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DESIGN AND CONTROL OF EFFICIENT WIRELESS ELECTRICAL ENERGY TRANSFER

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Abstract

The wireless energy transfer systems permit the transfer of electricity between electricity networks with wireless connection. The process involves applying AC power to charge a resonant coil, after which the power is sent to the resistive load. An oscillating circuit was utilized to convert DC to AC to create an electromagnetic field by transmitting a frequency and triggering a receiver coil. When the magnetic waves are produced, the voltage is rectified utilizing a rectifier technique, which generates a direct current signal. The designed system communicates electrical power from one place to another utilizing the inductive coupling technique. The electricity applied to the input side communicated through wireless association. The field energy communication is possible via utilizing inductive linking as a wireless energy transmission method. Induction built linking is the process of communicating system to transfer the electricity from one place to other via mutual electromagnetic induction technology. The wireless power communication via induction coupling is an advanced method to transmit power, which has vast potential to modernize the mode and allocate electrical power. The key objective of this study is transmission electrical power from one system to another using the inductive linking method without using any wires. The system constructed via utilizing electrical apparatuses, containing a full wave and inverter circuit. The inductors utilized to transmit or receive energy in waveforms as the wave transmission in the form of electromagnetic. The inductive linking technique of wireless power transfer is a consistent and safe resources of transmitting mechanism. This work utilizes Proteus software to construct and analyze the schematic diagram. This work validates that the coupling technique is practicable and be able to be utilized in numerous applications. Overall, this study demonstrates the possibility of using wireless power transmission and its usefulness in various applications.

INTRODUCTION

Current electric vehicles are integrated with wireless charging systems. High DC and AC systems and power converters are utilized in conventional systems. The transformation of wired based charging system into a wireless charging system improves charging accessibility. This study demonstrates practical and simulation-based outcomes for charging performance. [1]. The wireless energy transfer system reduces carbon footprints, and the utilization of artificial intelligence optimizes the current and improves the wireless transmission efficacy for car charging. The designed prototype improved transmission efficacy and stability. The simulation outcome achieved 90% efficiency with a verified experimental setup to operate at a frequency of 85kHz frequency [2]. The invention of wireless power transmission permits the transfer of energy to the load. The main aim of a wireless energy transfer system is to identify the coupling and power conditions for the optimum solution for energy transfer. This work verified the operating conditions for a wireless energy system [3]. The global transformation towards innovations in wireless energy transfer represents an optimal solution to improve the accessibility and efficacy of electric vehicles compared to conventional systems. This study thoroughly discusses the innovations in the experimental setup for wireless charging using field methodologies, such as capacitive and inductive charging. For the optimal solution, the enhancement in wireless energy transfer was analyzed in this study with parameter verifications [4]. Wireless energy transfer technology needs to be improved using bidirectional wireless energy transmission. The conversion methodologies include resonant circuits and power-management topologies [5]. The laser energy transfer technology has grown rapidly in recent years owing to its environmentally friendly nature. This study compared a conventional system with a wireless system to minimize the loss with less environmental effect [6]. Emergency exit lights are required for safety purposes and utilize lights using wireless microwave energy. This study presents a prototype for wireless-powered emergency lights. The system uses a wireless energy transmission system that includes a DC circuit to operate the system [7]. The consistency of power supply is one of the biggest tasks in Internet of Things-based technologies. The wireless energy system is an optimal solution for efficiently charging low-energy-consuming devices by implementing the IoT. This study focuses on low-complexity constructed systems used for transmitting energy [8]. Advances in Long-Range Wireless Power Transfer: A Review." Kim's recent review explores the latest advancements in long-range wireless power transfer, highlighting its potential for powering devices at considerable distances [9]. Wireless Power Transfer for Drones: Current State and Future Directions." Lee's article provides an overview of the present form of wireless energy transfer for drones and explores potential future directions for the technology [10]. Challenges and Opportunities. Wang et al. discussed the challenges and opportunities of wireless power transfer for biomedical implants, considering safety and efficiency [11]. This review discussed the utilization of wireless energy transfer for self-governing submerged cars (AUVs), emphasizing its potential for extending mission durations [12]. Wireless Power Transfer: Challenges and Opportunities." Liu and colleagues investigate the synergy between 5G technology and wireless power transfer, emphasizing the potential for enhanced efficiency and capabilities [13]. Wireless energy transmission for Electric cars related review article by zhang and colleagues offers a inclusive impression of wireless energy transfer technologies as they relate to electric vehicle charging, a crucial and evolving field The conventional power system needs to be innovated to increase the scalability and consistency of the system. The current upgradation in magnetic energy transmission from power sources, that is, transmitter and receiver, for wireless power transmission system. The wireless system utilizes vehicular, mobile, and different systems via a wireless sensor network. [14]. Scientists are working on power transfer using wireless connections. Innovative technology is mostly utilized by mobile technologies via electrodynamics. The energy transfer system is of three types: metallic, dielectric, and cavity-based resonators [15].

