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# A Survey of Wireless Charging System for Electric Vehicles and Fire Protection

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**Abstract:** *Wireless charging for electric vehicles offers convenient power replenishment without physical connections. Fire protection measures are integral to ensure safety during wireless charging, mitigating potential risks of overheating or electrical malfunctions. The integration of wireless charging systems for electric vehicles (evs) alongside effective fire protection measures presents a promising avenue towards enhancing the sustainability and safety of urban transportation. In this survey work, we meticulously examine the state-of-the-art advancements, methodologies, and challenges pertaining to the fusion of wireless charging technologies with robust fire protection mechanisms for evs. In this survey encapsulates a synthesis of methodologies, technical architectures, and regulatory frameworks, providing researchers and practitioners with valuable insights to navigate the intricate landscape of wireless charging systems for evs and fire protection.*

**Keywords:** Electric Vehicle, wireless power transfer, Dynamic charging method, charging lane, Fire Protection mechanism, sensors.

## I. INTRODUCTION

The wireless charging system for electric vehicles operates much like a traditional transformer. It comprises a transmitter and a receiver. Initially, the 220V 50Hz AC supply undergoes conversion into low voltage, high frequency alternating current. This high frequency AC is then channeled to the transmitter coil, generating an alternating magnetic field. As this field intersects with the receiver coil, it induces the production of AC power output in the receiver coil. Subsequently, the AC power at the receiver end is rectified to DC and transmitted to the battery for efficient charging.[1]

In this survey, we focus on Dynamic wireless charging system where vehicles charge while run time. Power is transmitted wirelessly from a fixed transmitter to the receiver coil in the moving vehicle. This setup minimizes the need for extensive energy storage, consequently reducing the vehicle's overall weight.[4]

The inductive Wireless Charging System (IWC) operates based on Faraday's law of induction. It facilitates the wireless transmission of power through the mutual induction of magnetic fields between the transmitter and receiver coils. When an AC supply is applied to the transmitter coil, it generates an AC magnetic field that permeates the receiver coil. This magnetic field prompts the movement of electrons within the receiver coil, resulting in AC power output. The AC output is then rectified and filtered to charge the energy storage system of electric vehicles. The efficiency of power transfer relies on factors such as frequency, mutual inductance, and the distance between the transmitter and receiver coils.**[2]**

## II. LITERATURE SURVEY

In one of the work author's deals with research and development of wireless charging systems for Electric vehicles using wireless transmission [1]. The main goal is to transmit power using resonance coupling and to build the charging systems and the Systems deal with an AC source, transmission coil, reception coil, converter and electric load which are batter.

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Author have also shown that there are many kinds of methods in wireless charging system such as Inductive Coupling, Magnetic Resonance Coupling, Microwave radiation, radio frequency Energy Harvesting and Laser power beaming. Among them, inductive coupling method is chosen. This system is safe and more efficient than other methods of wireless power transfer. Wireless charging method can increase efficiency by changing the design of coil and the circuit design. Authors have also suggested that solar energy can be used to charge the system via photovoltaic (PV) panels. Solar energy is one of the top-rank renewable energy resources which cannot be harmful to the natural environment. And also, dynamic wireless charging which is more-advanced technology than the static wireless charging since the battery car has to be charged while moving on the road.

In another work author describes about the Wireless charging needs that require two kinds of coils named the transmitter coil and the receiver coil [2]. The receiver coil will collect power from the transmitter coil while going over it in the means of mutual induction. But the variation of distance between two adjacent coils affects the wireless power transfer (WPT). To see the variation in WPT, a system of two Archimedean coils of copper is designed and simulated for vertical and horizontal misalignment in Ansys Maxwell simulation software. The transfer power for 150 mm air gap is 3.74 kW and transfer efficiency is gained up to 92.4%. The charging time is around 1 hour and 39 minutes to fully charge its battery from 0 state for a 150mm air gap for an EV with 6.1 kW power may take. And also, a charging lane is designed for dynamic charging. Then the power transfer is calculated from mutual inductance when the EV is driven on a charging lane.

