WIRELESS POWER TRANSFER FOR ELECTRIC VEHICLES

A PROJECT REPORT
(PHASE – II)

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project titled "**Wireless Power Transfer for Electric Vehicles"** is the bonafide work of **"B. SURYA PRAKASH (203002113), SANTHOSH.R(203002305)"** who carried out the project work under my supervision.

Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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EXTERNAL EXAMINER **INTERNAL EXAMINER**

ABSTRACT

This Project deals with the concept of utilizing wireless power transfer (WPT) technology for the purpose of charging electric vehicles (EVs). The primary focus of the project is to investigate the feasibility, efficiency, safety considerations, system architectures, and practical challenges associated with implementing wireless charging solutions for EVs.

Focusing specifically on wirelessly transferring 48V voltage, this study extensively explores electromagnetic theory, with a keen emphasis on inductive and resonant coupling principles to enable efficient energy transfer sans physical connections. Investigating critical design parameters such as frequency selection, coil design, resonant coupling, power electronics, safety protocols, and regulatory compliance, the project aims to optimize these elements to propel the advancement of Wireless Power Transfer (WPT) technology for Electric Vehicle (EV) charging. The project envisions a future marked by seamless, efficient, and environmentally friendly transportation solutions facilitated by WPT.

In conclusion, the project presents a comprehensive overview of the benefits and challenges of implementing wireless power transfer technology for electric vehicle charging

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WPT	Wireless power transfer
EV	Electric vehicle
AC	Alternating Current
DC	Direct current
BMS	Battery management system
BPF	Bandpass filter
RF	Radio Frequencies
EMF	Electromagnetic Force
μm	Micrometer
HF	High Frequency
IPT	Inductive Power Transfer
SMPS	Switched-Mode Power Supplies
SPS	Series–Parallel–Series
SS	Series-Series
SP	Series-Parallel
PP	Parallel-Parallel
ZVS	Zero Voltage Switching

CHAPTER 1
INTRODUCTION

In the quest to free electric vehicles (EVs) from the limitations of traditional wired charging, wireless power transfer (WPT) technology emerges as a promising solution. This innovative system utilizes magnetic resonance technology, an evolution of the established inductive power transfer theory developed over the past thirty years. Its primary objective is to eliminate the inconvenience and constraints associated with physical charging connections, thus addressing significant hurdles in the widespread adoption of EVs.

The evolution of WPT technology has seen rapid progress, particularly in recent times, making it an attractive option for both stationary and dynamic EV charging. The technology's fundamental principle, resonant inductive coupling, involves transferring power between a ground-based primary coil (charging pad) and a secondary coil in the EV. By tuning both coils to the same resonant frequency, power transfer efficiency is optimized, especially over short distances.

While WPT using magnetic resonance holds the promise of liberating humans from cumbersome wires, its application in EVs presents challenges due to the need for equivalent power flexibility. Instead, EVs typically rely on high-capacity battery packs to achieve satisfactory operating distances.

The primary challenge for EVs lies in electricity storage technology, as current batteries suffer from inadequate energy density, limited lifetimes, and high costs. To address this, EV owners often seek opportunities to plug in and recharge their batteries. WPT technology, capable of wirelessly transferring charging energy to EVs, offers a solution, making charging more convenient.

Advancements in WPT technology have made it highly attractive for both stationary and dynamic EV charging scenarios. With stationary WPT systems, drivers can simply park their cars and leave, while dynamic systems enable EVs to charge while in motion, potentially allowing them to run indefinitely without stopping. Additionally, EVs equipped with wireless charging could see reductions in battery capacity of up to 20% compared to those using conductive charging methods.

WPT systems have diverse applications beyond EVs, including electronic gadgets, lighting, material handling, and biomedical implants. Capacitive WPT is typically used for low-power applications, while wireless inductive power transfer (IPT) technology caters to both low- and medium-power applications. Recent research and development efforts in IPT technology for EV battery recharging have surged.

Some model investigates the application of a half-bridge inverter in bidirectional IPT (inductive power transfer) systems. It employs a phase-shifted modulation technique between the primary and secondary inverter ports to achieve optimal efficiency points, as illustrated in figure 1.1. The topology is examined under various load conditions while maintaining a constant frequency and output voltage. Additionally, the controllability of the converter model is assessed, and the transfer function of the converter is determined.

CHAPTER 2

LITERATURE SURVEY

M. Ahmed and O. O. Khalifa introduced a distinctive approach to wireless charging in their work titled "Wireless Power Transfer for Electric Vehicle Charging." They conducted tests under different conditions, evaluating distance and alignment, and achieved an impressive efficiency rate of 90%. Emphasizing the critical role of coil design, their findings underscore the significance of optimizing this component.

Addressing parking-related challenges, Denis Ashok, Akshat Tiwari, and Vipul Jirge developed a "Smart Parking System using IoT Technology." By harnessing the power of the Internet of Things (IoT), their system creates a well-organized parking environment. Users are seamlessly directed to available parking spaces through illuminated indicators, eliminating the need for time-consuming searches. The system's automated nature also reduces labor requirements, enhancing efficiency.

To enhance power transfer efficiency in electric vehicles, R. Kavin, V. Koushika Gowri, M. Naveena, T. Navishree, and J. Nithish proposed a novel approach titled. "Wireless Power Transmission in Electric Vehicles Using Solar Energy." Their method incorporates MOSFET switches in the inverter to improve coil performance and achieve faster and more efficient charging. By leveraging higher frequencies, this approach enhances the overall driving experience of electric vehicles, addressing challenges related to charging time and cost.

Zamani, M. Nagrial, J. Rizk, and A. Hellany conducted a comprehensive review titled "A review of inductive power transfer for electric vehicles." Focusing on inductive coupling, their review encompasses the fundamental principles of inductive power transfer and offers an overview of state-of-the- art wireless power transfer systems for electric vehicles. This work contributes to the understanding and advancement of inductive power transfer technologies in the context of electric car charging.

Siqi Li, Member, IEEE, and Chunting Chris Mi, Fellow, conducted a comprehensive review titled" Wireless Power Transfer for Electric Vehicle Applications," This glass is eco-friendly as it is built with the help of e-waste but does not provide any information about the object.

Benitto Albert Rayan, Umashankar Subramaniam, S. Balamurugan their work titled "Wireless Power Transfer in Electric Vehicles: A Review on Compensation Topologies, Coil Structures, and Safety Aspects" and techniques used Wireless Charging Technologies Conductive Type, Plug-In Charging, or Wired Charging Different shapes of coil designs, and types of compensation topologies have been studied for varying power levels in EV applications.

Hua (Kevin) Bai, Daniel Costinett, Leon M. Tolbert, Ruiyang Qin, Liyan Zhu, Ziwei Liang, and Yang Huang discuss EV charging technologies in their work titled 'Charging Electric Vehicle Batteries: Wired and Wireless Power Transfer.' They describe the typical structure of an electric vehicle, which includes a motor drive inverter converting high-voltage DC bus voltage into AC to power the propulsion motor.

Additionally, power electronics are utilized in auxiliary circuits such as LED lighting and the battery management system (BMS).

S. Samanta and A. K. Rathore present their work on inductive wireless power transfer (IWPT) in their paper 'Analysis and Design of Current-Fed LC Converter for Inductive Wireless Power Transfer.' They introduce current-fed technology for IWPT, focusing on the detailed design of the DC-DC wireless power transfer stage with a current-fed topology. They highlight the role of a DC-link inductor before the inversion stage in limiting short-circuit current during inverter faults. The paper discusses the required resonance in both transmitter and receiver coils, utilizing parallel and series configurations, respectively, and compensating for high transmitter coil currents with a parallel resonating capacitor.

Novel Unity-Gain Frequency Tracking Control of Series-Series Resonant Converter to Improve Efficiency and Receiver Positioning Flexibility in Wireless Charging of Portable Electronics,' I. I. Nam, R. A. Dougal, and E. Santi address shortcomings of current wireless charging technology for portable electronics. They propose an SS resonant converter employing Unity-Gain Frequency Tracking (UGFT) control to overcome these limitations. The UGFT control eliminates the need for digital communication between transmitter and receiver for leakage inductance compensation and ensures robust operation against coupling and load variations. The converter can operate at the frequency of highest efficiency, reducing the need for downstream regulators. Detailed design criteria for SS resonant tanks are provided, supported by simulation results and experimental validation.

CHAPTER 3

PROPOSED WORK

3.1 Fundamentals of Wireless Technology

Wireless technology enables the transmission of electric energy or power without the necessity of physical wires. It builds upon the foundational principles of electricity and magnetism, leading to advancements in wireless technology.

i. Electricity

Electricity involves the flow of electrons (current) through a conductor, such as a wire, or charges through the atmosphere, as seen in lightning. It serves as a convenient means for energy to travel from one location to another.

ii. Magnetism

Magnetism is a fundamental force of nature that causes certain materials to attract or repel each other. Examples include permanent magnets like those found on refrigerators and the Earth's magnetic field. Oscillating magnetic fields, generated by alternating current (AC) flowing through a wire, vary over time and are often depicted and understood through representations of magnetic field lines.

iii. Electromagnetism

Electromagnetism describes the interdependence of time-varying electric and magnetic fields. For instance, an oscillating magnetic field produces an electric field, and vice versa.

3.2 Inductive Coupling

Inductive or magnetic coupling operates on the principles of electromagnetism. When a wire is near a magnetic field, it induces a magnetic field within the wire. Energy transfer between wires via magnetic fields is known as inductive coupling. As illustrated in Figure 3.1, the magnetic flux generated by one circuit intersects with the second circuit, resulting in magnetic coupling between the two circuits, facilitating energy transfer. This transfer of energy occurs through the mutual magnetic field shared by both circuits. In electrical engineering, two conductors are considered mutually inductively coupled or magnetically coupled when changes in current flow through one wire induce a voltage across the ends of the other wire through electromagnetic induction.

