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Towards the Nature of Wireless Power Transmission System

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***Abstract* - In the modern era, efficient ways of transfer of data and energy are indispensable components in daily lives. Wireless data transmission has become a ubiquitous approach in recent years, enabling seamless energy transfer technology. Various efforts have been endeavored to unlock the potential of wireless energy transmission, achieving significant progress in its implementation. However, a major impediment persists in the limited distance over which wireless energy can be effectively transmitted. The present work explores the innovations and perspectives surrounding wireless power transmission systems, delving into the advancements made so far and addressing the challenges that limit its widespread acceptance. Also, this work examines the impact of using multiple coils in a Tesla-based model on power transmission distance, as well as to compare this method with a conventional power transmission approach. Furthermore there are plenty of applications of wireless power transfer to explore. Key words: Wireless power transfer, Wireless charging, charging flexibility, Energy Transfer, electromagnetic induction.**

Keywords: Wireless Power Transmission, WPT, Tesla-based model, Power transmission.

I. INTRODUCTION

In today's rapidly advancing technological landscape, the shift towards wireless solutions is becoming increasingly prevalent, from smartphones to electric vehicles [5]. The Transfer of power in a reliable and efficient way is always challenging as per accuracy and design is concerned [5]. Wireless power transmission (WPT) [10], [15], gains much attention, with ongoing research efforts aimed at discovering new methods for transmitting power over long distances. Although the field of WPT is vast and still holds many unexplored possibilities, many research papers [10], [15] delve into some of the most promising studies, discussing their advantages, disadvantages, and overall effectiveness of the system. Presently, most of the electrical power is transferred by the uses of traditional wires and cables. The major issues in these types of systems is the handling difficulty and the losses due to resistance of the material used. Generally the percentage of loss of power during this type transmission is high if length of the wire increases [5]. A convenient non-contacting charging solution for the issue is the WPT, which can be applicable from low-power devices to high power devices. In the case of electrical charging the WPT revolutionized the way of charging compared to conventional charging methods. The main advantage of WPT is the elimination of wire contacts, messy wires, compact design and high portability etc. [14]. Also WPT methods can be more reliable where wire connection finds to be dangerous, inconvenient and not practical [14]. In this regard, the present work aims to give an overview of the current scenario of the WPT methods and an approach to apply Tesla's idea of wireless transmission [5] to study. One of the key objectives of our project is to explore the feasibility of utilizing multiple coils, numbering four in this case, to enhance the efficiency and range of wireless power transmission. By employing multiple coils operating at the same frequency, the present work aims to generate large waves directed towards specific targets, thereby optimizing energy transfer over extended distances.

II. LITERATURE REVIEW

The concept of WPT has an earlier origin with groundbreaking contributions from Nikola Tesla [5]. Since then, there has been continuous progress in improving the efficiency, range, and practical applications of WPT systems, as researchers have sought to overcome the limitations of traditional power transfer methods. The idea of wireless power transmission has fascinated researchers for decades. Wireless data transmission has already applied for energy transmission in electronic devices and remains a major focus for innovation and advancements. The WPT is an innovative technology that is quickly being adopted across various industries and consumer markets. As the global market shift towards hassle free systems accelerates, WPT is driving advancements in flexibility, convenience, and technological innovation. The system [1] presents the design of a high frequency wireless power transfer system (HFWPT) to reduce power transmission complexity. It can be expected that the high frequency

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resonance coupling will improve the efficiency of transmission allowing one to transmit at a lesser frequency which is nearly in a range of few kHz [1]. WPT charging technology has the potential to bring about a positive change in mindset of people regarding Electric Vehicles (EV) make the charging process automated, convenient and safe for users and large scale introduction of WPT charging infrastructure can help reduce the battery pack size and in turn make the EVs more efficient and WPT charging through large air gaps and least possible human interaction are required [14]. Also, [7], [13] presented an idea about the method electrical energy can be transmitted as microwaves so that a reduction in the transmission, allocation and other types of losses can be achieved [7]. WPT is also playing a key role in the development of smart cities and the Internet of Things (IoT). In smart cities, wireless power can enable a wide range of applications, from powering streetlights and traffic signals to providing energy for public transport systems and smart homes. In the IoT ecosystem, thousands of interconnected devices such as smart sensors, wearables, and household appliances can be wirelessly powered, enhancing connectivity and reducing dependency on batteries. This creates a more efficient and sustainable urban environment.