MATERIAL AND METHODS

Methodology:

The methodology of a wireless power transmission project through inductive coupling method comprises different stages that are discussed below:

Building the transmitter: The first step in this system is to design and build the transmitter coil.

The transmitter contains of a wire twisted in a particular design that allows the production of a magnetic linking once an alternating current is move over it. The length and form of the coil depend on the energy supplies and area over which the power is to be linked.

Building the receiver: The receiver was constructed and manufactured via procedure same to that of the transmitter wire twisted, but with shape in shape and length. The receiver performances as a power collector that choices up the field twisted by the transmitter and transforms it back into electrical power.

Power source: A power typically alternating current power supply, is associated to the transmitter. The power source necessity delivers the necessary energy to the transmitter, which is converted into a high current.

Frequency matching: The AC source produced by the power source must match the resonant. This confirms that the transmitter be able to proficiently transmit power to the receiver.

Distance: The length amongst the transmitter and receiver displays an important part in the efficacy of the energy transmission. The distance among the transmitter and receiver is typically conserved inside a few centimeters to a meter to ensure maximum efficacy.

Components:
Stepdown Transformer: The high voltage and low current primary section of the transformer transformed to the low voltage and high current secondary section of the transformer through step down transformer. The transformer work on magnetic coupling scenario and it is an equipment that transform voltage level of electrical energy that transmit from the primary section windings and back to the electrical energy of the secondary transformer Section. Step down transformers are mostly utilized in transmission systems and electrical equipment's for numerous purposes. Step-down transformers are utzilized in this system to decrease the voltage from 220 to 14 Volts AC, which is later utilized in the system for full-wave rectification input.

Table 1 Transformer Technical Specification

S.No.	Parameters	Description
01	Type	Step Down Transformer
02	Input Voltage	220V AC
03	Output Voltage	12V/24V AC
04	Current	3Amp

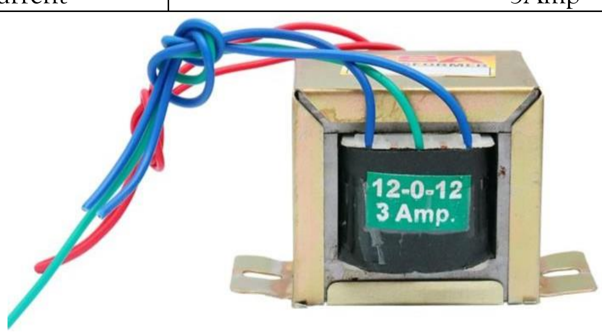

Figure 1. Step down transformer

Bridge Rectifier: It convert the Alternating supply to a Direct current supply voltage by arranging four diodes. Irrespective of the polarity of the input alternating current, the output current of the bridge circuit is continuously the similar. The bridge circuit has its four diodes linked in a bridge configuration. The output is observed across load resistor R when an alternating signal is supplied.

Inverter Circuit:
Inverters or Power inverters are simple electronic circuits that can convert a direct current signal into an alternating current of the desired voltage level The main component of this inverter circuit was the TTC5200 NPN power transistor. It is a silicon NPN triple-diffused-type bipolar power transistor that offers a wide variety of features, including ESD and thermal overload protection. It has a high collector output voltage of 230V. The TTC5200 transistor is typically used in power amplification applications. In this circuit, the fixed VDC can be converted into VAC with the help of a fast switching transistor 5200, and then a 3 pole coil transmits the VAC with the help of mutual induction, and then the process of power transmission ends here.

Table 3. Inverter IC Technical Specification

S.No.	Parameters	Description
01	Type	TTC5200
02	Collector/Emitter Volt	220V AC
03	Power	150W
04	Current	15 Amp

Transmitting coil: Transmitting coils are central components that generate alternating magnetic fields when powered by alternating current (AC). These magnetic fields interact with nearby receiving coils, inducing voltage through electromagnetic induction, allowing wireless electrical energy transfer. Tuning, alignment, and control circuitry are key aspects for optimizing efficiency and adapting power transfer to specific needs.