The level of inductive coupling between two conductors is quantified by their mutual inductance. In Figure 3.1, the power transfer efficiency of inductive coupling can be enhanced by increasing the number of turns in the coil, the strength of the current, the cross-sectional area of the coil, and the intensity of the radial magnetic field. Inductive coupling is particularly effective over short distances due to the rapid decay of magnetic fields.

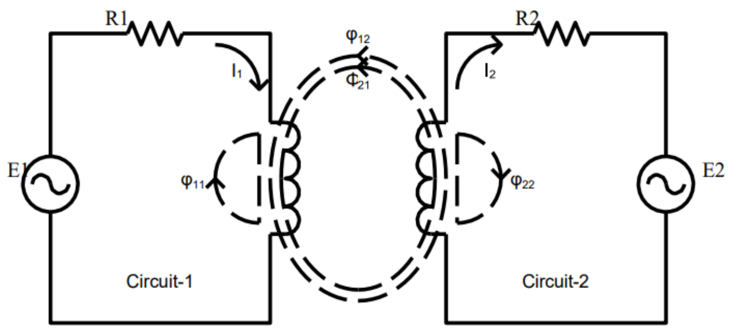


Fig.3.1: Inductive Coupling with Four Component Fluxes

3.3 Inductive Charging

Inductive charging utilizes electromagnetic fields to transfer energy between two objects. A charging station employs inductive coupling to transmit energy to an electrical device, which then stores it in its batteries. Due to the small gap between the two coils, inductive charging is limited to short-distance wireless energy transfer. Induction chargers typically consist of an induction coil within a charging base station, generating an alternating electromagnetic field, while a second induction coil in the portable device receives power from this field and converts it into electrical current to charge the battery. When placed in proximity, these two coils function as an electrical transformer. Resonant inductive coupling allows for greater distances in inductive charging systems.

3.4 Coil Inductance and Design

An ideal inductor exhibits inductance without resistance or capacitance and does not dissipate or radiate energy. However, real inductors possess resistance (due to wire resistance and core material losses) and parasitic capacitance (resulting from the electric field between wire turns at slightly varying potentials). At high frequencies, capacitance begins to affect inductor behavior, causing real inductors to behave as resonant circuits and exhibit self-resonance.

At even higher frequencies, capacitive reactance dominates impedance. Energy dissipation occurs due to wire resistance and magnetic core losses from hysteresis. Additionally, iron core inductors display nonlinearity at high currents due to magnetic saturation. At elevated frequencies, resistance and resistive losses increase due to skin effect in the winding wires. Core losses also contribute to inductor losses at higher frequencies.

3.5 Single-Layer Coil

A single-layer coil, depicted in figure 3.2, offers two advantages. Firstly, like all air core coils, it is devoid of iron losses and nonlinearities. Secondly, single-layer coils possess low self-capacitance, resulting in a high self-resonant frequency.

$$L = \frac{(d^2 \times n^2)}{(1+0.45d)}\ \mu H \qquad \text{(Eq 3.1)}$$

In Eq 3.1 describes the inductance, where L is the inductance, d is the coil diameter in meters, l is the coil length in meters, and n is the number of turns.

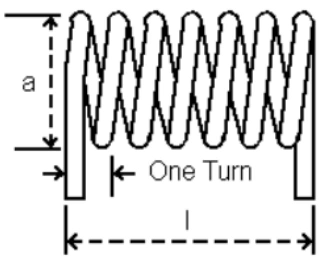


Fig.3.2: Single Layer Coil

3.5.1 Coil Losses

At high frequencies, particularly in radio frequency (RF) applications, inductors experience increased resistance and other losses. These losses not only result in power dissipation but also reduce the Q factor of resonant circuits, thereby widening the bandwidth. In RF inductors, predominantly air core types, specialized construction methods are employed to minimize these losses. These losses arise from the following factors:

I. Skin Effect

At high frequencies, the resistance of a wire to alternating current (AC) is greater than its resistance to direct current (DC) due to the skin effect. AC at radio frequencies tends to flow primarily along the surface of a conductor rather than penetrating deeply into its interior.

Consequently, in a solid wire, a significant portion of the cross-sectional area is underutilized for current conduction, confined to a narrow annulus on the surface. This effect elevates the wire's resistance within the coil, which may already possess high resistance due to its length and small diameter.

II. Parasitic Capacitance

Parasitic capacitance refers to the capacitance existing between individual wire turns within the coil. While this capacitance does not cause energy loss, it can alter the behavior of the coil. Since each turn of the coil is at a slightly different electric potential, an electric field develops between adjacent turns, resulting in charge accumulation on the wire. Consequently, the coil behaves as though it has a capacitor connected in parallel. At sufficiently high frequencies, this capacitance can resonate with the coil's inductance, forming a tuned circuit and inducing self-resonance in the coil.

3.6 Mutual Inductance

When a change in current in one coil causes an EMF in a different coil close by the first coil, mutual inductance occurs. For the design of the WPT system, this parameter is the most dependable.

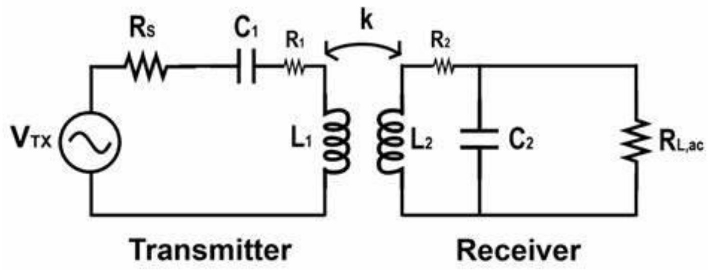
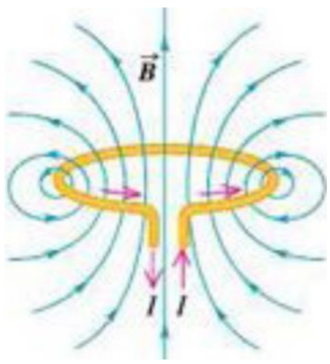


Fig. 3.3: Mutual Inductance

3.6.1 Magnetic Induction

A loop or coil made of conductive material, such as copper, and carrying an alternating current (AC), is highly effective at producing or capturing a magnetic field.



The lines represent the
Magnetic field that is created
When current flows through a coil.

Fig. 3.4: Magnetic Field

When connected to an AC power source, this conductive loop generates an oscillating magnetic field around it. Another conducting loop, placed close to the first one, can intercept a portion of this oscillating magnetic field. Consequently, an electric current is induced in the second coil. This induced current can then be utilized to power various devices. This method of transferring electrical power from one loop or coil to another is commonly known as magnetic induction. Electric transformers and generators are familiar examples of devices that operate based on magnetic induction.

3.6.2 High-Frequency Transformer

High-frequency (HF) power transformers find application in switched-mode power supplies (SMPS) and insulated DC-to-DC converters, serving the same purpose as their low-frequency (LF) counterparts but with reduced size, weight, and cost. This makes HF power transformers particularly suitable for situations where space, weight, and cost considerations are critical.

3.7 Block Diagram of Wireless Power Transfer (WPT)

In Figure 3.5, the system initiates with an AC power source operating at a low frequency, typically around 50 Hz. The incoming AC power is converted into DC power in the rectifier stage. Following this, the low-frequency DC power is converted into high-frequency AC power using a compensation network or an inverter.

The resulting high-frequency AC current is then transmitted through the primary coil, inducing alternating flux. Notably, the coils involved in this process are not physically connected by a core; instead, they are separated by an air gap, forming a loosely coupled configuration.

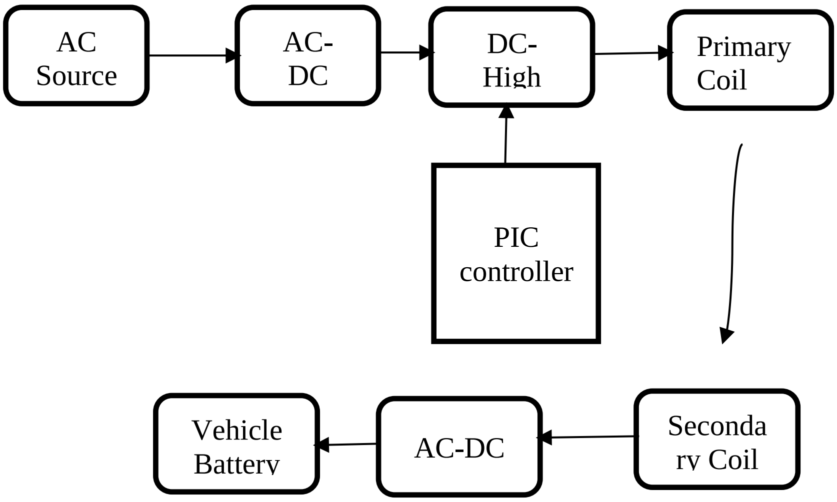


Fig.3.5: Block diagram of Wireless power Transfer (WPT)

3.7.1 Current WPT System

A typical WPT system comprises multiple stages, including a rectifier with power factor correction, an inverter, a compensation network on the transmitter side, a magnetic coupler encompassing the transmitter and receiver coils, a compensation network on the receiver side, and a rectifier for charging the DC battery. Additionally, a DC-DC converter may be introduced between the rectifier and inverter on the transmitter side to adjust the input DC voltage. Four primary compensation topologies are distinguished as series-series (SS), series-parallel (SP), parallel-series (PS), and parallel-parallel (PP), based on the configuration of capacitors connected to the transmitter and receiver coils.

Recent innovations have introduced novel compensation topologies, such as the series-parallel-series (SPS) topology. In this design, one capacitor is linked in series and the other in parallel with the transmitter coil. On the receiver side, one capacitor is connected in series with the coil, incorporating characteristics of both SS and PS topologies.

