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Advanced Control Techniques for Wireless Power Transfer in Electric Vehicles

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ABSTRACT: Wireless Power Transfer (WPT) technology enables efficient and contactless charging of electric vehicles, reducing dependence on conventional wired systems. This project presents the design and implementation of advanced control techniques to enhance the performance and efficiency of WPT systems based on resonant inductive coupling.

The proposed system incorporates a microcontroller-based control unit that applies closed-loop control, frequency tuning, and impedance matching to maintain optimal power transfer under varying conditions such as coil misalignment and load variations. These control strategies help minimize power losses, improve system stability, and ensure consistent energy delivery.

The developed system offers advantages such as increased efficiency, reduced maintenance, improved safety, and user convenience. This work contributes to the advancement of smart and sustainable charging solutions for electric vehicles, supporting the future of wireless and automated energy transfer technologies.

KEYWORDS: Wireless Power Transmission , Resonant Inductive Coupling , Electricity without Wires , Energy Transfer, Microcontroller ,Authentication System ,Power Efficiency , Reduced Power Loss ,Wireless Charging ,Electromagnetic Induction , Sustainable Technology , Smart Energy System , Contactless Power.

I. INTRODUCTION:

The WIRELESS POWER TRANSMISSION concept is not new. It was first demonstrated by Nikola Tesla in the year 1890. Nikola Tesla introduced electrodynamics induction or resonant inductive coupling by lighting up three light bulbs from the distance of 60 feet from the power source. We have also built a Mini Tesla Coil to transfer the energy.

Wireless Electricity Transfer or WET is a process to supply power through an air gap without using any wires or physical link. In this wireless system, the transmitter device generates a time-varying or high-frequency electromagnetic field, which transmits power to receiver device without any physical connection. The receiver device extracts power from the magnetic field and supplies it to electrical load. Therefore, to convert the electricity to an electromagnetic field, two coils are used as transmitter coil and receiver coil. The transmitter coil is powered by alternating current and creates a magnetic field, which is further converted into a usable voltage across the receiver coil.

Objectives:
To make a portable wireless charging of a vehicle with the use of ordinary power supply as a power source. Low cost as compare to existing operated machine.A simple and computationally efficient mini model vehicle model is presented. This work illustrates how wireless charging vehicle system works on different planes. Under reasonable assumptions, it is possible to determine the rover attitude and configuration, given its position and ground characteristics, and whether the rover will slide, tip over or maintain its balance. According to the different weight acting on the link, determines torque applied to it.

II. LITERATURE SURVEY

1.Amir Rezaei, Jeffrey B. Burl, Mohammad Rezaei, and Bin Zhou, International Journal of Engineering Research & Technology (IJERT),Catch Energy Saving Opportunity in Charge Depletion Mode, A Real Time Controller for Plug-in Hybrid Electric Vehicles.

2.oyune Song, Jaegue Shin, Seokhwan Lee et.al, Asian Journal of Electrical Sciences ISSN:2249-6297,Vol.7,No.1,2018,pp.6-9, Design of a High Power Transfer Pickup for On-Line Electric Vehicle (OLEV).

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3.Haoming Liu, Man Niu, Weijie Wang, International Journal of ChemTech Research, Reserving Charging Strategy for Electric Vehicles Based on Combined Model of Road-Charging Station-Electric Vehicle.

4.L. Cheng, Y. Chang, Q. Wu, W. Lin et.al..IEEE Transactions on Sustainable Energy. IEEE, vol. 5,Evaluating charging service reliability for plugin EVs from the distribution network aspect.

2.1 Existing system:

Wireless power transfer (WPT) systems, which have been around for decades, have recently become very popular with the widespread use of electric vehicles (EVs). In this study, an inductive coupling WPT system with a series–series compensation topology was designed and implemented for use in EVs. Initially, a 3D Maxwell (ANSYS Electromagnetics Suite 18) model of the system was generated. The impact of individual parameters on the coupling coefficient was analyzed through systematic variations in each parameter's values. As a result, a system with a higher coupling coefficient was obtained. Using this system, three distinct load cases were investigated for their efficiency in the Implorer (ANSYS Electromagnetics Suite 18) circuit. Subsequently, a prototype of the system was constructed, and the experimental results were compared with the model's results.

This study shows that both the output power and the efficiency of the system increase as the load resistance increases. The results obtained in this study are anticipated to offer valuable insights for the enhancement of WPT system design.