Table 4. Transmitting Coil Technical Specification

S.No.	Parameters	Description
01	Type	Round Copper Coil
02	No Of Turns	160
03	Diameter	6X6 inches

Receiving Coil: The receiving coil serves as a crucial component with the primary function of capturing and converting the transmitted electromagnetic energy into usable electrical power. Positioned in close proximity to the transmitting inductor, the receiving inductor interacts with the alternating field created by the transmitter. This interaction of magnetic field produces a current in the receiving through electromagnetic induction. Subsequently, this induced current is rectified and used to power electronic devices, charge batteries, or supply energy to various applications, all deprived of the essential for physical energy transfer links.

Mobile Charging Module: The incorporation of a mobile charging module as a load in our project serves the essential purpose of demonstrating the realism and practical application of the proposed system. By utilizing a mobile charging module, it demonstrates the ability to wirelessly power and recharge ubiquitous consumer devices, such as smartphones, which are integral to modern daily life.

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Table 2. Bridge Rectifier Technical Specification

S.No.	Parameters	Description
01	Type	4 Diode Bridge Rectifier
02	Input Voltage	12V AC
03	Output Voltage	11.2V DC
04	Current	2Amp

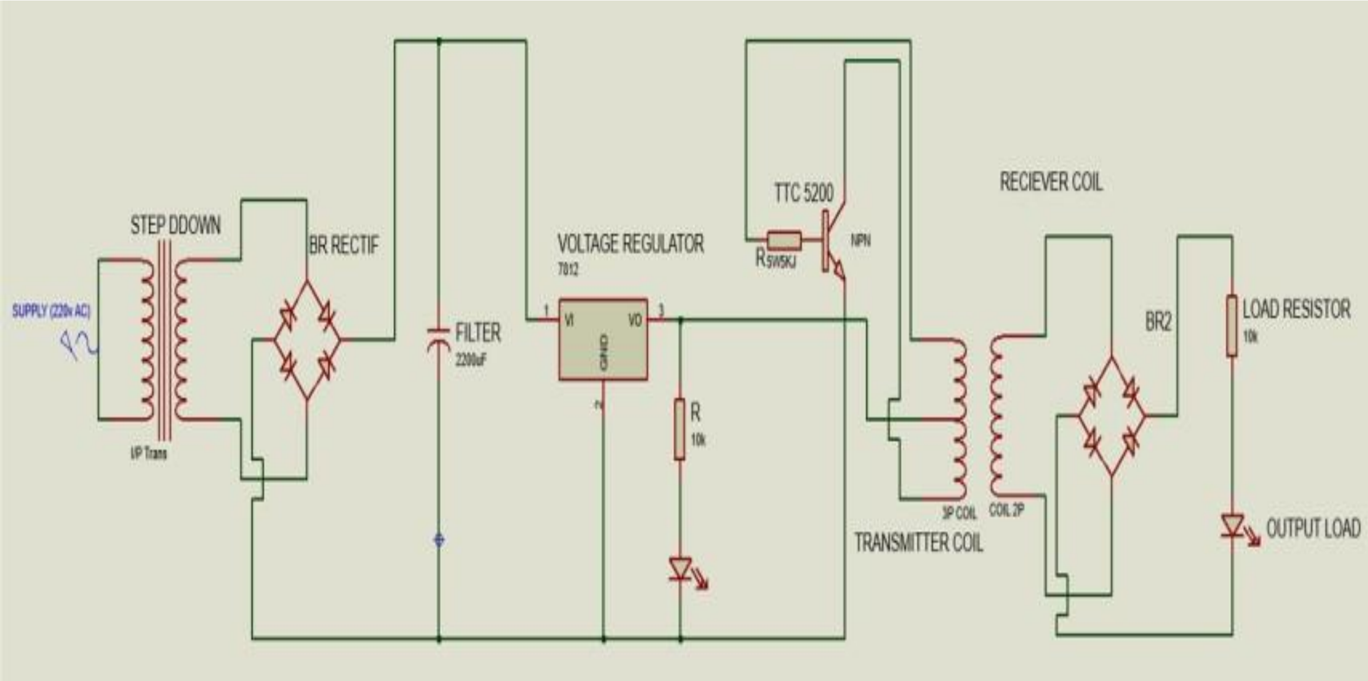

Figure 2. Schematic Diagram

Schematic Diagram: Figure 2 demonstrations the circuit diagram of the proposed wireless energy transmission system designed utilizing Proteus software to construct and analyze the parameters via simulation-based results.