Drawbacks:

- Requires intricate parameter design for control stability.
- The assumption of unity power factor by default may not accurately derive output power even at resonance frequency.

3.7.2 Proposed System

- The proposed wireless EV charging system follows a specific methodology.
- Initially, utility AC power undergoes conversion into a DC power source using an AC to DC converter with power factor correction.
- Subsequently, the DC power is converted into high-frequency AC to drive the transmitting coil through a compensation network. As a precaution against insulation failure of the primary coil, a high-frequency isolated transformer may be inserted between the DC-AC inverter and primary coil for additional safety.
- The high-frequency current flowing through the transmitting coil generates an alternating magnetic field, inducing an AC voltage in the receiving coil. Through resonance with the secondary compensation network, transferred power and efficiency are significantly enhanced.
- Finally, the AC power is rectified to charge the battery.

Advantages:

- The growing popularity of electric vehicles (EVs) in the automotive industry is attributed to various benefits, including increased energy security, enhanced fuel economy, reduced fuel costs, and decreased emissions.

3.8 Fundamental Theory

A standard wireless EV charging system, as depicted in Figure 3.6, consists of multiple stages aimed at wirelessly charging an EV. Initially, utility AC power is transformed into a DC power source through an AC to DC converter equipped with power factor correction.

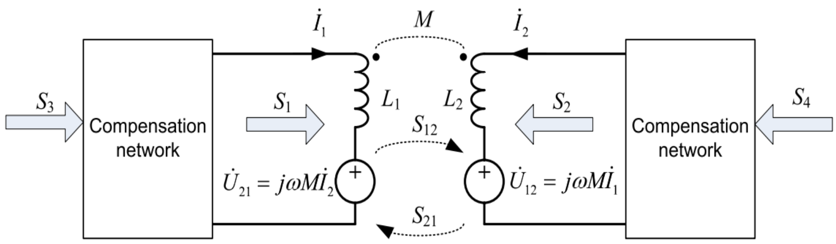


Fig. 3.6: Mutual Inductance with compensation network

The DC power is transformed into high-frequency AC to energize the transmitting coil via a compensation network. In light of potential insulation issues with the primary coil, a high-frequency isolated transformer may be inserted between the DC-AC inverter and the primary coil for added safety.

The high-frequency current flowing through the transmitting coil creates an alternating magnetic field, inducing an AC voltage in the receiving coil. By aligning with the secondary compensation network, both power transfer and efficiency witness significant enhancements.

Finally, the AC power is rectified to facilitate battery charging. Figure 3.6 illustrates that a wireless EV charger comprises detached transmitting and receiving coils, typically constructed with ferrite, and shielding structure, along with compensation networks.

Unlike conventional wired chargers, a transformer is replaced by a set of loosely coupled coils. To illustrate the WPT principle succinctly, the coil and compensation network are depicted separately in Figure 3.6, where L1 denotes the self-inductance of the primary transmitting coil and L2 represents the self-inductance of the receiving coil.

The currents in the two coils are denoted as I1 and I2 respectively, while U12 represents the voltage induced in the secondary coil by the primary coil's current. Similarly, U21 denotes the voltage induced in the primary coil by the current in the secondary coil due to coupling, or mutual inductance between the two. S3 and S4 represent the apparent power supplied by the power converter.

S12 and S21 denote the apparent power exchange between the two coils. The specific form of the compensation network is not specified here and will be discussed later. As shown in Figure 7, neglecting coil resistance and magnetic losses, we can derive a simplified expression for the exchanged complex power from L1 to L2.

3.9 Mathematical Model

As shown in Fig.3.6, neglecting the coil resistance and magnetic losses, we can calculate the simplified form of exchanged complex power from L_1 to L_2

$$\dot{S_{12}} = -\dot{U}_{12}\dot{I}_2^* = -j\omega M\dot{I}_1\dot{I}_2^* \quad \text{(Eq.3.2)}$$

$$= \omega M I_1 I_2 Sin\varphi_{12} - jMI_1 I_2 cos\varphi_{12} \quad \text{(Eq.3.3)}$$

$$\dot{S_{21}} = -\dot{U}_{21}\dot{I}_1^* = -j\omega M\dot{I}_2\dot{I}_1^* \quad \text{(Eq.3.4)}$$

$$= \omega M I_1 I_2 Sin\varphi_{12} - j\omega MI_1 I_2 cos\varphi_{12} \quad \text{(Eq.3.5)}$$

In Equation 3.5 I1 and I2 represent the root mean square values, and ϕ12 indicates the phase difference between I1 and I2. The active power transfer from the primary side to the secondary side can be mathematically expressed as

$$P_{12} = \omega M I_1 I_2 sin\varphi_{12} \quad \text{(Eq.3.6)}$$

When ϕ12 = π/2, indicating that I1 leads I2 by a quarter cycle, the maximum power transfer can occur from L1 to L2. The total complex power input into the two-coil system is.

$$\dot{S} = \dot{S_1} + \dot{S_2} \quad \text{(Eq.3.7)}$$

$$= j(\omega L_1 \dot{I_1} + \omega M \dot{I_2}) \dot{I_1^*} + j(\omega L_2 \dot{I_2} + \omega M \dot{I_1}) \dot{I_2^*} \quad \text{(Eq.3.8)}$$

$$= j\omega(L_1 I_1^2 + L_2 I_2^2 + 2MI_1 I_2 cos\varphi_{12}) \quad \text{(Eq.3.9)}$$

The overall reactive power entering the two-coil system is:

$$Q = \omega(L_1 I_1^2 + L_2 I_2^2 + 2MI_1 I_2 cos\varphi_{12}) \quad \text{(Eq.3.10)}$$

Greater magnetizing power leads to increased copper and core losses. Optimizing transformer efficiency involves maximizing the ratio between active and reactive power. This ratio is articulated as:

$$\mathrm{F}(\varphi_{12}) = \left|\frac{P_{12}}{Q}\right| = \left|\frac{\omega M I_1 I_2 sin\varphi_{12}}{\omega L_1 I_1^2 + \omega L_2 I_2^2 + 2\omega M I_1 I_2 cos\varphi_{12})}\right| \quad \text{(Eq.3.11)}$$

k represents the coupling coefficient between L1 and L2. To attain the highest value of f(ϕ12), we solve the following equations:

$$\frac{\partial}{\partial \varphi_{12}} f(\varphi_{12}) = 0, \frac{\partial^2}{\partial^2 \varphi_{12}} f(\varphi_{12}) < 0 \quad \text{(Eq.3.12)}$$

$$cos\varphi_{12} = -\frac{2K}{x+\frac{1}{x}} \; ; \; sin\varphi_{12} = \sqrt{1-\frac{4k^2}{\left(x+\frac{1}{x}\right)^2}} \qquad \text{(Eq.3.13)}$$

By introducing the quality factor of the two coils, denoted as Q1 = ωL1/R1 and Q2 = ωL2/R2, the efficiency of transfer can be represented as:

$$\eta = \frac{I_2^2 R_{Le}}{I_1^2 R_1 + I_2^2 R_2 + I_2^2 R_{Le}} = \frac{R_{Le}}{\frac{(R_2 + R_{Le})^2}{k^2 Q_1 Q_2 R_2} + R_2 + R_{Le}} \qquad \text{(Eq.3.14)}$$

By establishing a = RLe/R2, we derive the efficiency expression as a function of a.

$$\eta(a) = \frac{1}{\frac{a+\frac{1}{a}+2}{k^2 Q_1 Q_2}} + \frac{1}{a} + 1 \qquad \text{(Eq.3.15)}$$

The Peak efficiency is achieved through the solution of the following equations.

$$\frac{\partial}{\partial a}\eta(a) = 0 \quad , \frac{\partial^2}{\partial^2 a}\eta(a) < 0 \qquad \text{(Eq.3.16)}$$

The maximum efficiency is achieved at.

$$a_{\eta\, max} = (1 + k^2 Q_1 Q_2)^{1/2}$$

$$\eta_{max} = \frac{K^2 Q_1 Q_2}{\left(1 + \sqrt{1 + k^2 Q_1 Q_2}\right)^2} \qquad \text{(Eq.3.17)}$$

CHAPTER 4

SCHEMATIC MODEL OF WPT

4.1 Schematic Circuit of WPT

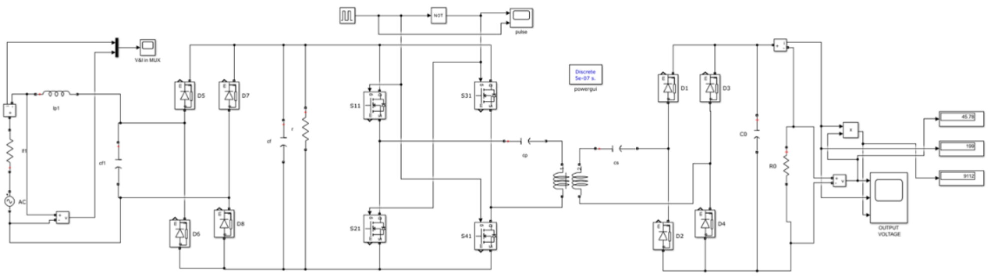


Fig.4.1 Schematic circuit of WPT

Explanation

To ensure the correct flow and increase of current from an AC source, we need to measure and adjust the current accordingly. The fundamental concept for increasing current involves adding a resistor, with its value ranging from low to high. By default, the current lacks in-phase components, so we employ an LC filter to bring it into phase. If the current remains out of phase, the final DC voltage output may be insufficient. In this scenario, the LC filter also functions as an EMI filter.

To enhance output current and maintain a high DC value, a normal diode rectifier block is utilized. Additionally, in simulation scenarios, a resistor across the capacitor serves the purpose of measuring the value without requiring hardware implementation.

