

Optimizing Energy Efficiency in Wireless Power Transmission Systems for Industrial Applications

Dr. Sandeep Reddy^{1*} and Priya Mohan²

^{1*}Department of Mechanical Engineering, Dhanalakshmi College of Engineering, Chennai, India.

²Department of Mechanical Engineering, Dhanalakshmi College of Engineering, Chennai, India.

Abstract--- Optimizing energy efficiency in wireless power transmission (WPT) systems is crucial for industrial applications, where energy consumption directly impacts operational costs and sustainability. Wireless power transmission offers a convenient and scalable solution for powering industrial equipment without physical wiring. However, existing WPT systems face significant challenges, including low transmission efficiency over long distances, interference from surrounding environments, and the high cost of energy loss during the transmission process. These limitations hinder the widespread adoption and effectiveness of WPT in industrial settings. To address these issues, the proposed method introduces the Industry-Based Wireless Power Transmission (I-WPT) system, a novel framework designed to enhance energy efficiency in industrial applications. The I-WPT system incorporates advanced algorithms and optimized power transfer protocols to minimize energy losses and ensure stable, long-distance power transmission in complex industrial environments. The findings demonstrate that the I-WPT system significantly reduces energy loss compared to conventional wired and wireless power systems. The proposed method offers a sustainable, cost-effective solution for modernizing industrial power systems.

Keywords--- Wireless Power Transmission, Energy Efficiency, Industrial Applications, I-WPT System.

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I. Introduction

Wireless power transmission tends to transform power delivery using this emerging technology (Zhu et al., 2024). This term refers to technology related to power delivery through wireless means, which is convenient, very efficient, and well-suited for the vast range of industrial applications (Razek, 2024). WPT without direct wiring increases flexibility in operations. It decreases the complexity of a power infrastructure, making it very suitable for industries when machinery and equipment are scattered or in motion (Rao et al., 2024). Nevertheless, wider industrial applications of WPT have been accompanied by many challenges (Segun-Falade et al., 2024). The long-distance efficiencies are determined by lower transmission, accounting for environmental interference. The system cost operations and the overall performance is significant for the energy loss and the environmental factors interference (Meenakshi et al., 2024).

II. Related Works

WPT-based Magnetic Resonator Coupling (WPT-MRC): WPT eliminates the hassle of wires and cables, making it easy to charge all sorts of electronic gadgets (Kamel et al., 2024). However, with distance, there is a loss in efficiency as energy transmission between transmitter and receiver weakens. For this research, it is planned to develop and implement a WPT-based MRC method to provide power to temperature and humidity-measuring environmental sensors.

Wireless Sensor Network (WSN): In WSNs, maximizing the lifecycles of operations in a network is highly dependent on energy efficiency. To obtain this goal, several critical components must be combined: they ensure that the network will last and be resilient (Archana & Prakasam, 2024). One of the first steps to achieve this is state-of-the-art routing algorithms and protocols. Various optimization approaches have also been used to enhance energy efficiency.

Wireless Power Transfer in Electric Vehicle (WPT-EV): The mobility-friendly environment is set to be a game-changing aspects for the charging modules by the EV (Electric Wireless). Research in this field is subject to social dynamics, which were the focus of this study. To do this (Bachhati et al., 2024) evaluate the impact of famous scholars and influential publications, investigate the relationships between researchers, and examine the networks of authors and nations that collaborate.

III. Proposed Methods

An Industry-Based Wireless Power Transmission (I-WPT) system would mitigate the failures in conventional wireless power delivery for industrial use by bringing forward advanced algorithms for the efficient use of adaptive frequency control and optimized coil designs to improve efficiency in the transmission process and minimize energy loss. This innovative approach represents a sustainable and cost-effective solution for maximizing the increasing energy demands that modern industrial settings face.