III. PROPOSED BLOCK DIAGRAM:

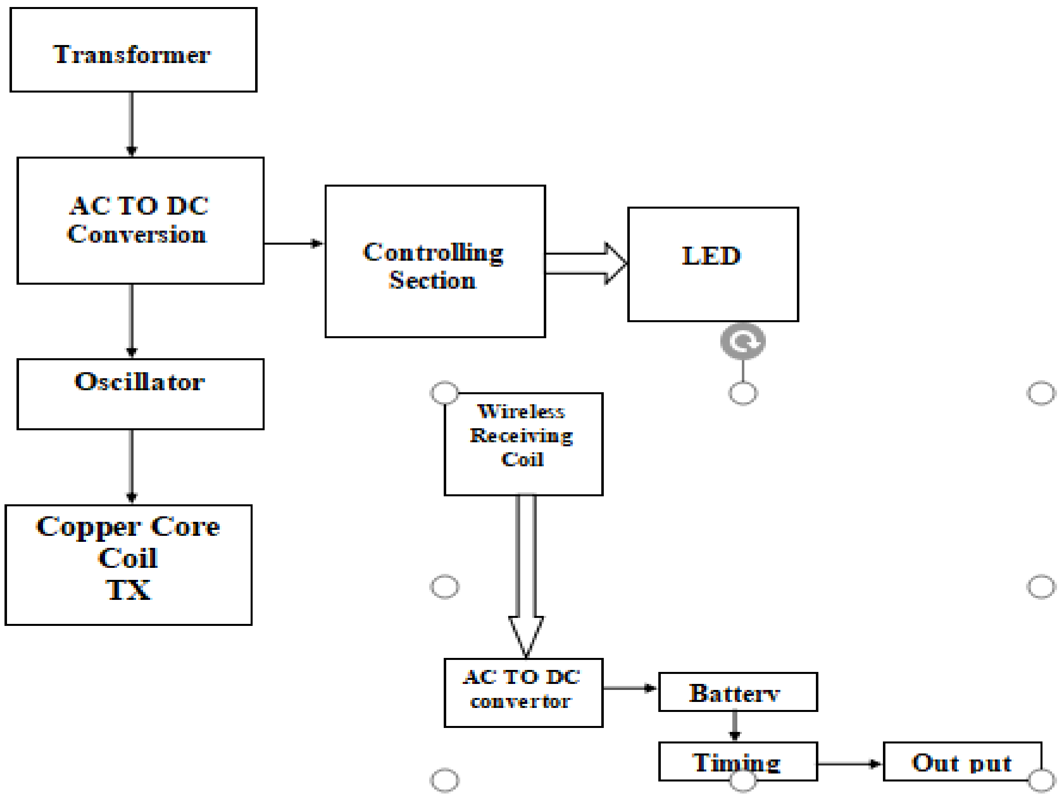

FIG. 3.1 BLOCK DIAGRAM

IV. HARDWARE DESCRIPTION

4.1. INDUCTIVE COUPLING:

Inductive or Magnetic coupling works on the principle of electromagnetism. When a wire is proximity to a magnetic field, it generates a magnetic field in that wire. Transferring energy between wires through magnetic fields is inductive coupling.

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If a portion of the magnetic flux established by one circuit interlinks with the second circuit, then two circuits are coupled magnetically and the energy may be transferred from one circuit to the anothercircuit. This energy transfer is performed by the transfer of the magnetic field which is common to the both circuits.

In electrical engineering, two conductors are referred to as mutual-inductively coupled or magnetically coupled when they are configured such that change in current flow through one wire induces a voltageacross the end of the other wire through electromagnetic induction. The amount of inductive coupling between two conductors is measured by their mutual nductance.

Power transfer efficiency of inductive coupling can be increased by increasing the number of turns in the coil, the strength of the current, the area of cross-section of the coil and the strength of the radial magnetic field. Magnetic fields decay quickly, making inductive coupling effective at a very short range.

4.2. INDUCTIVE CHARGING:
Inductive charging uses the electromagnetic field to transfer energy between two objects. A charging station sends energy through inductive coupling to an electrical device, which stores the energy in the batteries. Because there is a small gap between the two coils, inductive charging is one kind of short- distance wireless energy transfer. Induction chargers typically use an induction coil to create an alternating electromagnetic field from within a charging base station, and a second induction coil in the portable device takes power from the electromagnetic field and converts it back into electrical current to charge the battery. The two induction coils in proximity combine to form an electrical transformer. Greater distances can be achieved when the inductive charging system uses resonant inductive coupling.