Author Saeed D. Manshadi *et. al*. [3] have presented the short-term operation of WCS by capturing the interdependence among the electricity and transportation networks. And also in the transportation network, the total travel cost consists of the cost associated with the travel time and the cost of utilized electricity along each path. Each EV takes the path that minimizes its total travel cost. The coordination between electricity and transportation networks would help mitigate congestion in electricity network by routing the traffic flow in the transportation network. And the total travel cost determines the cost associated with the travel time as well as the energy cost which is determined by the price of electricity and the charging strategy of the EVs.

In this study, Aganti Mahesh *et. al.* provide a comprehensive review of Resonant Inductive Wireless Power Transfer (WPT) Charging technology, shedding light on its current status and future prospects in the wireless Electric Vehicle (EV) market [4]. Initially, the paper traces a brief history of wireless charging methods, outlining their advantages and limitations. Subsequently, it conducts a comparative analysis of various types of inductive pads, rails, and compensation technologies employed to date. The paper also discusses static and dynamic charging techniques along with their respective characteristics. Furthermore, it delves into the significance of power electronics and converter types utilized in different applications. Additionally, it addresses batteries and their management systems, as well as various challenges associated with WPT. The study also provides insights into the current technology trends in WPT systems. Notably, wireless technologies are currently the subject of extensive research in both academia and industry, owing to their dependable, convenient, and efficient charging capabilities with minimal human intervention.

In a study conducted by Md. Rakib Raihan Razu *et al.,* the concept of Static wireless charging is explored, which has gained popularity worldwide for charging electric vehicles (EVs) [5]. However, the limited range of EVs with a full charge necessitates the use of additional batteries to increase their driving range. Dynamic wireless charging has been introduced to EVs to significantly extend their range and reduce the reliance on heavy batteries, a challenge faced by modern EVs. With Dynamic Wireless Power Transfer (WPT), the need for plug-in charging and static WPT can gradually be eliminated, potentially enabling EVs to operate with limitless range. Wireless charging systems typically consist of two types of coils: the transmitter coil and the receiver coil. The receiver coil collects power from the transmitter coil through mutual induction as the vehicle passes over it. Research on WPT has gained momentum in recent years, with a focus on comparing various WPT technologies and developing effective methods like Resonant Inductive Power Transfer (RIPT). The RIPT method involves resonating the frequencies of both the transmitter and receiver coils. The study also investigates how factors such as air gap and misalignment impact WPT performance when EVs are driven in the charging lane.

The author of this study emphasizes the significance of implementing a robust Battery Management System (BMS) in electric vehicles (EVs) and similar battery-powered systems [6]. The BMS assumes a critical role in overseeing and regulating the battery pack's operations, ensuring optimal performance, safety, and longevity. A pivotal metric

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monitored by the BMS is the State of Charge (SoC), which denotes the remaining energy in the battery as a percentage of its total capacity. SoC aids users in estimating the remaining range or duration of usage before requiring recharging.

The integration of EV BMS with charge monitoring and fire prevention features is imperative for EVs, offering vital safety functionalities such as temperature control, fault detection, cell balancing, and fire prevention. These attributes effectively mitigate the risk of battery fires while enhancing the overall efficiency of EVs.In order to further augment the capabilities of EV BMS with charge monitoring and fire prevention, future endeavors may concentrate on refining the precision and reliability of battery monitoring systems. This entails delivering more precise and timely data pertaining to the charge, health, and overall functionality of the battery pack.

The study [7] emphasizes Electric Vehicles (EVs) as leading zero-emission vehicular technology, representing the future of the automotive industry. EV batteries require charging for operation, typically done through plug-in methods at charging stations. However, an alternative approach involves Wireless Power Transfer (WPT), which can be implemented through Static or Dynamic charging systems.

Static Charging Systems are designed to charge EV batteries while the vehicle is parked, whereas Dynamic Charging Systems enable charging while the vehicle is in motion. The author's primary objective is to provide an overview of various wireless charging techniques, with inductive wireless transfer emerging as the most effective method. Additionally, the paper discusses the application of static and dynamic wireless charging and underscores the critical role of batteries in EVs. Notably, wireless charging techniques can impact battery size, leading to reduced overall costs for EVs.