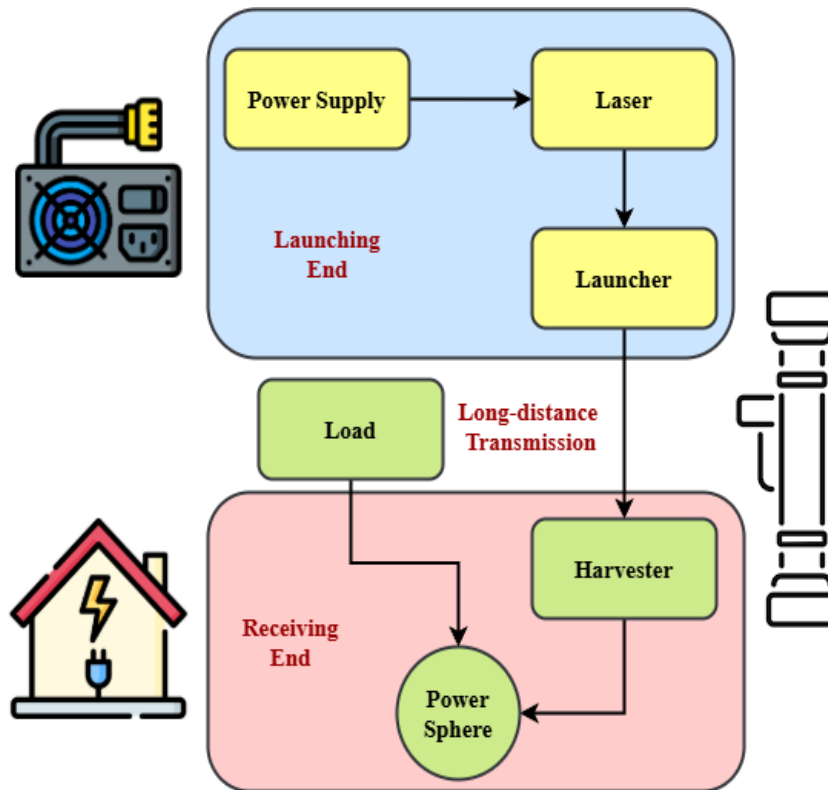


Figure 1: Components of a System

There are four basic parts to the laser WPT system, as seen in Figure 1 based on the launch end, the transmission medium, the reception end, and the load. A laser, a launcher, and a laser power source make up the launch end. Air and water are examples of transmission media since they allow the laser to transfer energy. At the other end, a circuit controller, a power sphere, and a harvester. The electricity comes from the laser power source. Light energy is transformed into electrical energy by the laser. A greater final power achieved is directly proportional to the efficiency of the electro-optical conversion, which is defined as the amount of light energy that can be communicated with the same input power.

$$\partial_g = D[f - pa''] + Fw[Qpr - mnk''] - Eq[g: ep''] \quad (1)$$

The modification of frequency Fw and coil design $Qpr - mnk''$ to reduce power loss is represented by the equation (1) ∂_g , and interference from the environment $Eq[g: ep'']$ and operations is taken into consideration by $D[f - pa'']$. In industrial contexts, consistent and efficient wireless power transmission is guaranteed, which captures real-time monitoring to rectify energy discrepancies in the analysis of boost transmission efficiency.

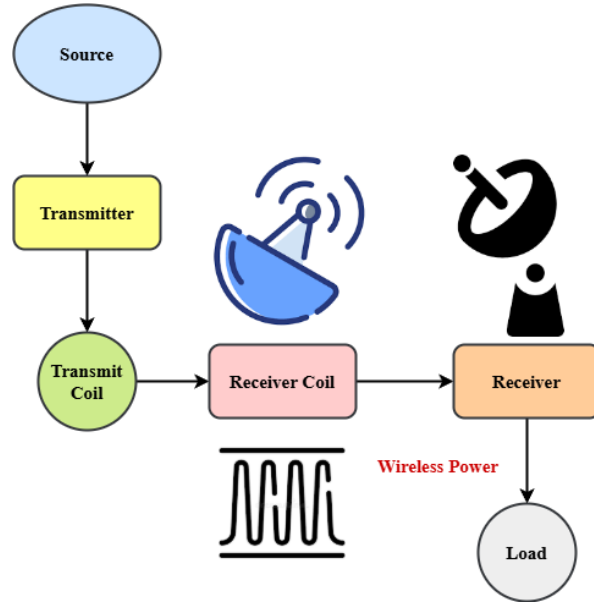


Figure 2: Charging Mechanism for Near Field System

The idea of inductive coupling, which involves the transmission of energy using magnetic fields, is extensively used in electromagnetic field theory (WPT), communications, and other domains. As seen in Figure 2, the sending and receiving circuits are linked wirelessly using two coils placed on each other. As shown, the transmitting coil produces a magnetic field B using the Biot-Savart in response to a current I supplied by the power source.

