STM JOURNALS

Recent Trends in
Sensor Research & Technology

ISSN: 2393-8765
Volume 12, Issue 2, 2025
May–August
DOI (Journal): 10.37591/RTSRT

https://journals.stmjournals.com/rtsrt

Review RTSRT

An Extensive Review of IoT and Wireless Power Transfer Based Movable Spotlight

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Abstract

This study provides an in-depth overview of IoT and Wireless Power Transfer-Based Movable Spotlights. The rapid expansion of the Internet of Things (IoT) has created new opportunities for smart gadgets, allowing them to seamlessly integrate into our daily lives. In addition to this trend, wireless power transfer (WPT) technologies have emerged as a transformative alternative for powering devices without traditional connected connections. This study explores the integration of Internet of Things (IoT) and Wireless Power Transfer (WPT) technologies in developing a movable spotlight system. It presents the system's design, implementation, and potential applications. A comprehensive literature review is conducted to establish the foundation for the proposed model. The study also outlines the simulation tool used to evaluate the system's performance. Key aspects such as practical applications, benefits, and limitations of the model are briefly discussed. The study emphasizes how the convergence of IoT and WPT can enhance mobility and efficiency in lighting systems. Finally, the study concludes with a summary of findings and discusses future research directions and scope for improvement, aiming to inspire further development in smart and wireless lighting solutions. The work contributes to advancing intelligent systems through innovative technological integration.

Keywords: Internet of Things (IoT), Wireless Power Transfer (WPT), movable spotlight

INTRODUCTION

The Internet of Things, also known as the IoT, is a revolutionary technology which integrates numerous devices and things to make them intelligent and associated, improving exchange of information and enriching individual standards of life. IoT-enabled things can assist in delivering communication or action commands to the different linked gadgets. IoT provides people complete control over employment expenses while making their everyday lives smarter. Furthermore, it eliminates expenses and enhances service delivery [1–4]. One of the most significant innovations in daily life, IoT will continue to gain acceptance as more companies discover how correlated gadgets might assist them stay competitive. In this study, we proposed a model of movable spotlights in which the role of IoT is to adjust the spotlight remotely, and the WPT technique is used to wirelessly recharge the spotlight battery because the spotlights are located at the top of the auditorium. It can be difficult to replace the battery when it is discharged. This model can be highly useful in areas such as stage lighting, security monitoring, smart retail, and automated exhibitions where a spotlight needs to focus on a moving target without the limitations of wired connections.

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Received Date: May 14, 2025
Accepted Date: May 16, 2025
Published Date: June 25, 2025

Citation: Arthaya S. Marathe, Harshada S. Malode, Priyadarshanee, A. Mahajan, D.B. Ahire. An Extensive Review of IoT and Wireless Power Transfer Based Movable Spotlight. Recent Trends in Sensor Research & Technology. 2025; 12(2): 16–20p.

LITERATURE REVIEW

WPT techniques for subsequent-generation cellphone networks, namely transmit forming beams for wirelessly powering mobile UEs in densely distributed MISO femtocell networks, were previously studied by Bonati *et al*. [1]. In an effort to prioritize users accordingly to their location and battery situation, the authors implemented several types of genie-aided and heuristic regulations to determine what users must be recharged and within what time frames.

Li *et al*. suggested the wireless moving spotlight system with a remote control [2]. It is a wireless power transfer technology that transmits electricity without the need for cables. A negative aspect of the moveable spotlight's design is the restricted range for position adjustments. To navigate over a moveable spotlight's distance restrictions, the authors designed a project that takes advantage of near-field transmission techniques. For moving the spotlight at 0, 90, and 180° angles, a servo motor was used. A NodeMCU ESP8266 was interconnected to the servo motor, which was managed using the application called Blynk. The transmitter coil and an oscillator circuit with a maximum operating frequency of 180 kHz contribute to the transmitter circuit.

The wireless power transmission concept was introduced by Singh *et al*. [3]. Recent technical developments that enhance modern life have been studied. In the near future, when newer standards are appearing, the three evolving wireless power technology standards that are actively competing with one another are possibly one of the problems being discussed. Because wireless power transmission technology enables electrical energy to be transmitted wire-free across an air gap from the source of electricity to an electrical device, it has a promising future.

The issue of determining which wireless power transmission (WPT) technology topology is great for a medical implant application is addressed by Ahire *et al*. [4]. The coupling between inductive and magnetic resonance (MRC) WPT systems have recently been proposed as an appropriate and reliable replacement for traditional cable or wire charging systems, and for MRC-WPT systems for boosting the PTE over particular distances, substituting topologies are essential. Series-series (SS), series-parallel (SP), parallel-series (PS), parallel-parallel (PP), and series-non-resonant secondary (SN) or the primary side series (PSS) are some of the most fundamental topologies that are researched. The selection of the most suitable topology according to system specifications and application, as well as the empirical use of reflected impedance theory to power transfer efficiency, are investigated and addressed. The compensation capacitor used in a WPT system that includes a magnetic component, resonance frequency selection is needed.