The results indicate that is accurate, and the voltage and current parameter comparison is presented in figure 3.

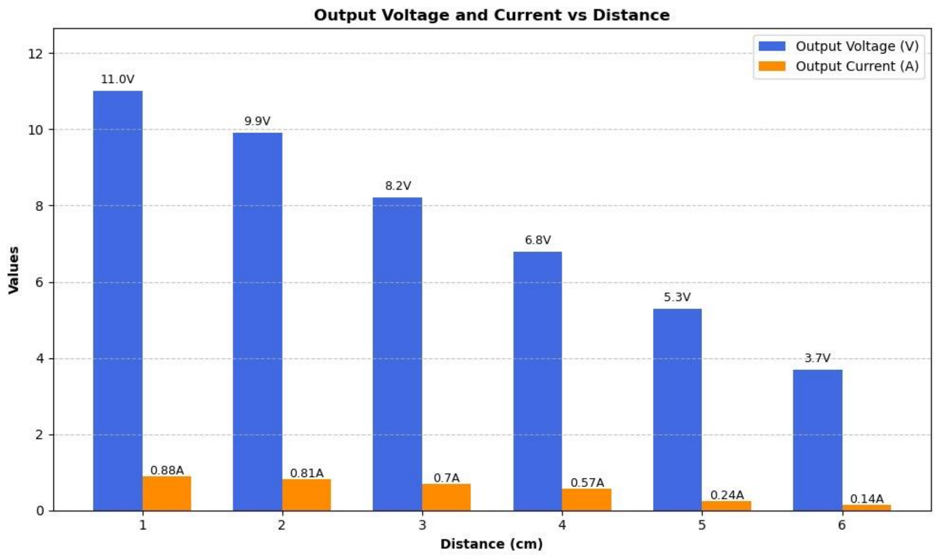

Figure 3. Schematic Diagram

Mathematical Model:

$$\mathbf{Vd} = \mathbf{Vin} - \mathbf{Vout}$$

$$E = \frac{Vout}{Vin}\ x\ 100$$

Where
V_d = Voltage Drop
Vin = Input Voltage
V_{out} = Output Voltage
E= Efficiency

RESULTS AND DISCUSSION

In this prototype, the system transmits electric energy from one place to other place utilizing the inductive coupling technique. The input 220 Volt AC stepdown transformer transformed into 15 Volt alternating current and then changed into direct current utilizing a bridge circuit. A 7812 voltage regulator utilized to control the voltage to fix 12 Volt DC and applied to the inverter IC ttc5200, and then AC voltage was applied to the transmitter. On the other hand, the receiver receives the and a bridge circuit is installed to rectify the AC voltage to DC voltage and provide wireless transmission via the coupling method.

Energy Efficiency: The system is energy-efficient and robust, providing an innovative paradigm of low energy consumption. The system transmits power efficiently. Furthermore, the integration of IoT-based technologies tracks the energy and measures the parameters for the integrated devices.

Constraints: Wireless power transmission using inductive link is a technique of wirelessly transferring energy between two objects using a magnetic field. However, this technology has several constraints that limit its practical applications. Some of these constraints are as follows:

1. Short Range: The inductive coupling method is effective only at a short range of a few centimeters to a few feet. This constraint limits the usefulness of this technology for powering devices over long distances.
2. Directionality: The transmission of power using an inductive linking technique necessitates physical arrangement between the transmitter and the receiver. If the arrangement is not proper, the power transmission efficacy is condensed, creating it an unproductive power transmission technique.
3. Efficiency: The efficacy of the inductive linking technique is lessening than that of cable energy communication. Due to the power sufferers involved in wireless energy communication, only a fraction of the interconnected power is distributed, resultant in power wastage.

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4. Temperature: Inductive linking reasons heat generation in matters due to closeness. Consequently, the scheme necessity to constructed in such technique that it be able to grip this heat generation.
5. Interference: Magnetic interference after the natural resources be able to affect the proficiency and consistency of the inductive coupling technique. This interference be able to create from additional electronic equipment's or inductive charging systems.