4.3. POWER SUPPLY:
The power supply section is an important one. It should delivery constant output regulated supply for successful working of the project. A 12V-0-12V / 1 Amp transformer is used for our purpose, the primary of this transformer is connected to the mains supply through a ON/OFF switch and a fuse holder for protecting from overload and short circuit protection.

TRANSFORMER:
A transformer is a static device, which is used to transform electric power of same frequency in another circuit. It can lights or lower the voltage the circuit but with a corresponding decrease or increase in current. It works with the principle of mutual inductance in our project we are using step down transformer for providing a necessary supply for the electronic circuits. In our project we are using a (0-12)V transformer.

FILTER:
The filter is an electronic circuit, which is employed to reduce the rectifier output ripple. This is achieved by passing the AC output component around the load by a shunt capacitor or limiting the magnitude at a low value in the load by a series inductance are combination of this two more efficient.

CAPACITOR FILTER:
The capacitance is so chosen that the alternating currents find the load reactance shunt in C. Only a small alternating current component passes in R, producing a small ripple voltage. The capacitance alters the conditions under which the diode operates. When the diode output voltage is increasing, the capacitor stores energy, by charging the peak of the input cycle. With falling source voltage starts to fall faster than the capacitor voltage can fall, as determined by the time constant of C and the load. The capacitor continuous to maintain the load voltage at a higher value and lower ripple than if a capacitor was not present. The diode delivers a charging pulse of current pulse of current in each cycle, and then disconnects sources form the load.

RECTIFIERS:
A rectifier is defined as a electronic device used for converting AC voltage into unidirectional voltage. A rectifier utilizes unidirectional conductions device like vacuum diode or PN-junction diode.

Rectifier are classified depending upon the period of conductions as,
1. Half wave rectifier
2.Full wave rectifier
In our circuit we need continuous supply without any interruption.
Hence we use Full wave rectifier whose output is free from interruption.

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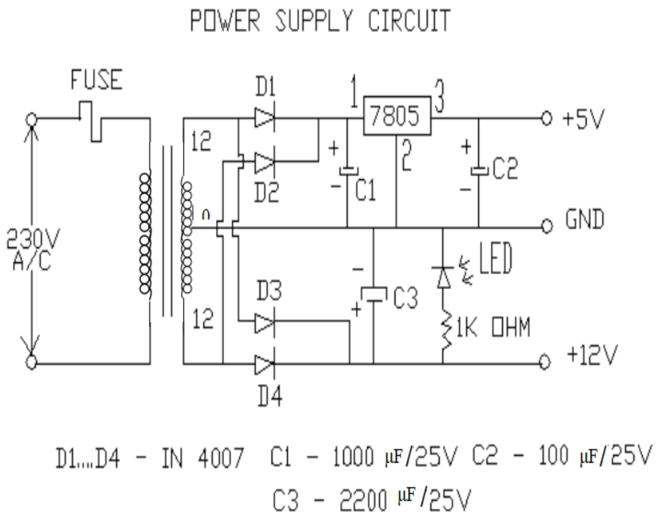
VOLTAGE REGULATORS:

A voltage regulators is an electronic circuit that provides a stable DC voltage independent of the load current, temperature and AC line voltage variations although voltage regulators can be designed using op-amps, it is quicker and easy to use IC regulator. Further more, the IC voltage regulators are versatile and relatively inexpensive and are available with futures such as programmable output, current / voltage boosting and floating operations for high voltage applications.
Some important Types of Linear IC Voltage Regulator are,

1. Fixed positive / negative output regulators.
2. Adjustable output voltage regulators.



4.4. POWER FACTOR SECTION

The output section is divided into two circuit one is buzzer for alarm purpose and another is relay driver circuit to active the +12V relay mechanisum. The buzzer require very low current and it is possible to activate it directly through an output port of 89C51 (with out any buffer). However the buzzer should be fixed rigidly to the cabinet, otherwise it will fail to produce the required vibrations.

- Single type capacitor is used to control the power factor (not capacitor bank). Totally 2 capacitor is used. (this unit is capable of controlling the PF of 500 Watt only.
- Here we are using IC - 741 as zero crossing detector. The capacitor is connected in parallel with the a.c. load line. The connection are done through the mechanical relay contacts.
- We are using the 89C51 for interface with the zero crossing detector (ZCD) circuit and the relay driver circuit. The output from the ZCD circuit is connected to PORT 1, the relay driver circuit are connected from PORT ext and the indicator for current status are indicated from output PORT.
- Microcontroller program is included along with this description . there is no need of circuit to control the power factor because the capacitor is connected in parallely with the load.