Bakar *et al*. have studied the concept of wirelessly transmitting electrical power to a load is a challenging concept [5]. The invention of wireless chargers has opened up a whole new universe. Nikola invented the “Tesla Tower” in the 19th century with the objective of wirelessly transmitting power. The whole world has been making a concerted effort to get rid of wires ever since. WPT utilizing Inductive Coupling, which is subset of NFWPT, transfers power from the transmitter coil to a receiver coil via a magnetic field. An efficient way of short-distance power transmission, inductive coupling, is finding use in smart phones and in medical applications. Wireless power transfer has also made charging facilities for electric vehicles popular.

Kumar *et al*. addressed IoT educational institutions and developers to collaborate to improve technology on an extensive level and optimize social advantages [6]. Improvements are achievable, however, only if taken the consideration to many difficulties and limitations of the current technological methods. This survey suggests that researches in the Internet of Things must take in to consideration a number of issues and challenges in order to create an improved model. Key areas of IoT applications that include IoT researchers and developers were also explored. Along with providing services, IoT generates huge quantities of data. Hence, the meaning of big data analytics is analyzed, since it can yield precise findings that could be implemented in the creation of enhanced Internet of Things systems.

An overview of an Internet of Things-based real-time meteorological data monitoring system is provided by Ahire *et al*. [7]. Future prospects for the field are discussed, along with the findings of related investigations and the literature review. A selection of sensor types with particular requirements have been explored and selected in order to record meteorological data. The capabilities of advanced microcontroller devices for processing sensor data are briefly reviewed as are different wireless modules' functional frequency range and physical distance covered for wireless data transmission from far locations to Internet of Things gateways. IoT cloud platforms and gateway types are carefully reviewed, and the appropriate choices are selected for monitoring meteorological data in real time. The literature states that all remote sensors and devices must have constant power in order to perform without interruption. Thus, nearby wireless power or unconventional energy harvesting or near-field wireless transmission of energy systems are based on the electromagnetic principle.

BLOCK DIAGRAM FOR IOT BASED MOVABLE SPOTLIGHT AND WPT SYSTEM

The diagram in Figure 1 represents a system for remotely controlling a spotlight using a microcontroller. A power supply energizes the Node MCU ESP-8266 microcontroller, which also acts as the main control unit.

The microcontroller is connected to a stepper motor that physically adjusts the spotlight's position. Through a Wi-Fi connection, the system interfaces with a web browser, enabling users to send commands for spotlight operation [8]. The spotlight is directed or adjusted via the stepper motor based on the commands received. The microcontroller processes the inputs from the browser and translates them into movements for the motor. This setup allows real-time wireless control of the spotlight. The ESP-8266 ensures seamless communication and execution of user commands.

An illustration of the wireless power transfer system is given in the block diagram in Figure 2. An oscillator functioning at 180 kHz acts for transforming the source or input power into a signal with a high frequency at the start of the process. A transmitter (Tx) receives this high-frequency signal and then employs it to develop an alternating electromagnetic field in order to wirelessly transfer energy. This transmitted energy gets absorbed by the receiver (Rx), which then transforms it back into an electrical signal. A rectifier is then used to transform the received AC signal into a DC voltage that can be utilized in charging a battery. The input power converters that produce and send power wirelessly and the output power converters that efficiently receive, regulate, and store the energy make up the whole system.

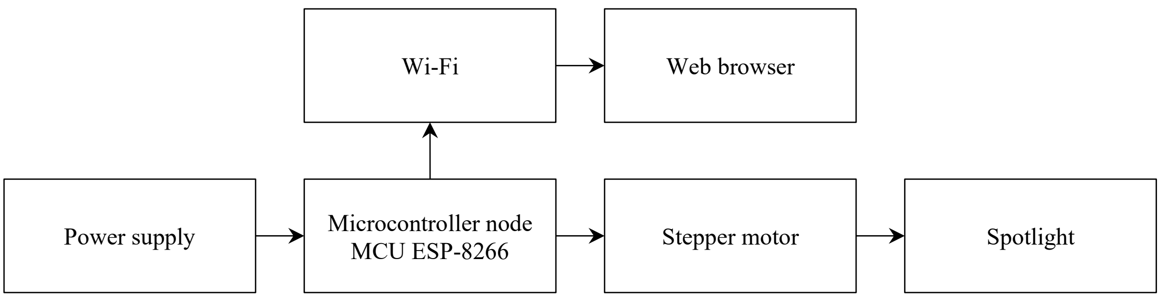

Figure 1. Block diagram of proposed model of Movable spotlight.