WPT has the potential to revolutionize space exploration by providing power to satellites, space stations, and spacecraft without requiring physical connections. The use of microwave-based or laser-based WPT can transmit power over vast distances in space, enabling the recharging of space equipment and robots on planetary surfaces.

Not only are smartphones equipped with this technology, but various other devices like laptops, TVs, radios, gaming controllers, and wireless speakers are also transitioning to wireless solutions [12]. This trend reflects the growing demand for convenience and the removal of cables and connectors. Through the integration of Tesla's principles and contemporary advancements in electromagnetic theory, the current system endeavors to overcome the limitations of conventional wireless power transmission systems. By elucidating the intricacies of our approach and highlighting its potential implications, this research aims to contribute to the ongoing discourse on wireless power transmission and pave the way for future innovations in this transformative field.

III. TYPE OF TRANSMISSION

Electromagnetic Induction:

One of the earliest methods of wireless power transmission, electromagnetic induction, dates back to the pioneering work of Michael Faraday [11]. This principle involves the transfer of energy between coils through the generation of magnetic fields. While effective over short distances, electromagnetic induction faces limitations in scalability and efficiency, particularly over longer ranges [11].

Resonant Inductive Coupling:

Building upon the principles of electromagnetic induction, Resonant Inductive Coupling (RIC) emerged as a promising approach for WPT [11], [13]. By resonating the transmitter and receiver coils at the same frequency, RIC systems achieve higher efficiency and extended ranges compared to conventional inductive methods. However, challenges such as alignment sensitivity and electromagnetic interference persist, limiting widespread adoption.

Microwave Power Transmission:

Microwave power transmission (MPT) [11], [13] offers an alternative method for wireless energy transfer, utilizing electromagnetic waves in the microwave frequency spectrum. MPT enables power to be transmitted over longer distances with relatively high efficiency [11]. However, issues related to electromagnetic radiation exposure and the necessity for precise beamforming present practical obstacles to widespread adoption.

Laser-Based Power Transmission:

Laser-based power transmission (LBPT) offers a novel approach to wireless energy transfer, utilizing focused laser beams to transmit power across distances [11], [13]. LBPT systems exhibit high directionality and efficiency, making them suitable for targeted energy delivery. However, atmospheric attenuation and safety considerations remain significant hurdles for practical deployment [11].

While each of these existing technologies offers unique advantages and applications in wireless power transmission, they also present distinct limitations and challenges. A comparative analysis by [6], [11] shows that even though there are various techniques to enhance the performance of WPT, still the full potential of WPT is not explored or utilized fully [11]. This work tries to address these shortcomings by exploring innovative approaches, such as leveraging multiple coils and optimizing frequency utilization, to enhance the efficiency and range of wireless energy transfer systems. Through a comprehensive analysis of existing methodologies and the development of novel solutions, aims to contribute to the advancement of wireless power transmission technology.

Current Status of the Wireless Power Transmission (WPT)

WPT technology, which enables the transmission of electrical energy without physical connections or cables, is experiencing significant growth across various sectors. Currently, the market for WPT is expanding rapidly, driven by

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rising demand for wireless charging solutions in consumer electronics, electric vehicles (EVs), and industrial applications.

1. Global Market Overview:

The global WPT market has seen remarkable progress in recent years, primarily due to increasing adoption in smartphones, wearable devices, and electric vehicle (EV) charging systems [6], [11]. According to industry reports, the market is expected to witness substantial growth in coming years.

2. Regional Insights:

As the largest market for wireless power transmission, of the global market share. The widespread adoption of WPT in countries is driven by the high demand for consumer electronics, increasing government investments in electric vehicle charging infrastructure, and advances in manufacturing technologies [3].

WPT market is growing rapidly, particularly in the fields of electric vehicle charging and smart home devices. The focus on renewable energy, smart cities, and advanced manufacturing processes has accelerated with the adoption of WPT technologies [8].

3. Applications and Market Segments:

Consumer Electronics: Wireless charging is becoming a standard feature in devices like smartphones, smartwatches, and other portable electronics [11]. Leading technology manufacturers have incorporated WPT into their devices, providing users with convenient charging options that do not require physical connectors [11].

Electric Vehicles (EVs): One of the most promising applications of WPT is in the electric vehicle industry. Wireless charging solutions for EVs are gaining popularity, offering convenience, safety, and enhanced user experience [5].