The inverter across the capacitor acts as a voltage source inverter, facilitating seamless integration with a full bridge inverter operating at 85 kHz.

The system includes transmitter and receiver coils, which operate based on a resonant circuit. The capacitance values for both primary and secondary sides are chosen to match, ensuring resonance. The coupling inductor's ratio is typically set at 1:1, tailored to optimize voltage output gain.

Initially, the capacitor value is set high to facilitate low frequency on the primary side. Conversely, a lower capacitor value on the secondary side facilitates high frequency, resulting in the desired 48V output voltage and corresponding current.

4.2 Simulation Result of 48V WPT circuit

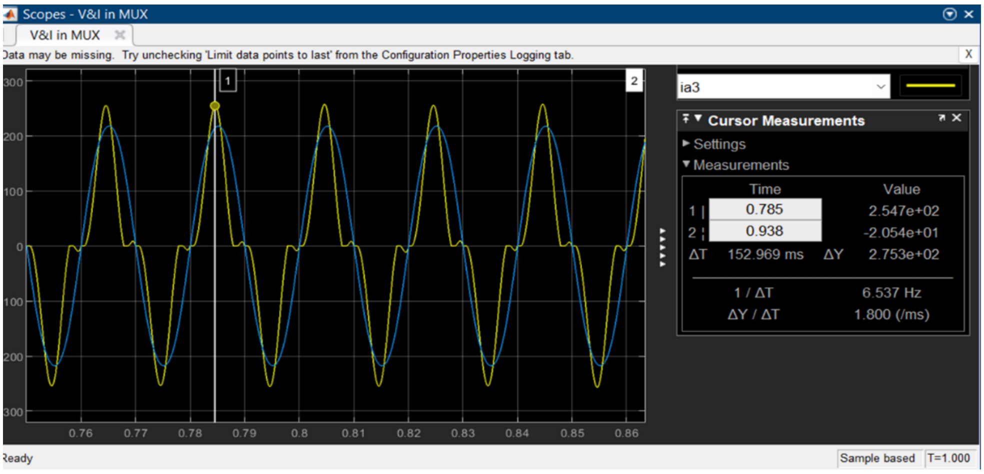


Fig. 4.2: Input Voltage and current of WPT

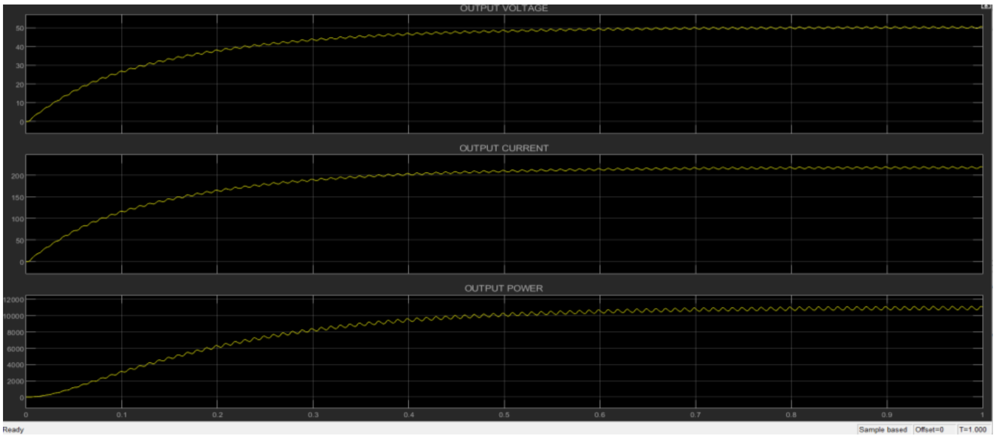


Fig.4.3: Output Voltage, Current and power of WPT

Table:4.1Comparison table of voltage, current and power Variation depends on Coupling coefficient with WPT

K (Coupling coefficient)	Mutual impedance	Voltage	Current	Power
0	0	0	0	0
0.25	71	0.1	0.3	0.03
0.5	140	0.2	1	0.2
0.75	215	0.5	2.5	1.25
0.85	240	1	4	4
0.9	255	2	6.5	13
0.95	270	4	16.3	62
0.98	278	13.5	58	1963
1	280	48	200	9600

In Comparison table of voltage, current and power, it shows how the Coupling Coefficient (K) influences Voltage, Current, and Power. When K increases, Voltage, Current, and Power also increase, showing better energy transfer efficiency.

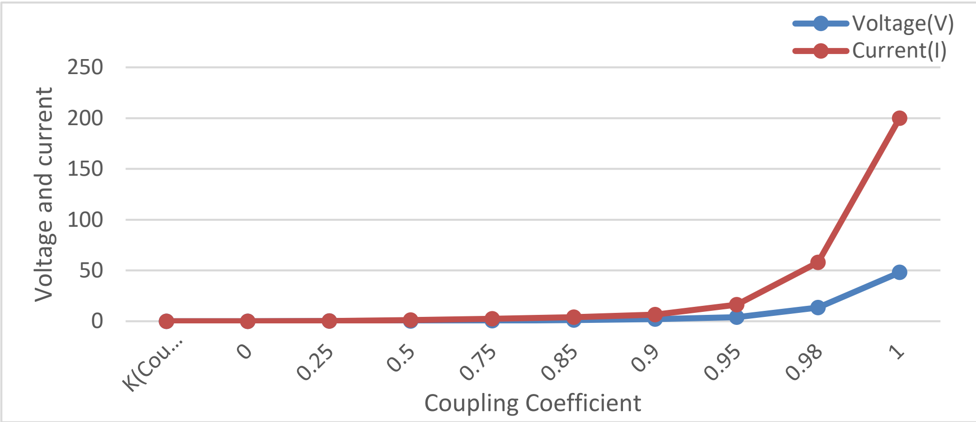


Fig.4.4: voltage and current variation depend on coupling coefficient.

In Figure 4.4, a graph plots Voltage and Current against the Coupling Coefficient. Both lines go up as K increases, indicating that better alignment between coils results in more efficient power transfer. This parameter is crucial in wireless power systems because it determines how effectively energy moves between coils. So, the higher the Coupling Coefficient, the better the power transfer.

CHAPTER 5

HARDWARE MODEL

5.1 Circuit Design

In this project, the focus is on developing a wireless vehicle charger capable of simultaneous data and power transmission. The primary side of the system operates on a utility power source of single-phase 110 V, while the secondary side receives the transferred power from the primary side. Alongside power reception, the secondary side also sends digitalized data back to the primary side through the same conduction coils. To illustrate the concept, a simplified schematic diagram of the proposed system is depicted in Figure.

Initially, the AC grid voltage undergoes rectification via a rectifier on the primary side, utilizing a Flyback converter tuned to the operating frequency of power transfer. Q1 on the primary side ensures optimal efficiency in delivering power, employing the principle of Zero Voltage Switching (ZVS). On the secondary side, Q2 serves two purposes: controlling the output current and transmitting the modulated signal.

Parameter tuning of the LC circuit is crucial at the primary unit. While this tuning relies on the load, it's unnecessary to adjust the resonant system because of the low coupling factor. The operational frequency is determined by.

$$f = \frac{1}{2\pi\sqrt{L_P C_P}} \qquad \text{(Eq.5.1)}$$

Here, Lp and Cp represent the inductance and capacitance at the primary unit, respectively.

5.2 Coil Design

To calculate and design the magnetic component of the system is a key factor of the high efficiency of the transmission of energy and reduce the mass dimensional parameter of the coils. The influence of the design of the geometric parameter on the magnetic field and electrical characteristics of the coil is investigated. Based on the conducted analysis coils with and without a ferrite core are developed and simulated a change in the parameter of the coils in case adding of ferrite coil.

The coupler is a crucial component of the IPT system, comprising the transmitter and receiver coils positioned apart with an air gap between them. The coil structure consists of a copper coil with wire winding. Ferrite pad or bar, shielding plates. The winding is most often made with copper wire to reduce the skin effect especially on medium and high frequency, caused by eddy current. The use of a copper wire also allows reducing the weight and dimension of the inductance coil while maintaining or improving the quality and active resistance value.

To improve the coupling coefficient between the coil and reduce the leakage of the magnetic field. Ferrite pads different shapes are added to the coil flux so that leakage flux can be reduced, and high coefficient of the coupling can be realized. Incorporating a ferrite core enhances the self-inductance, quality, and mutual inductance of the coil, although this could elevate core and copper losses.

The main goal of this is optimization of the coil parameter without reducing their transfer power and checking the influence of the ferrite core on the inductance parameter.

Shielding minimizes the field of leakage and its negative impact on the surrounding material and the impact on the human body. Simultaneously, employing shielding methods to redirect or absorb magnetic fields incurs certain losses, thereby diminishing the overall efficiency of the WPT system. Shielding materials may include magnetic substances like ferrite or metallic materials, commonly aluminum, and can be passive or active.

5.2.1 Selection of coils geometry

Common and practical configurations of IPT inductors consist of circular, square, and rectangular shapes. The outcomes regarding magnetic coupling vary based on the coil area. A circular coil has a higher magnetic coupling for a given coil area, which implies a higher transmission efficiency for the same area-related power density of the IPT coil. This is due to distortion of the field distribution around the corners of the quadrangular coils.

Circular and square shapes provide the highest coupling coefficient when changing the distance between them. Reliable results for most comparable parameters in round coils. In a circular coil, the magnetic field is unidirectional and forms a fountain-like shape above the ferrite. This magnetic field uniformly spreads in all directions, resembling a fountain.

The unidirectional flux pattern aids in minimizing leakage flux. Given a transmitted power of 50 watts, there is no need for additional shielding, particularly when utilizing a ferrite core.