Prototype Testing: The last step in the testing involved to measure the the efficacy and effectiveness of the wireless power communication scheme. Diverse testing approaches, such as the quantity of transmission productivity and power output, were utilized to evaluate the productivity of the scheme. The procedure of wireless electricity communication via inductive link technique involves scheming and construction the transmitter and receiver, confirming frequency matching and an appropriate power. The attainment of the system depends on correct scheme of the coils, frequency matching, and verifications, primary to the development of wireless power communication system. During the testing phase, the system measures the effectiveness and process of the system. The test cases are presented in table 5,6, 7 and 8.

Table 5: Prototype Testing Case 1

Preconditions	Wireless power transfer system is powered on
Actions	Activate the prototype
Expected Result	System Start
Result	Pass

Table 6: Prototype Testing Case 2

Preconditions	Circuit and sensors are loaded
Actions	Activate the circuit and sensors
Expected Result	The circuit and sensors working accurately
Result	Pass

Table 7: Prototype Testing Case 3

Preconditions	Wireless power transfer system components testing
Actions	Testing procedures
Expected Result	System tested
Result	Pass

Table 8: Prototype Testing Case 4

Preconditions	System operation
Actions	Activate the system
Expected Result	The system working accurate and timely transfer power

Result	Pass

System Interface: Figure 4 displays the hardware employment of the projected power transmission system.

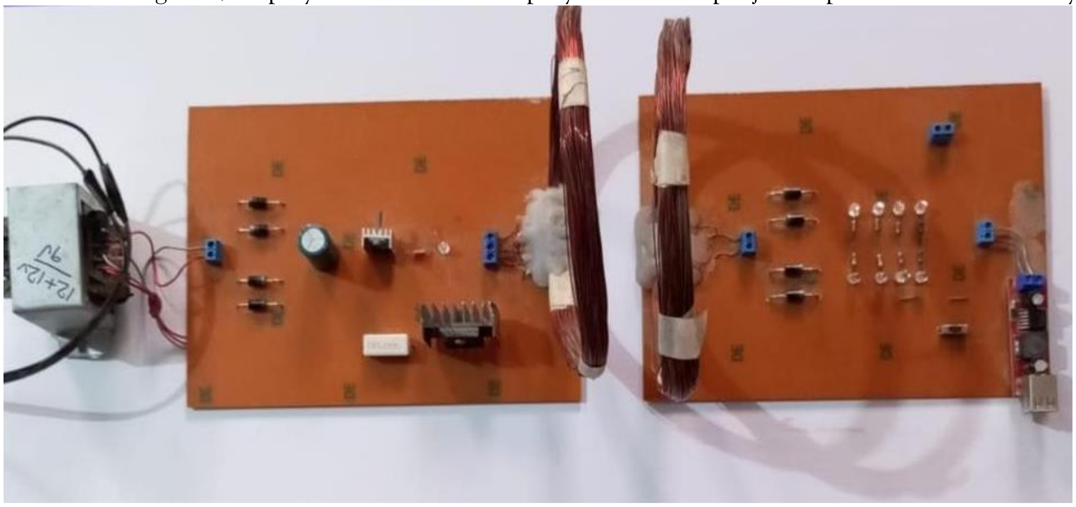

Figure 4. System Interface

CONCLUSION

In the conclusion the wireless energy communication utilizing the inductive link technique is created on the standardized way to manage the field that can energized a scheme with wireless transmission. Precisely, wireless electrical communication utilizing inductive linking relies on two coils, a transmitter and a receiver inductor, to generate a field. The user interface for a wireless electricity communication scheme uses inductive coupling. The scheme includes a transmitter coil, receiver coil, and supporting components such as capacitors and resistors. The wireless electricity transmission utilizing the inductive linking technique system aims to distribute electrical energy wirelessly via electromagnetic waves without using any physical wires. This work utilized Proteus software to simulate the circuit schematic diagram and analyzed its functionality previously constructing the actual circuit. The method contains designing a transmitter network that switch the AC signal to a transistor that drives a primary inductor wire. The receiver circuit consists of a rectifier circuit that transforms the alternating signal from the secondary coil into a direct current signal and a capacitor that smoothens the output voltage. The conclusion of the study is that wireless power communication utilizing the inductive coupling technique is a well-organized and protected way to communicate power wirelessly. The system demonstrated the feasibility of the process, which be able to be utilized in numerous applications, containing medicinal and engineering applications. Generally, the prototype validates the option of utilization and transmission of power in a wireless mode. Further integration of IoT and machine learning techniques improves the system stability and consistency.

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