a cross between a standard Bipolar Junction Transistor (BJT) and a Field Effect Transistor (MOSFET) making it ideal as a semiconductor switching device. The IGBT transistor takes the good parts of these two types of transistors that is the high input impedance and high switching speeds of a MOSFET with the low saturation voltage of a bipolar transistor and integrate them to produce another type of switching device which is capable of controlling large collector-emitter currents with virtually zero gate current drive.

SECONDARY SECTION:

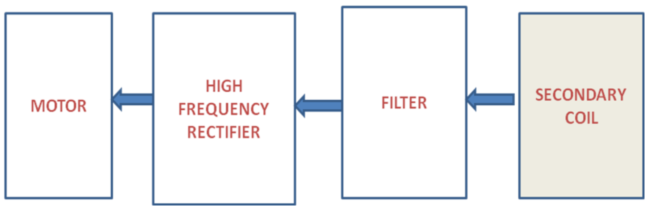


Figure 2: Block Diagram of secondary section

CALCULATIONS:

The first step in the modeling of an LCPT system is to select the geometry of the coupling, to be able to calculate inductance L1, L2, and number of turns N. Secondly, the electrical parameters must be determined.

The inductance of the rectangular coil can be found out using the following equation;

$$L_{rect} \approx N^2 \frac{\mu_0 \mu_r}{\pi} \left[-2(w+h) + 2\sqrt{h^2+W^2} - h \ln\left(\frac{h+\sqrt{h^2+W^2}}{W}\right) - W \ln\left(\frac{W+\sqrt{h^2+W^2}}{h}\right) + h \ln\left(\frac{2h}{a}\right) + W \ln\left(\frac{2W}{a}\right) \right]$$

Where N is the number of turns,W is the width ,h is the height of the rectangular coil and a is the wire radius.

APPLICATIONS:

The Loosely coupled power transfer many applications such as contactless power supply for professional tools, wireless battery charging across large air gaps for electric vehicles, for compact electronic devices, medical implants and mobile phones. Other applications of loosely coupled power transfer include material handling systems and public transport systems where the secondary systems are electrically isolated and they move along the long track. Electric isolation is also essential for power supplies in harsh environments such as mining and outdoor lighting. The advantages of such systems are reliability, safety, low maintenance and long product life.

3. CONCLUSIONS

The practice of Loosely Coupled Power Transfer is well known, but it is difficult to determine the parameters of the coils and the resonant frequency to obtain a most advantageous system. This paper describes a new design process to select the parameters of an air cored loosely coupled Power Transfer with a large air gap, and shows that it is possible to deliver high power with high efficiency if a proper design is selected. In this project a loosely coupled power transfer system for multilevel tractions has been designed. According to this system, there is no need of separate charging system for different capacity secondary systems. In case of vehicle charging system, we don't need separate charging pumps for two wheelers, four wheelers, and heavy motor vehicles. A control coil is setup along the primary winding so that when the secondary coil in the vehicle is brought near the primary coil in the charging pumps then corresponding to the voltage in the secondary coil a magnetic flux is produced which linked with the control coil. The control coil senses the secondary voltage and is fed back to microcontroller. Due to this control coil feed backing the primary coil is switched corresponding to the secondary voltage. Further modification can be done on the system by linking electrical tractions to the digital communication system so that the device information can be revealed.

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