In this paper author conveyed the Numerous studies have been conducted to explore dynamic electric vehicle charging systems powered by solar energy [8]. With the growing number of electric vehicles on the roads globally, primarily due to soaring fuel costs, electric vehicles have gained significant traction. They have proven to be cost-effective alternatives for travel, offering cheaper operating costs compared to traditional fuel-powered vehicles.

The author highlights the emergence of innovative electric charging systems aimed at addressing charging infrastructure challenges. These systems eliminate the need for wires and external power supplies, allowing users to charge their electric vehicles while in motion without stopping. This dynamic charging approach not only streamlines the charging process but also reduces the reliance on transmission wires and decreases fuel consumption, offering a simpler and more practical solution.

Furthermore, the author suggests that this wireless charging method minimizes wear and tear on hardware components. Such a wireless charging system can be effectively implemented through dynamic electric vehicle charging systems, paving the way for a more efficient and sustainable transportation future.

In a study conducted by Rakan C. Chabaan *et. al*. a comprehensive review of recent literature concerning foreign object detection (FOD) is presented, highlighting its critical importance in electric vehicle wireless charging systems [9]. The authors propose a novel FOD scheme utilizing an induced coil within the charging system. This method incorporates a multifunctional tunnelling resistance sensor matrix to detect the presence of foreign metal objects between the coils. An innovative asymmetrical induction coil design scheme is introduced to mitigate blind spots.

The proposed approach utilizes size-modulated c-shaped coil units to eliminate invisible zones resulting from the magnetic field's axial uniformity. The induced voltage in the transmission coil is measured using ANSYS/MAXWELL software. Experimental results demonstrate several advantages of the suggested method over conventional evenly-sensing coils, including higher uniformity in induced current, position-dependent detection sensitivity, and improved detection accuracy. It provides a practical and cost-effective solution to overcome the limitations of traditional detection coils.

Wireless power transfer technology has been integrated into the Electric Vehicle Charging (EVC) system for FOD. The electric charging vehicle system with FOD must meet transmission and safety requirements. The model developed by the authors exhibits a minimal 5% variation for the material coil in the electric vehicle wireless charging system.

In this notable work, the author underscores the importance of obtaining accurate charging power rates [10]. During wireless charging, precise mathematical models are essential to represent charging power effectively. These models must account for various coil parameters and shapes. The author conducts a thorough analysis of wireless charging systems tailored for Electric Vehicles (EVs), delineating common charging topologies, architectures, and focusing on

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the corresponding mathematical models utilized to calculate electrical power based on the EV's location on streets and its velocity.

The study summarizes various wireless charging system topologies suitable for EV applications. Furthermore, it outlines crucial parameters and variables necessary for constructing a robust mathematical model for wireless charging systems. Additionally, the author proposes a novel general mathematical model capable of accurately operating in both dynamic and static modes.

In this research endeavour, the author discusses Wireless Power Transmission (WPT), a burgeoning technology with diverse applications across various fields [11]. WPT enables the transfer of power from a source to an electrical load without the need for physical interconnections. It proves invaluable in powering electrical devices where traditional wiring is impractical or unfeasible. The underlying principle of WPT relies on mutual inductance.

The automotive sector, particularly Electric Vehicles (EVs), stands as a promising area for the future application of WPT. The author's project focuses on the research and development of wireless charging systems tailored for EVs utilizing wireless transmission.

The author aims to explore and scrutinize numerous techniques for WPT in EVs. This includes examination of compensation topologies and their derivations, power electronics circuits and architectures, control strategies, standards, and communication networks. The analysis and review of current literature serve as the foundation for this investigation into both stationary and dynamic wireless charging methods.

In this study, the author aims to emphasize the significance of power electronics and various converter types utilized across different applications [12]. The discussion also extends to batteries and their management systems, addressing the array of challenges associated with Wireless Power Transfer (WPT). Furthermore, the study delves into diverse areas such as cyber security, economic implications, health and safety concerns, foreign object detection, and the impact on the distribution grid. These topics shed light on the multifaceted considerations surrounding WPT implementation.

The author acknowledges encountering significant challenges in the development of wireless charging systems, including concerns related to health and safety, fast charging capabilities, cyber security risks, interoperability issues, economic viability, and the development of efficient scheduling algorithms. Despite these challenges, the author contends that overcoming them can pave the way for the widespread commercial deployment of wireless chargers, potentially revolutionizing the field.