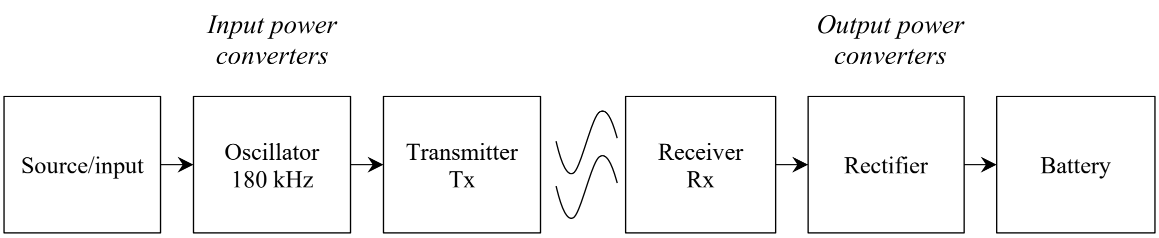

Figure 2. Block diagram of proposed model of WPT.

PROPOSED WORK

The proposed model can be realized by simulating the IoT technique using the Proteus simulation tool and WPT using Ansys Maxwell. In Ansys Maxwell simulation tool, WPT technique can be simulated by creating primary and secondary coil separated by 10 mm distance on 3D geometry. The design involves defining coil geometry, material properties, and air gaps to optimize coupling efficiency. Copper is used for coils, while ferrite or air serves as the core [9]. AC excitation in the primary coil generates voltage in the secondary coil, with solvers like the eddy current and transient solvers analyzing performance. Key results include mutual inductance, coupling coefficient, power transfer efficiency, and losses. Magnetic flux distribution is visualized using contour plots, and parametric analysis optimizes coil design. The simulation helps develop efficient wireless charging systems for EVs, consumer electronics, and medical devices. The movable spotlight system can be developed utilizing hardware components such as a power supply, microcontroller, wireless module (Wi-Fi), stepper motor, and spotlight, in addition to the mobile app.

Applications

In smart homes, the ability to control lighting remotely and automatically based on user preferences or environmental factors is a huge benefit. With IoT and WPT integration, movable spotlights can be strategically placed around the house and controlled via smartphone apps [10].

In film and photography, lighting is a critical aspect of achieving the desired effect. A movable spotlight system powered wirelessly can provide the flexibility needed in dynamic shooting environments. The spotlight can be controlled remotely to adjust the light's angle, intensity, and position without the hassle of power cords.

Retail stores, malls, and commercial spaces often need flexible lighting solutions that can adapt to changing displays or product placements. IoT-based movable spotlights can help highlight products or promotions in these environments.

Advantages

The key advantage of the wireless power transfer system is that it eliminates the need for physical power cables. This allows the spotlight to be moved and repositioned freely without the constraints of being connected to a fixed power source. Traditional lighting setups often require extensive wiring and cabling, which can be time-consuming, costly, and disruptive to install. Wireless power transfer removes the need for physical wiring, reducing installation costs and effort [4].

The ability to control and monitor the spotlight remotely from a mobile app or web interface adds a layer of convenience and ease of use. Users can control lighting settings such as brightness, positioning, and schedules without needing to interact with the physical device.

Disadvantages

While the system eliminates the need for extensive wiring, the initial cost of setting up wireless power transfer technology and IoT-based components (such as NodeMCU ESP8266, transmitters, receivers, and control interfaces) can be higher compared to traditional wired lighting systems. The installation of both wireless power transfer and IoT systems can be more complex and time-consuming [5].

If the movable spotlight uses batteries for backup or power storage (in case of power failure or when it is moved far from the transmitter), the lifespan and maintenance of these batteries become a concern. Frequent recharging or replacing of batteries can add to the system's upkeep costs.

CONCLUSION

The integration of IoT and Wireless Power Transfer (WPT) in a Movable Spotlight system represents a significant advancement in intelligent lighting solutions. This study explores the synergy between wireless energy transmission and IoT-driven automation to create a flexible, energy-efficient, and adaptable lighting system. By eliminating wired constraints, the system enhances mobility and operational efficiency, making it highly suitable for applications in smart homes, outdoor environments, and industrial settings. The study underscores the potential of WPT in reducing energy losses and improving system durability while leveraging IoT for real-time control, automation, and energy optimization. Future research directions could focus on enhancing power transfer efficiency, integrating AI-based adaptive lighting control, and expanding scalability for large-scale implementations. The findings contribute to the growing field of smart lighting technologies, paving the way for sustainable, autonomous, and intelligent illumination systems in both residential and commercial domains.

Acknowledgement

We are very thankful to MET's, Institute of Engineering, Bhujbal Knowledge City, Nashik, for providing resources required for project work.

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