4.5. ANALOG TO DIGITAL CONVERTION

This section will explore interfacing ADC (analog to digital Converter) chips and temperature sensors to the 89C51. first, we describe ADC chips,then show how to interface an ADC to the 89C51. Then we examine the characteristics of the LM35 temperature sensor and show how to interface it to the 89C51.

ADC DEVICES:

Analog to digital converters are among the most widely used devices for data acquisition. Digital computers use binary (discrete) values, but in the physical world everything is analog (continuous). Temperature, pressure (wind or liquid), humidity and velocity are a few examples of physical quantities that we deal with every day. A physical quantity is converted to electrical (voltage, current) signals using a device called a transducer. Transducers are also referred to as sensors. Although there are sensors for temperature, velocity, pressure, light, and many other natural quantities, they

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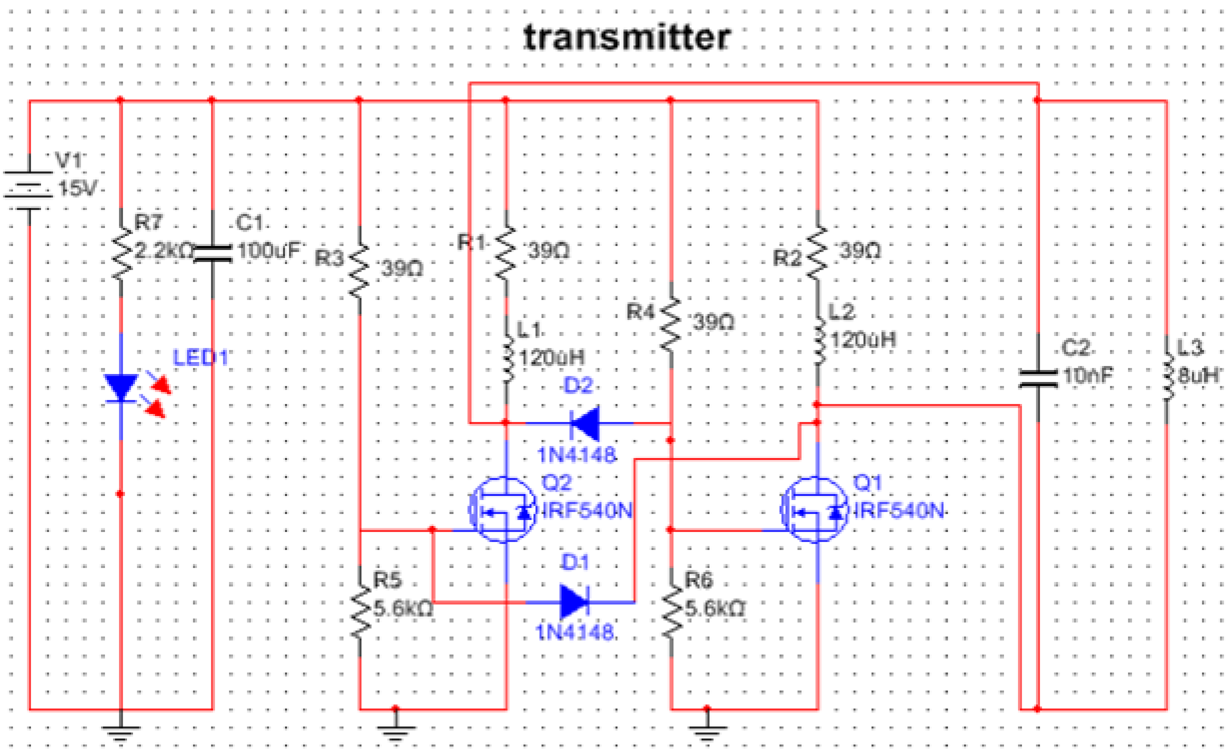
produce an output that is voltage(or current). Therefore, we need an analog to digital converter to translate the analog signals to digital numbers so that the microcontroller can read them. A widely used ADC chips the ADC 0804.

RD(READ):
This is an input signal and is active low. The ADC converts the analog input ot its binary equivalent and holds it in an internal register. RD is used to get the converted data out of the ADC804 chip. When CS=0,if a high to low pulse is applied to the RD pin, the 8-bit digital output shows up at the D0-D7 data pins. The RD pin is also referred to as output enable.