5.2.2 Selection of Pads Shape, Material Type and Need of Shielding

In pad (or core) the coil is fitted or wound on them. There are many variations in geometric shapes and pad types. For circular coils, the most common pads can be flat plate. E and U-shaped. The best shape that directs the magnetic flux is the E-pad. Although flat plate has most simple form and good directs the max.

Material for shielding, guiding, and confining magnetic flux is essential to ensure good coupling as well as to meet the magnetic field absorption limits.

Among core materials, ferrite is preferable because of its high relative permeability and low losses at high frequencies, essential for mitigating the decline in quality factor resulting from core losses compared to aluminum. Its lower saturation flux density allows flux distribution over a larger core volume. However, it's worth noting that ferrites are expensive, fragile, and contribute to the overall volume of the coil.

With shielding. The efficiency of the system can be reduced by reducing the coil inductance and increasing losses, which requires additional compensation capacitance to achieve a resonant state. Shielding can reduce the efficiency of a system by 1-3%.

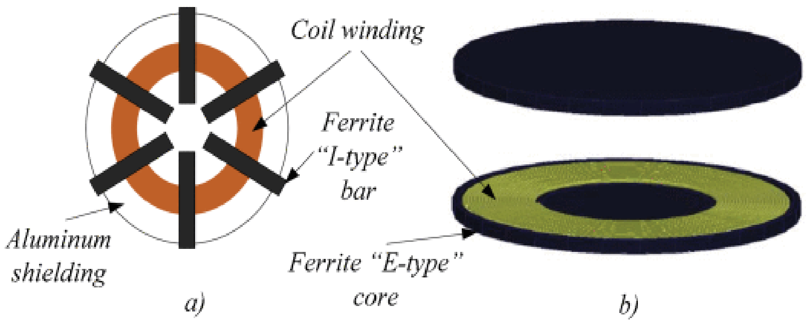


Fig.5.1: Coil structure of WPT
(a)circular pad (b) circular coil with E-ferrite pads

Shielding is especially relevant for electric vehicles where the power is high and respectively field with electromagnetic radiation. Variable magnetic fields induce eddy currents in metal objects, for example in the bottom of the car, which leads to additional losses and heating of the metal.

After selecting the inductor shape, the design and arrangement of windings around the coil must be determined. It's observed that, for a single-layer spiral coil made of copper wire, with fixed internal and external radius.

The outer and inner radii of the circular coil are crucial parameters affecting the coupling coefficient. A smaller inner radius, for a given outer radius, consistently improves magnetic coupling. However, once the inner radius reaches about half of the outer radius, further increasing the magnetic coupling shows diminishing returns. The conductor diameter, distance between turns, and winding separation have negligible impact on the coupling coefficient. Additionally, the primary number of turns and the ratio N1/N2 have minimal effect on the coupling coefficient.

The arrangement of windings and the total length of the copper wire also affect the inductance and resistance of the coil. Increasing the number of turns enhances the quality factor but simultaneously increases resistance. This reinforces the notion that the circular coil should ideally have a small inner radius. These discussed parameters contribute to the development of coils with optimal geometric characteristics.

5.2.3 Design and modelling of circular coil

The structure of the coil is a circular planer winding placed above the cardboard. Circular coil is better than rectangular coil due to its perfect coupling in proper alignment and reduces flux leakage.

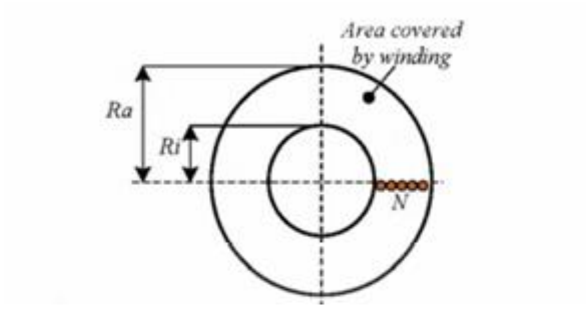


Fig.5.2 Schematic diagram of a main parameters

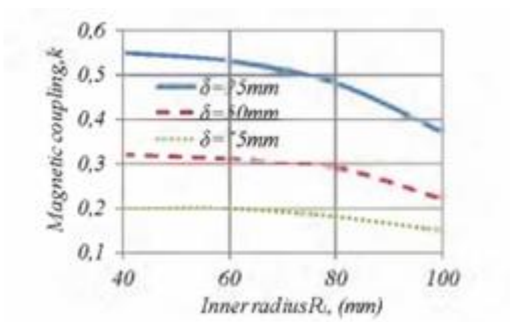


Fig.5.3 The relationship between the magnetic coupling coefficient k and the inner radius Ri of two identical spiral coils with an outer radius of Ra varies, as illustrated for three distinct air gaps.

Let Diameter of copper wire be 0.3mm

Let the parameter of material.

d1=13cm

d2=7.15cm

h=1.5cm

Cross section area of core $s=(d1-d2)/(h/2)$

$s= (8-5.5)/ (4.5/2) =7.8$cm

We require two turns for one voltage.

At primary coil, N1=23 turns

Secondary coil, N2=25 turns

1 Turn requires 14 cm of copper wire.

Required to design a wire winding:

$23\times18=414\sim420\ cm$

$25\times18=450\ cm$

5.3 Hardware Requirements

For the hardware implementation we use different components. They are listed below as

- Inductors
- Resistor
- Lamp
- Driver Circuit
- Coil
- Battery
- PIC Microcontroller 16F877A.

- Voltage Regulators
    - 7812 voltage regulators
    - 7805 voltage regulators
- MOSFET IRF 840
- Optocoupler TLP 250
- Step down transformer 230V/12.
- Capacitor 1000 μF
- Octal buffer IC 74ALS244A/74ALS244A-1
- Diode 4007

i. Controller Circuit PIC 16F877A

The Programmable Interrupt Controller (PIC) is employed to deliver appropriate gate pulses to the eight MOSFETs at precise intervals. Ensuring the correct switching of the MOSFETs is essential for generating the desired sinusoidal waveform. The PIC is programmed to manage the MOSFET switching effectively.

PIN DIAGRAM

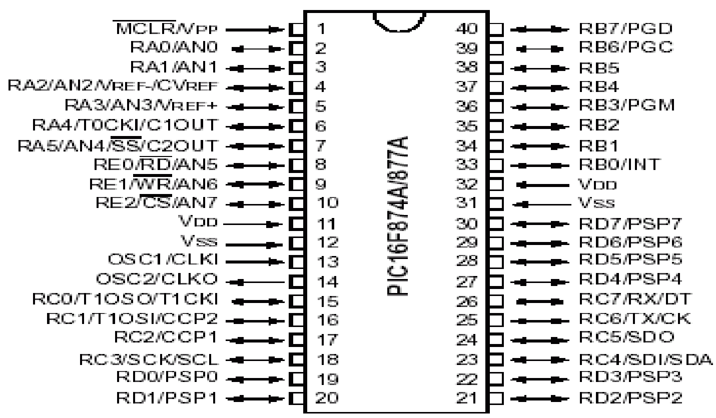


Fig.5.4: PIC16f877a Pin diagram

The PIC16F877A Microcontroller boasts the following features:

- Operating speed: 20 MHz, with a 200 ns instruction cycle.
- Operating voltage range: 4.0-5.5V.
- Industrial temperature range: -40° to +85°C.
- 15 Interrupt Sources.
- 35 single-word instructions.
- All single-cycle instructions except for program branches (two-cycle)

In addition, it offers special microcontroller features such as:

- Flash Memory: 14.3 Kbytes (8192 words).
- Data SRAM: 368 bytes.
- Data EEPROM: 256 bytes.
- Self-reprogrammable under software control.
- In-Circuit Serial Programming via two pins (5V).
- Watchdog Timer with on-chip RC oscillator.
- Programmable code protection.
- Power-saving Sleep mode.
- Selectable oscillator options,In-Circuit Debug via two pins.

The code for the PIC Controller is utilized to deliver accurate gate pulses to the eight distinct MOSFETs at appropriate intervals:

```
#include <xc.h>
#include<pic16f877a.h>
// Configuration bits__CONFIG (_CP_OFF & _WDT_OFF &
_XT_OSC & _LVP_OFF & _PWRTE_ON);
#define COUNT1 0x21

void delay() {
   unsigned char COUNT1 = 1;
   while (COUNT1 != 0) {
      COUNT1--;
   }
}

void main () {
   TRISD = 0x00;     // Set PORTD as output
   PORTD = 0x55;     // Initialize PORTD with 0x55

   while (1) {
      delay ();      // Call delay function.
      PORTD = 0xAA; // Set PORTD to 0xAA
      delay ();      // Call delay function.
   }
}
```

Peripheral Features

- 33 I/O pins organized into 5 I/O ports are available.
- Timer0: An 8-bit timer/counter with an 8-bit prescaler.
- Timer1: A 16-bit timer/counter featuring a prescaler and the ability to be incremented during Sleep mode via an external crystal/clock.
- Timer2: An 8-bit timer/counter equipped with an 8-bit period register, prescaler, and postscaler.
- Two Capture, Compare, PWM modules offering capabilities such as 16-bit Capture input with a maximum resolution of 12.5 ns, 16-bit Compare with a maximum resolution of 200 ns, and 10-bit PWM.
- Synchronous Serial Port supporting two modes: SPI Master and I2C Master and Slave.
- USART/SCI with 9-bit address detection.
- Parallel Slave Port (PSP) consists of 8 bits wide with external RD, WR, and CS controls.
- Brown-out detection circuitry facilitating Brown-Out Reset.

Analog Features:

- 10-bit, 8-channel A/D Converter.
- Brown-Out Reset feature.
- Analog Comparator module comprises two analog comparators, programmable on-chip voltage reference module, programmable input multiplexing from device inputs and internal VREF, and externally accessible comparator outputs.