Industrial and Medical Applications: In industrial environments, WPT systems enable the transfer of power without cables in harsh conditions, where wires could be damaged or present safety hazards [4], [9].

IV. METHODOLOGY

The WPT system developed for this work is based on principles derived from electromagnetic wave propagation and interference patterns. The experiment focuses on exploring the potential effects of using multiple transmitting coils to increase the efficiency and range of power transfer. However, it is important to note that this is an exploratory experiment and, while informative, did not fully meet the initial expectations for optimizing transmission distances, which need further trials.

Concept of Wave Propagation

The present WPT system fundamentally relies on electromagnetic waves that radiate from a transmitter to a receiver. These waves behave similarly to water ripples when a stone is dropped into a pond, spreading outwards from the point of origin. By using multiple transmitting coils in an attempt to guide and enhance the transmission of electromagnetic energy towards a specific receiver, and thereby focusing the waves in a particular direction.

Use of Multiple Coils and Constructive Interference

The system employed multiple transmitting coils (See Fig 1) to investigate constructive interference where two or more waves combine to increase overall amplitude, which thereby increase the transmission distance. The idea is that by aligning coils to emit electromagnetic waves at the same frequency, the waves would constructively interfere, creating a stronger and more focused wave front. This process is similar to how two overlapping water waves can create a larger wave when their peaks coincide.

Figure 1: Copper primary coils

To achieve this, coils were synchronized to ensure that the emitted waves reinforced one another in the desired direction. The goal was to focus the energy more effectively towards the receiving coil, with the expectation of improving

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transmission efficiency and range. In theory, this method should have allowed for greater energy transfer over longer distances by concentrating the electromagnetic waves along a specific path. The system methodology provided valuable insights into the challenges and possibilities of wireless power transmission using multiple coils. Although the results did not fully meet the initial expectations, the experiment underscored the complexity of achieving constructive interference (See Fig 2) and efficient energy directionality in a practical setup. Further research and refinement, including better synchronization techniques and focusing devices, may unlock new ways to enhance wireless power transmission.

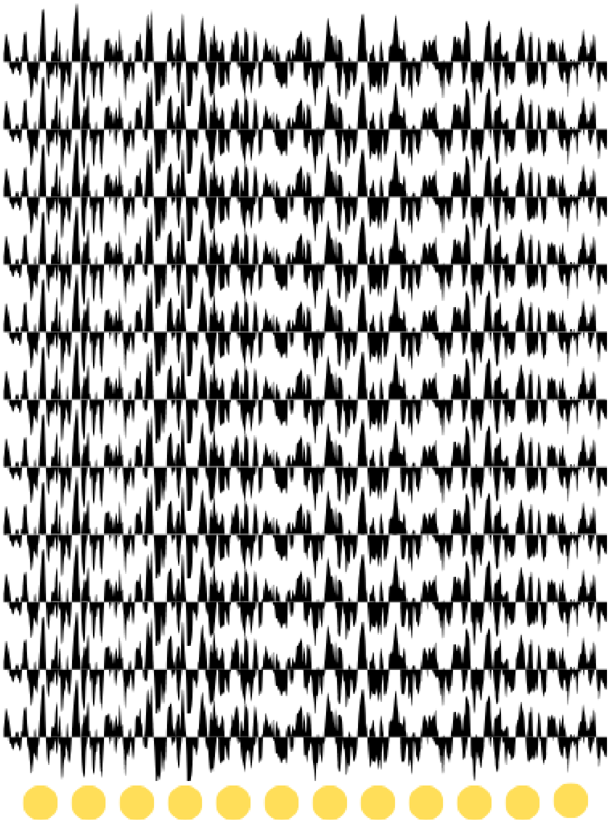

Figure 2: Sequence of electromagnetic waves while using multiple coils

Components:

The main components of the WPT system are as follows:

1. Diode (10 to 22 ohm)
2. Copper wire for primary coil
3. Button
4. PCB board
5. Power supply
6. 12V power connector
7. LED
8. BD2430 transistor
9. Connecting wire
10. Heat sink