$$|f[\cup p, -os'']|: \rightarrow Fa[\propto [g - oa'']] + Fq'' \quad (2)$$

The input power changes $\propto [g - oa'']$ and system oscillations Fq'' are represented by the equation (2), $|f[\cup p, -os'']|$, and adaptive frequency modifications to reduce power interruptions are accounted for by Fa . It records optimized load balancing, guaranteeing a steady power supply in ever-changing industrial environments on the analysis of overall system performance.

IV. Results and Discussion

The experimental results confirmed that the I-WPT system highly enhanced energy efficiency compared to traditional approaches. By experiment, the system performs with lesser energy loss and more stable performance despite the complexity of industrial environments. Analysis of Boost Transmission Efficiency shown in Figure 3.

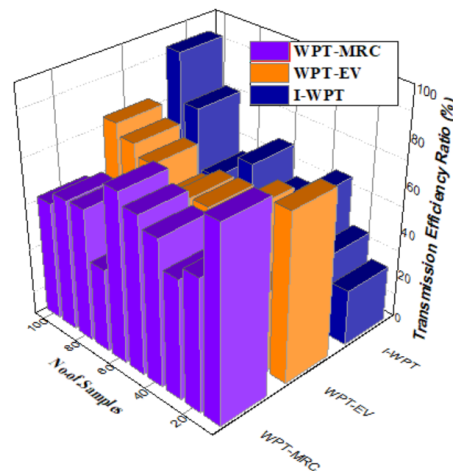


Figure 3: Analysis of Boost Transmission Efficiency

The analysis of boost transmission efficiency also demonstrates that the I-WPT system is superior in performance with a boost transmission efficiency of 93.50%. Due to higher energy losses, the efficiencies of the WPT-MRC and WPT-EV systems are less than those of the I-WPT system. The two most significant factors that make I-WPT perform superbly are adaptive frequency control and optimized coil designs. Such designs minimize power loss and interference, resulting in a reliable, efficient industrial I-WPT.

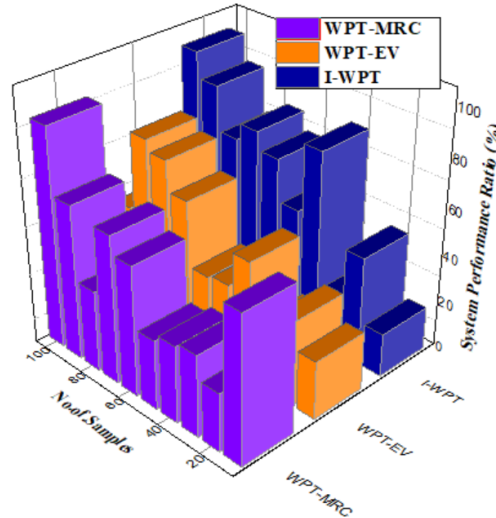


Figure 4: Analysis of Overall System Performance

Figure 4 presents an impressive total efficiency of 98.30%. Compared with the much higher efficiency of the I-WPT system, the WPT-MRC and WPT-EV systems have poorer efficiency due to unnecessary energy loss and poor control of loads. All such advanced capabilities enabled overall performance improvement of the I-WPT system with sophisticated smart load balancing, adaptive frequency regulations, and real-time monitoring.

V. Conclusion

Conventional wireless transmission methods waste energy and are inefficient in many industries; however, the I-WPT system does not face these issues. Adaptive frequency regulation with advanced coil designs and sophisticated algorithms can ensure that the I-WPT system can work consistently in various industries while optimizing transmission efficiency. The real-world trials revealed that the I-WPT system significantly reduces energy loss, which could mean that I-WPT may help businesses in sustainability and cost-effectiveness. Regarding advantages and future leaps for wireless power delivery, I-WPT technology is a giant leap forward for contemporary industrial applications. Future work will further optimize the I-WPT system to enhance energy transmission efficiency over longer distances and even more complex industrial environments. Scalability and cost-reduction strategies to extend the scope of I-WPT systems to more extensive industrial applications will also be researched in the future.

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