MOSFET

A cross-section of an n-MOSFET is depicted when the gate voltage VGS remains below the threshold necessary for establishing a conductive channel, resulting in minimal or no conduction between the source and drain terminals, thus keeping the switch off. When the gate voltage becomes more positive, it attracts electrons, inducing an n-type conductive channel in the substrate beneath the oxide, thereby allowing electrons to flow between the n-doped terminals and turning the switch on.

To address the increase in power consumption due to gate current leakage, a high dielectric material is employed instead of silicon dioxide for the gate insulator, while metal gates replace polysilicon. The gate is insulated from the channel by a thin insulating layer, traditionally made of silicon dioxide and later silicon oxynitride.

The IRF840 Power MOSFET switch is utilized. This type of MOSFET, designed to handle significant power levels, shares its operating principle with its low-power counterpart, the lateral MOSFET. Known for high commutation speed and efficiency at low voltages, the power MOSFET is widely utilized in various applications such as power supplies, DC to DC converters, and low voltage motor controllers. Due to its unipolar nature, the power MOSFET can switch at extremely high speeds without the need to remove minority carriers as required with bipolar devices. The primary limitation in commutation speed is attributed to the internal capacitances of the MOSFET, which must be charged or discharged during switching, a process influenced by the current flowing through the gate capacitances limited by the external driver circuit.

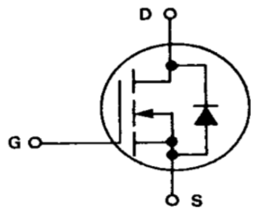


Fig.5.5: IRF840 Power MOSFET Pin diagram

ADVANTAGES

- Silicon gate for fast switching speeds.
- Low R_{ds}(on) to minimize On-losses, specified at elevated temperature.
- Rugged---SOA is power dissipation limited.
- Source to drain diode characterized for use with inductive loads.
- Dynamic dv/dt rating
- Repetitive avalanche rated.
- Fast switching

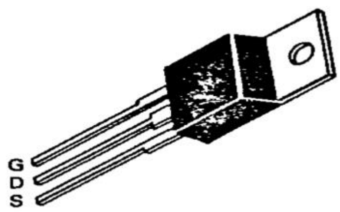


Fig.5.6: IRF840

Table:5.1 Product Summery table of IRF840

PRODUCT SUMMERY	
Vds(v)	500
Rds(on)(ohm)	Vgs=10V,0.85
Qg(max)(nC)	63
Qgs(nC)	9.3
Qgd(nC)	32
Configuration	Single

Third-generation Power MOSFETs offer designers an optimal blend of attributes including rapid switching, robust device construction, minimal on-resistance, and cost efficiency. The TO-220AB package is widely favored across commercial and industrial sectors for applications with power dissipation levels of up to approximately 50 W. Its low thermal resistance and economical packaging contribute to its widespread adoption in industry.

These N-Channel enhancement mode silicon gate power field effect transistors (MOSFETs) are highly advanced, meticulously designed, and rigorously tested to withstand specific energy levels in the breakdown avalanche mode. Tailored for applications such as switching regulators, converters, motor, and relay drivers, as well as driving high-power bipolar switching transistors, they offer high speed and demand low gate drive power. Moreover, these MOSFETs are capable of direct operation from integrated circuits.

Characteristics:

- Maximum drain current (Ids) of 8A, with a drain-source voltage (Vds) rating of 500V and an on-resistance (Rds(on)) of 0.850Ω.
- Single Pulse Avalanche Energy Rated.
- Safe Operating Area (SOA) determined by power dissipation limitations.
- Switching speeds in the nanosecond range.
- Linear transfer characteristics.
- High input impedance.

i. Power Supply

All electronic devices require a power supply to operate. However, the internal circuitry of such devices typically operates on low voltage DC power. Since the standard wall outlet provides high voltage AC power at 230V and 50Hz, there is a need to convert this high voltage AC into low voltage DC. In the following section, we will delve into the detailed block diagram of the power supply.

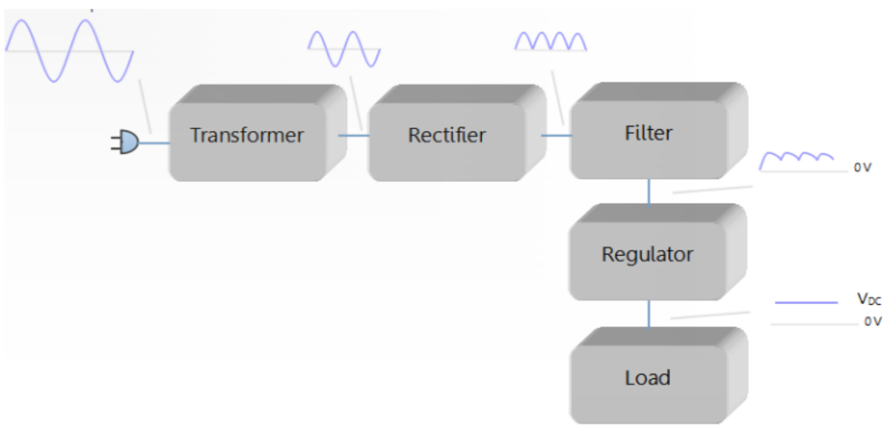


Fig.5.7: Block diagram of Power Supply

ii. AC Input Rectifier

The AC input from the mains undergoes rectification initially through a rectifier. This rectifier typically employs a full-wave diode bridge or module, generating an unregulated DC voltage fed to the Smoothing capacitor. Since the input AC carries voltage pulses that may affect the power factor, control techniques are implemented to ensure that the average input current follows the sine wave.

iii. Inverter

This stage transforms the rectified DC into AC using a power oscillator. The power oscillator incorporates a small output transformer with a few windings operating at a frequency between 20-100 kHz. Switching is managed by a MOSFET amplifier. The resulting AC voltage is often optically isolated from the input AC for safety purposes, achieved by utilizing an optocoupler IC.

iv. Voltage Converter

In this stage, a high-frequency transformer is utilized, and the inverted AC drives its primary windings, generating an alternating voltage at the output. If a DC output is necessary, the AC output is converted to DC through a rectifier circuit employing either Silicon diodes or Schottky diodes (known for fast recovery and minimal loss of current with low forward voltage drop). The rectified DC output is then filtered through a filter section consisting of inductors and capacitors. In some non-isolated SMPS configurations, an inductor replaces the transformer, functioning as either a boost or buck converter. For high-voltage SMPS setups, a Capacitor-Diode multiplier may replace inductors or transformers.

v. Output Regulator

The output stage continually monitors the output voltage by comparing it with a reference voltage using a feedback system. For safety measures, the output stage is isolated by an opto-isolator, as observed in computer SMPS setups. Some SMPS designs may employ open-loop regulation without a feedback circuit, where a constant voltage is supplied to the transformer input.

vi. Rectifier

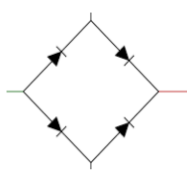


Fig.5.8: Bridge Rectifier

A rectifier is an electrical device designed to convert alternating current (AC), which reverses direction periodically, into direct current

(DC), which flows in one direction only. This conversion process is called rectification. Rectifiers come in various forms, such as vacuum tube diodes, mercury-arc valves, copper and selenium oxide rectifiers, semiconductor diodes, silicon-controlled rectifiers, and other silicon-based semiconductor switches.

While rectifiers are commonly used as components of DC power supplies and high-voltage direct current (HVDC) power transmission systems, they have diverse applications beyond generating DC power. For instance, rectification is employed in radio signal detectors. In gas heating systems, flame rectification is utilized to detect the presence of a flame.

vii. Voltage regulator IC 7805

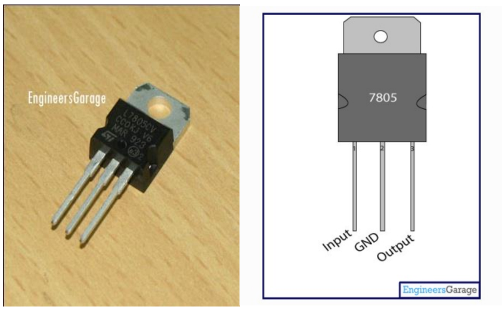


Fig.5.9: Voltage Regulator IC 7805

The 7805 is an integrated circuit voltage regulator that belongs to the 78xx series of fixed linear voltage regulator ICs. These regulators are designed to stabilize the output voltage in a circuit, ensuring a constant voltage level even in the presence of fluctuations in the input voltage.

Pin Description

Table:5.2 Pin description of IRF840

PIN NO	FUNCTION	NAME
1	Input voltage(5V-18V)	Input
2	Ground(0V)	Ground
3	Regulatedoutput:5V(4.8V-5.2V)	Output

viii. Diode

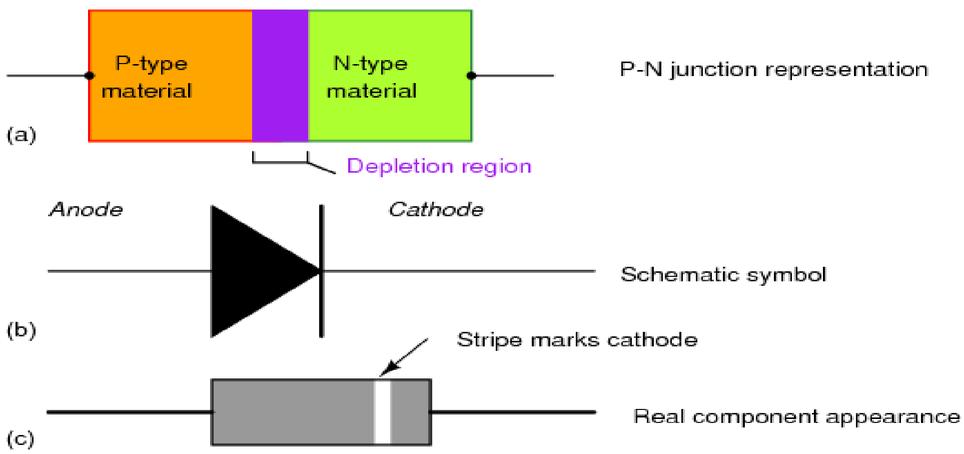


Fig.5.10: Diode

In electronics, a diode is a fundamental two-terminal electronic component characterized by its nonlinear resistance and conductance, unlike linear resistors which follow Ohm's law. The most prevalent type today is the semiconductor diode, composed of a crystalline semiconductor material connected to two terminals. Another type, the vacuum tube diode, consists of two electrodes within a vacuum tube: a plate and a cathode, although it is now rarely used except in select high-power applications. A key function of a diode is to permit electric current flow in one direction, known as forward direction, while blocking it in the opposite direction, referred to as reverse direction. This property essentially acts as an electronic version of a check valve, facilitating rectification, which converts alternating current to direct current and extracts modulation from radio signals in radio receivers.