WR(WRITE;A BETTER NAME MIGHT BE "START CONVERSION"):
This is an active low input used to inform the ADC804 to start the conversion process. If CS=0 when WR makes a low to high transition, the ADC804 starts converting the analog input value of Vin to an 8-bit digital number. The amount of time it takes to convert varies depending on the CLK IN and CLK R values explained below. When the data conversion is complete, the INTR pin is forced low by the ADC804.

CLK IN AND CLK R:
CLK IN is an input pin connected to an external clock source when an external clock is used for timing. However, the 804 has an internal clock generator. To use the internal clock generator (also called self-clocking) of the ADC804, the CLK IN and CLK R pins are connected to a capacitor and a resistor, as shown in fig. In that case the clock frequency is determined by the equation:
f= 1/1.1 RC
Typical values are R= 10K ohms and C= 150 pf. Substituting in the above equation, we get f=606khz. In that case, the conversion time is 110 micro sec.

CIRCUIT DIAGRAM:



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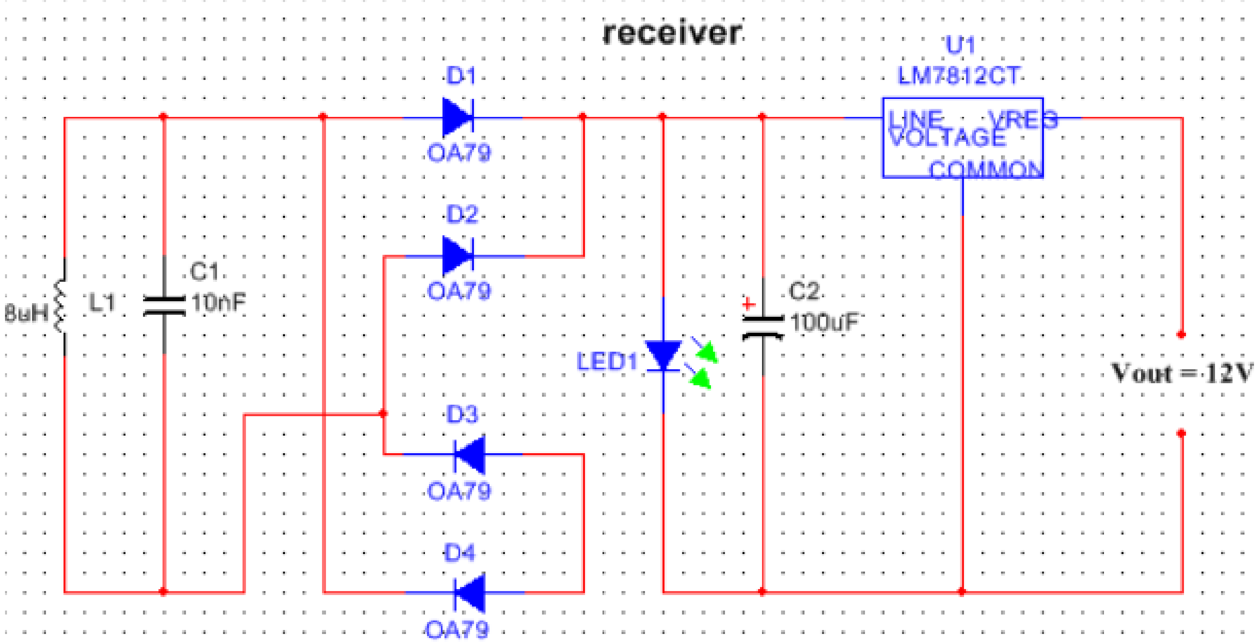

V. CONCLUSION:

The implementation of advanced control techniques significantly enhances the efficiency, reliability, and performance of wireless power transfer systems for electric vehicles. By integrating closed-loop control, frequency tuning, and impedance matching, the system effectively overcomes challenges such as coil misalignment and varying load conditions.

The use of a microcontroller ensures real-time monitoring and dynamic adjustment, resulting in optimized power transfer and reduced energy losses. Additionally, the proposed approach improves safety, minimizes maintenance requirements, and increases user convenience compared to traditional wired charging methods.

Overall, this work demonstrates that advanced control strategies play a crucial role in making wireless charging systems more practical and efficient, thereby supporting the widespread adoption of electric vehicles and contributing to sustainable transportation solutions.

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