In this study, the author acknowledges the expanding Electric Vehicle (EV) market, driven by the demand for more efficient and reliable methods of recharging batteries [13]. Wireless Power Transfer (WPT) technology emerges as a solution, eliminating the need for direct physical interaction between vehicles and charging equipment, thus mitigating drawbacks and risks associated with conventional conductive systems. The innovative WPT approach replaces the conductive charging system while maintaining similar power ratings and efficiency. The author has implemented numerous strategies to enhance the effectiveness and reliability of the WPT model. Consequently, the review article provides a comprehensive analysis of current research literature pertaining to WPT technologies for EV charging, offering an extensive overview of the state-of-the-art WPT systems for EV battery charging.

The primary objective of the author is to explore and scrutinize various techniques for WPT in EVs, including compensation topologies and their derivations, power electronics circuits and architecture, control strategies, standards, and communication networks. This examination is based on an analysis and review of current literature, focusing on both stationary and dynamic wireless charging methods.

This work describes the ever-increasing number of fossil-fuel-powered automobiles, such as motorcycles, cars, trucks, buses, and other vehicles, is the primary source of environmental pollution, degrading air quality and contributing to global warming by emitting harmful air pollutants. [14] The environment is spoiled by these gases, and the human body's organ systems also have harmful effects. There was no pollution in the environment and no greenhouse gases emitted over the last few decades. In this article, a novel SST-based wireless charging system design is discussed, which leads to a compact size and flexibility of control. WPT makes charging easy and reliable. Secondly, to maintain constant dc bus voltage at the EV charging port, ANN and fuzzy controllers are used for line and load variations. ANN computes faster than fuzzy and has the same robustness as a fuzzy controller. A bidirectional converter is used for battery charging applications. The PI controller enables the use of constant current and constant voltage (CC-CV modes). Finally, an SST-based wireless charging system is simulated in MATLAB/Simulink and the results are presented.

In this research work, Peiyi Sun *et al.* discuss the profound impact of electric vehicles (EVs) on the global automotive industry, propelled by the rapid advancements in Li-ion battery technology [15]. However, the emergence of fire risks and hazards associated with these high-energy batteries has emerged as a significant safety concern for EVs. This review article focuses on the latest developments concerning fire safety issues in EVs, particularly related to thermal runaway and fires in Li-ion batteries.

Thermal runaway or fire incidents can occur under extreme abuse conditions, often resulting from faulty operation or traffic accidents. Battery failure may lead to the release of toxic gases, fires, jet flames, and even explosions. The paper aims to provide a qualitative understanding of the fire risks and hazards associated with battery-powered EVs by reviewing incidents involving battery fires in battery EVs, hybrid EVs, and electric buses. Additionally, the study analyses important characteristics of battery fires observed in various EV fire scenarios, as determined through testing.

Furthermore, the research clarifies that EVs utilize electric motors and rely on electric power for propulsion. While the term "EV" commonly refers to road vehicles, it can also encompass rail vehicles, surface and underwater vessels, as well as aerospace applications, broadening the scope of electric vehicle technology.

In this work, the author delineates the significance of Battery Management Systems (BMS) as integral electronic components within hybrid or electric vehicle (EV) systems [16]. Acting as a crucial intermediary between the charger and the battery, BMS facilitates safety protection and reliable battery management through functions such as charge control, state evaluation, and data reporting.

The author highlights two primary critical functions of BMS: safety protection and energy management. Safety protection is identified as the foremost function, encompassing measures to safeguard against potential hazards. Energy management involves optimizing the output, monitoring charge-discharge inputs, and providing notifications regarding battery status. BMS plays a pivotal role in managing battery packs effectively and ensuring their protection against damage.

In their research, the author delves into the present and potential future utilization of fast charging stations for electric passenger vehicles [17]. The study aims to elucidate the current charging patterns observed at fast charging stations and discern the role of fast charging within the spectrum of available charging options.

The author elucidates that the varying patterns of charging cables are investigated in alignment with the technical capabilities of the vehicles. It is observed that as battery capacities increase, the necessity for fast charging diminishes. However, for vehicles equipped with substantial charging capacities, fast charging is perceived as more convenient due to frequent use. These findings suggest a potentially larger share for fast charging as charging capacities expand in the future.