Despite this basic on-off behavior, diodes can exhibit more complex characteristics. Semiconductor diodes only conduct electricity once a specific threshold voltage is reached in the forward direction, a state termed forward biased. The voltage drop across a forward-biased diode shows minimal variation with current and is influenced by temperature, enabling its use as a temperature sensor or voltage reference. Manufacturers can modify the nonlinear current-voltage behavior of semiconductor diodes by altering semiconductor materials and introducing impurities, leading to the creation of specialized diodes with diverse functionalities. Examples include Zener diodes for voltage regulation, diodes for surge protection in circuits, diodes for tuning radio and TV receivers, and diodes for generating radio frequency oscillations (e.g., tunnel diodes, Gunn diodes, IMPATT diodes). Additionally, some diodes, such as light-emitting diodes (LEDs), produce light when current passes through them. Tunnel diodes are notable for their negative resistance property, which finds application in certain circuit configurations.

ix. Inductor

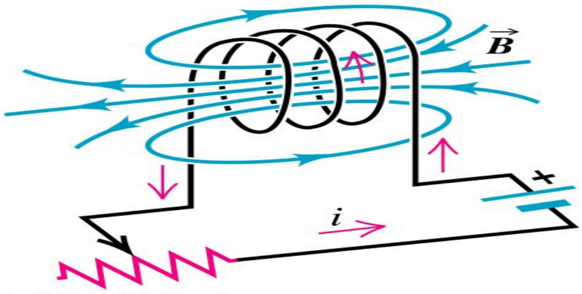


Fig.5.11: Inductor

An inductor, also known as a reactor or coil, is a passive electrical component with two terminals utilized for storing energy in a magnetic field. While any conductor possesses inductance, inductors are typically constructed by winding the conductor into loops to enhance the magnetic field. As the magnetic field inside the coil varies over time, it induces a voltage according to Faraday's law of electromagnetic induction. This induced voltage, in line with Lenz's law, opposes the change in current responsible for its creation. Inductors are fundamental components in electronics, particularly in circuits were current and voltage experience time variations. They have the capability to delay and reshape alternating currents, making them invaluable in various applications.

Inductors, often referred to as chokes, serve as integral parts of filters in power supplies, where they are utilized to block AC signals from traversing through a circuit. Additionally, inductors play a crucial role as energy storage devices in certain switched-mode power supplies. In such systems, the inductor is energized for a specific portion of the regulator's switching frequency and de-energized for the remainder of the cycle. The ratio of energy transfer during these cycles determines the relationship between input voltage and output voltage. This inductance, denoted by XL, is often combined with an active semiconductor device to ensure precise voltage control.

x. Capacitor

Fig.5.12: Capacitor

A capacitor, previously known as a condenser, is a passive electrical component with two terminals used for storing energy in an electric field. Practical capacitors come in various forms, but they all consist of at least two electrical conductors separated by an insulating dielectric material. For instance, a common construction involves metal foils separated by a thin layer of insulating film. Capacitors are extensively employed as components in electrical circuits across a wide range of everyday electrical devices.

When there exists a voltage difference (potential difference) across the conductors, a static electric field forms across the dielectric, causing positive charge accumulation on one plate and negative charge accumulation on the other plate. Energy is then stored in this electrostatic field. An ideal capacitor is characterized by a single constant value known as capacitance, measured in farads. This capacitance represents the ratio of electric charge on each conductor to the potential difference between them.

Capacitance is maximized when there is a narrow separation between large areas of conductor, hence why capacitor conductors are often referred to as "plates," reflecting an early method of construction. However, in practice, the dielectric between the plates allows a small amount of leakage current and has a limit to its electric field strength, leading to a breakdown voltage. Additionally, the conductors and leads introduce undesirable inductance and resistance. Capacitors find widespread application in electronic circuits for blocking direct current while permitting alternating current to pass, in filter networks, for smoothing the output of power supplies, in resonant circuits that tune radios to specific frequencies, and for various other purposes.

5.4 HARDWARE DESIGN

5.4.1 Connection diagram of MCU board and WPT circuit

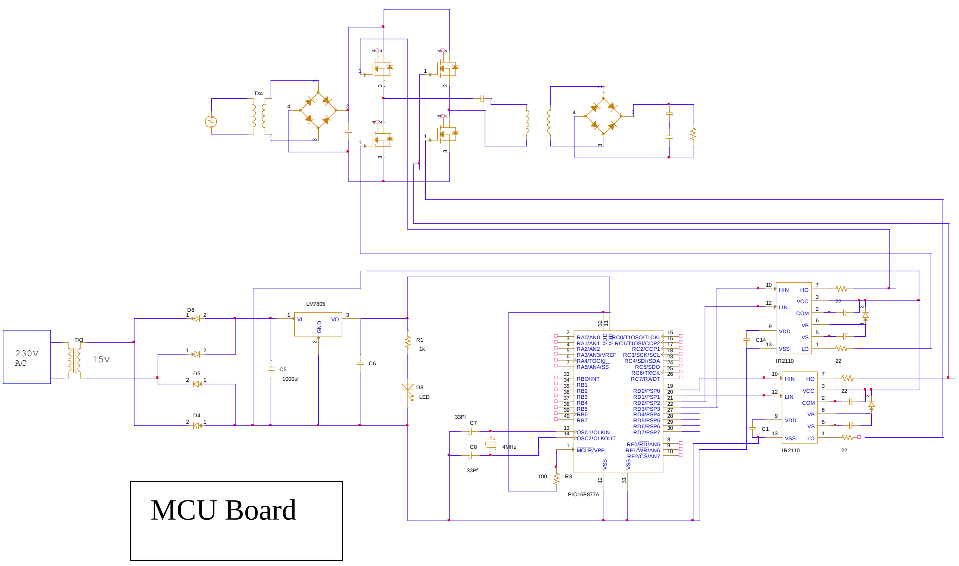


Fig.5.13: Hardware connection diagram of WPT

Circuit Explanation

- The setup begins with a 230V AC power supply (at 50Hz).
- Two transformers are used to step down voltage to 15V and 12V for MCU board and Power inverter board, respectively.
- Then a rectifier circuit is connected to convert AC to DC.
- In MCU board,7805 Voltage regulator is connected which filters the noise from the power supply.
- PIC16F877a microcontroller is used in MCU board to configure the FAN7392 Gate-driver IC and IRF840 MOSFET.
- FAN7392 Gate-driver IC is a monolithic High- and Low-side gate IC, who can drive high speed MOSFETs and IGBTs that operate up to +600V.
- To set 85KHz at power Inverter, we used crystal oscillator which is connected to MCU board.
- The output from MCU board is connected to MOSFETs of inverter board and copper coil of 0.3 mm with 23 turns is connected to output of inverted board.
- The primary coil transfer voltage in wireless medium of 10cm and secondary coil receives it.
- 10. On the secondary side, copper coil with 25 turns is connected to a rectifier circuit and connected to a load.

Table:5.3 Design Parameter of connection diagram

S. No	Description	Specification
1.	Input Voltage	230V
2.	Output voltage	48V
3.	Frequency	85kHz
4.	Output current	0.6mAh
5.	Primary Coil	23 Turns
6.	Secondary coil	25 Turns

5.4.2 Implementation Diagram

Hardware – Primary Circuit

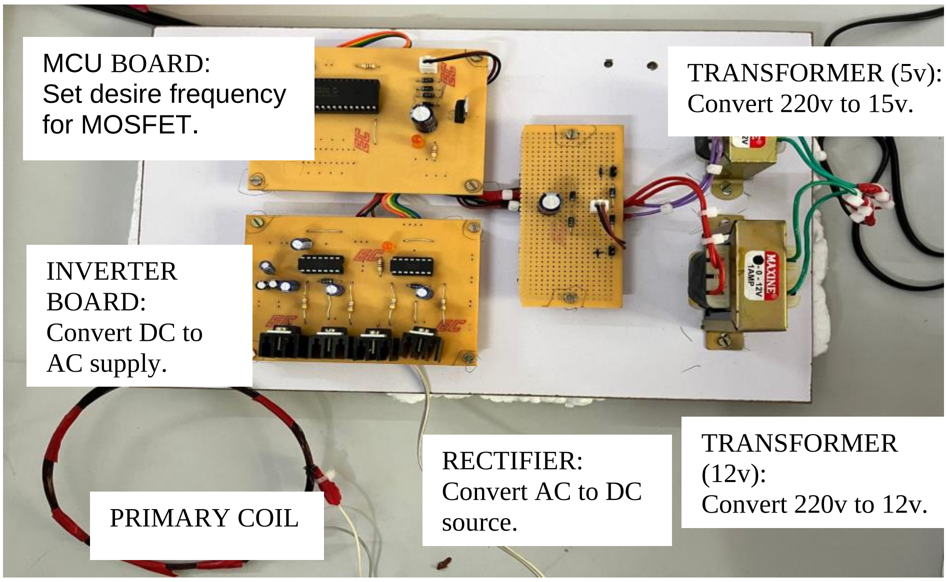


Fig.5.14: Primary circuit of WPT

In this figure 5.14, The Primary circuit comprises several key components, each with specific functions. The MCU Board is responsible for setting the frequency for MOSFETs, crucial for controlling power transfer. The Inverter Board converts DC to AC, generating high-frequency AC essential for induction. The Primary Coil generates a magnetic field when AC passes through, enabling wireless power transfer. The Rectifier converts AC back to DC, for device charging or powering the primary coil. Additionally, Transformers (5v and 12v) step down the voltage from 220v to 15v and 12v respectively, ensuring compatibility with components and devices. Together, these components facilitate efficient wireless power transfer, contributing to the seamless operation of the system.