V. RESULT AND DISCUSSION

While the concept of constructive interference (See Fig 2) and the use of multiple coils (See Fig 1) seemed promising, the experimental results revealed that the anticipated gains in transmission range and efficiency were not as significant as expected. The setup demonstrated some level of energy concentration, but various factors such as coil alignment, signal phase coherence, and energy losses limited the effectiveness of the system. In practice, perfect synchronization and constructive interference were difficult to achieve consistently. Misalignment between the coils or even slight phase differences between the emitted waves led to destructive interference in some cases, reducing the efficiency of energy transfer. Additionally, energy dispersion in unintended directions was observed, which diluted the overall power reaching the receiver. The system also explored wave-focusing mechanisms, similar to how a magnifying glass concentrates light. The use of electromagnetic wave focusing devices showed potential for directing energy to specific points, but further optimization is needed to fully realize this capability. The practical limitations in achieving precise focusing with the available equipment highlighted areas for future improvement. The prototype of our wireless power transmission system consisted of four coils (See Fig 3), strategically placed to transmit energy wirelessly. Initial testing revealed that the transmission distance was limited, with the system only able to power a light when it was in close proximity to the coils (See Fig 4).

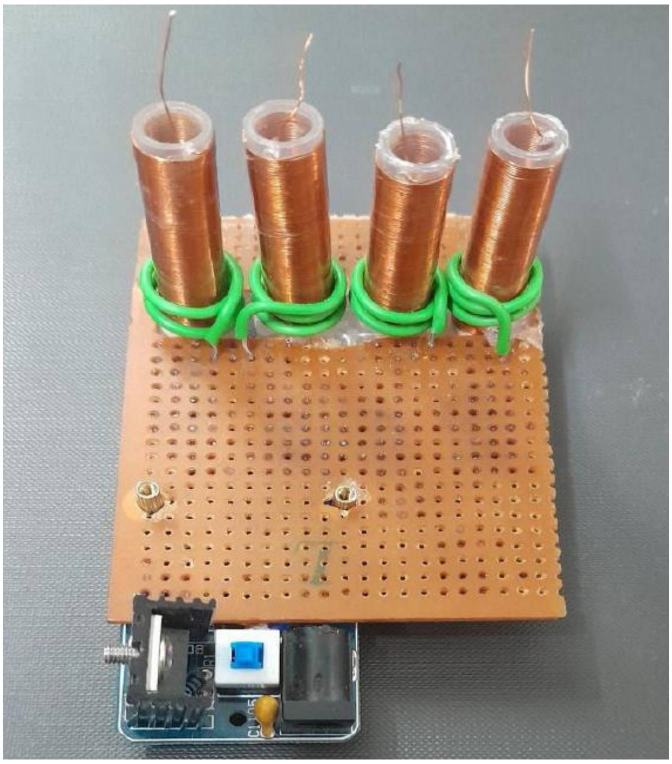

Figure 3: prototype image

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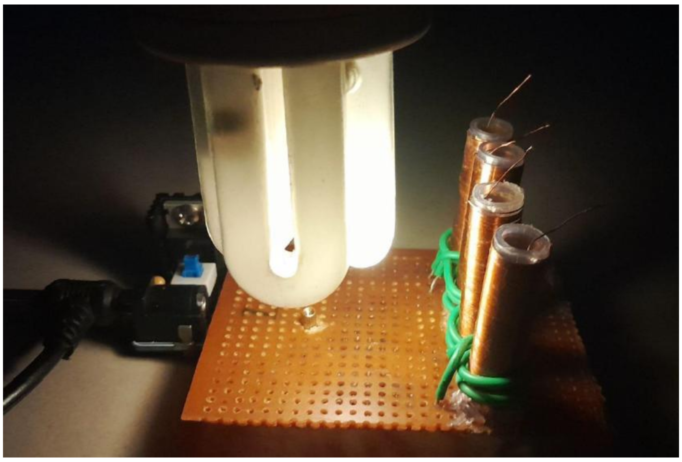

Figure 4: Test experiment images

However, the results indicated that increasing the number of coils operating at the same frequency could potentially enhance the power transmission in a particular direction. Further experimentation is required to optimize the system and improve its efficiency for practical applications.

VI. FUTURE ENHANCEMENTS

WPT holds great promise as advancements in technology definitely continue to push the capability of the basic idea with further technological innovation, electric vehicle revolution development. In future iterations of the present system, is to conduct experiments on a larger scale to explore its capabilities further. By scaling up the work to achieve better results and address the limitations observed in the initial prototype. Additionally, to focus on incorporating new methods and technologies to extend the distance of wireless power transmission, thereby enhancing its practicality and usability in various applications.

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