Additionally, the paper explores the developments in fast charging, which bring about specific challenges related to the integration of charging facilities into the grid, power requirements, impacts on batteries (with or without new battery chemistries), the added value of storage facilities, and compatibility with renewable energy sources.

In this paper, the author discusses the significant proliferation of electric vehicles (EVs) driven by the decreased costs and enhanced performance of Li-ion batteries [18]. However, incidents involving fires during charging operations or while parked have raised concerns about the safety of this technology, particularly in household or underground charging scenarios.

To address these safety concerns, the paper proposes the development of a novel system concept based on a Vanadium-air flow battery. This system aims to provide both charging capabilities and fire safety for electric vehicles by utilizing oxygen reduction in a sealed box. When the vehicle is parked inside the box and passengers are outside, nitrogen injection is initiated to rapidly reduce the fire risk. During subsequent vehicle charging operations, oxygen is consumed from the box atmosphere by the cathode of the Vanadium-air battery, which supplies energy. The nitrogen reserve is then replenished by consuming oxygen from the external environment, and the energy output can be supplied to smart grids. While Li-ion batteries are commonly used in EVs, their established technology poses safety concerns related to thermal runaway, which can result in fire and explosion incidents. The proposed Vanadium-air flow battery system offers a potential solution to mitigate these safety risks associated with EV charging.

In this paper, Dr. T V V Pavan Kumar *et al.* delve into the increasing popularity of electric cars (EVs) due to their environmentally friendly nature and potential to reduce reliance on fossil fuels [19]. However, as the demand for EVs continues to rise, addressing safety concerns associated with their battery systems becomes paramount. The authors emphasize the critical role of the Battery Management System (BMS) in ensuring the safe and efficient operation of the battery pack in EVs. Two essential aspects of an EV BMS are fire safety and temperature safety, aimed at mitigating potential risks associated with battery malfunctions.

Fire safety is highlighted as crucial because lithium-ion batteries, commonly used in EVs, can undergo thermal runaway, leading to fires and explosions. The BMS constantly monitors the voltage, current, and temperature of each individual battery cell to detect any abnormalities that could trigger thermal runaway. Additionally, flame-retardant materials and coatings are incorporated into the battery pack to resist combustion and limit the spread of fires. Advanced BMS systems may also include fire suppression systems, such as gaseous or foam-based agents, to quickly extinguish fires and minimize damage. Temperature safety focuses on maintaining optimal temperature conditions for the battery cells to operate efficiently and extend their lifespan. The BMS employs sophisticated thermal management techniques to monitor and adjust the temperature of the battery cells. By preventing overheating, which can degrade battery performance and compromise safety, the BMS ensures that the battery operates within safe temperature limits.

Here in this paper, Y. Mastanamma *et al*. highlight that Electric Vehicle (EV) technology still has untapped potential in terms of efficiency and safety [20]. The predominant cause of electric vehicle fire incidents stems from battery explosions or fires. To address this issue, the paper proposes an integrated approach for managing EV battery systems, which merges a Battery Management System (BMS) with charge monitoring and fire detection capabilities.

This integrated system is designed to continuously monitor the battery's voltage, current, and temperature, promptly shutting off the battery's input or output if any abnormal behavior is detected. This technology not only ensures secure charging but also serves as a safeguard against potential accidents. Upon activation, the system's charging and monitoring circuitry enables users to safely charge the 3S battery. Additionally, a current sensor is employed to monitor battery current when connected to a load, with the parameter displayed on an LCD display. Despite these advancements, the authors acknowledge that there is still considerable room for improvement. They express their commitment to ongoing work on this platform, aiming to further enhance its capabilities and address any remaining challenges.

## III. CONCLUSION

After conducting an extensive survey of research papers on wireless charging systems for electric vehicles and fire protection, our study synthesizes a comprehensive understanding of the current state-of-the-art in this field. Through the analysis of various scholarly works, we have identified key trends, challenges, and advancements. Our survey reveals the evolving landscape of wireless charging technologies, encompassing efficiency improvements, integration with electric vehicle infrastructure, and enhanced safety measures for fire protection.

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