Hardware - Secondary circuit

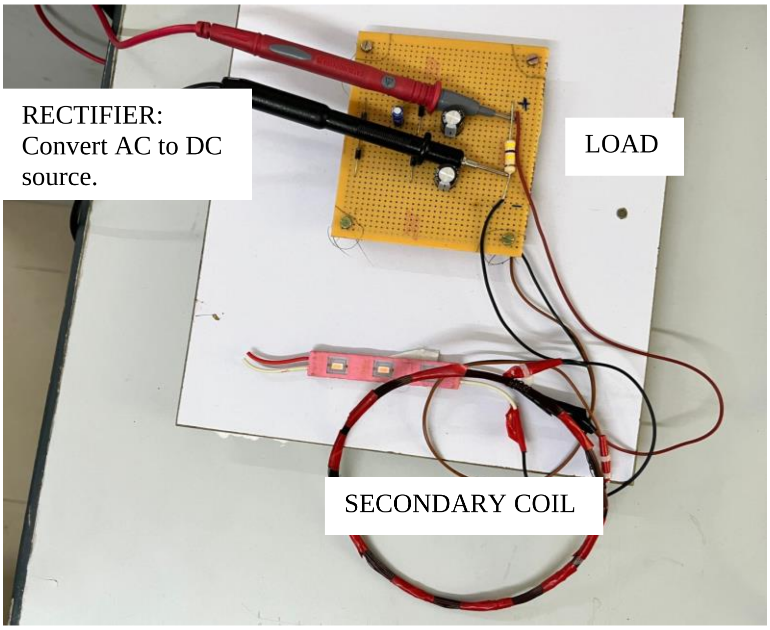


Fig.5.15: Secondary Circuit for WPT

In figure 5.15, you see the secondary circuit of a Wireless Power Transfer (WPT) system. It converts the power sent wirelessly into usable energy. The rectifier is like a converter, turning the incoming alternating current (AC) into direct current (DC) so devices or batteries can use it. The load is whatever is being powered or charged, like a phone or a battery. And the secondary coil catches the magnetic field from the primary coil, turning it into the AC that the rectifier handles. This circuit is essential for making sure the power sent wirelessly gets where it needs to go and can be used by devices.

Overall Circuit Setup

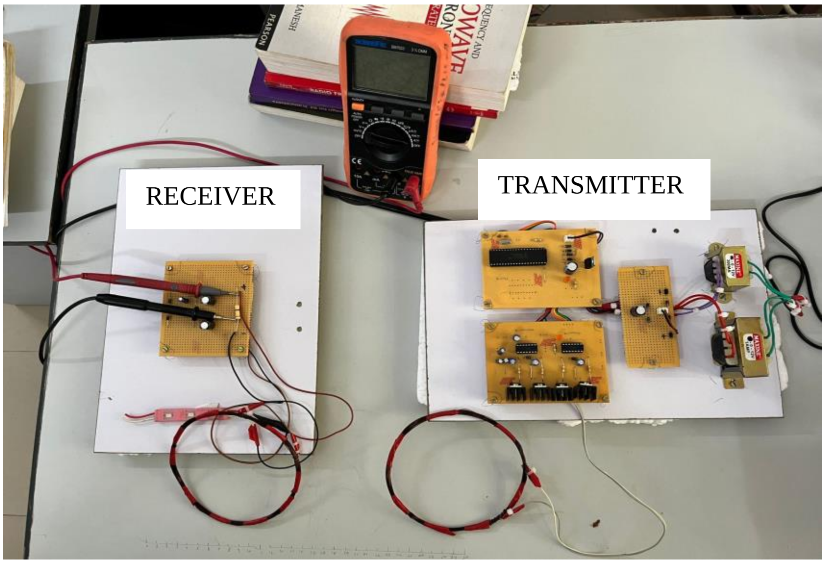


Fig.5.16: WPT Setup

5.4.3 Voltage, Current and Distance relation

Table:5.4 Voltage, Current and Distance relation

DISTANCE (cm)	VOLTAGE(V)	CURRENT (mA)@RL=0.48MΩ)
0	330	0.68
3	238	0.49
4	167.5	0.34
5	132	0.275
6	92.5	0.19
7	63.1	0.13
8	48.5	0.101
9	42.2	0.087
10	35.5	0.073
12	27.6	0.057
14	18.1	0.037
16	11.1	0.023
18	8.3	0.017
20	6	0.012
22	3.9	0.0081
24	3.1	0.0064
26	2.5	0.0052
28	1.9	0.0039
30	1.2	0.0025

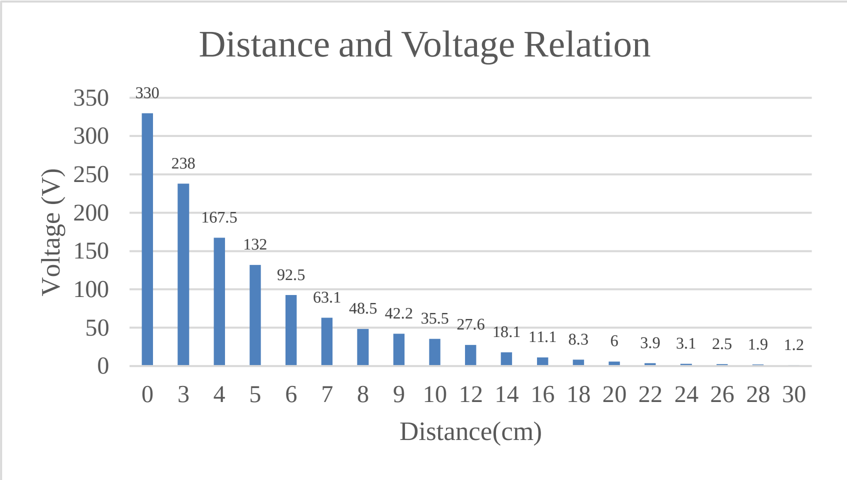


Fig.5.17: Voltage varying with distance of WPT.

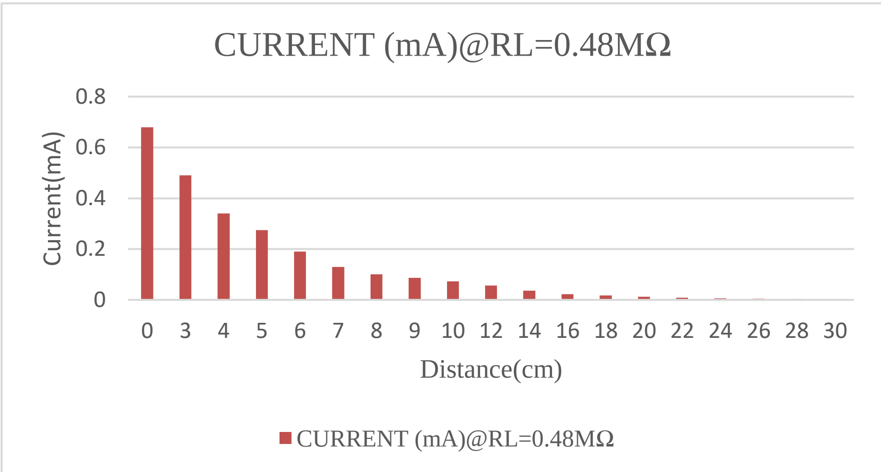


Fig.5.18: Current varying with distance of WPT

As the distance between the coils increases in a Wireless Power Transfer (WPT) system, both the voltage and current decrease. This decrease happens because the magnetic field strength weakens with distance. Consequently, the power transferred is directly proportional to the distance between the coils. In simpler terms, the farther apart the coils are, the weaker the power transfer becomes.

CONCLUSION

A new setup for wireless power transfer (WPT) has been introduced, employing a voltage-fed voltage boost configuration. This fresh design offers a lower inverter output voltage compared to existing parallel LC resonant tank setups, reducing the voltage requirements for switches. This allows for the selection of appropriate semiconductor devices with lower conduction losses for the inverter. By employing fixed duty cycle and variable switching frequency modulation, the inverter switches can dynamically adjust to meet the load's power demands. Furthermore, maintaining a lagging power factor at the inverter output ensures soft-switching turn-on for the inverter switches, even with varying loads. Mathematical analysis has been presented to explain the operation, design, and implementation of this system, which has been validated through simulation results.

In our simulation study of the inductive coupling circuit with a full bridge rectifier, we investigated the impact of varying the coupling coefficient (K) on energy transfer efficiency. Our findings revealed that higher K values improved power transfer efficiency, while lower values introduced challenges. The integration of a full bridge rectifier highlighted nuances in rectification processes, influencing factors such as voltage ripple and rectifier efficiency.

This exploration provides valuable insights for designing and optimizing wireless power transfer systems, emphasizing the need for continued research to enhance efficiency and performance in this evolving field.

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A PROJECT REPORT
(PHASE – II)

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Suryaprakash B (203002113)

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IN

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Department of

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