Review on IOT Based Wireless EV Charging Station Using Smart Grid Technique

Sudarshan Yedu Jadhav[1], Dr. Ganesh B. Dongre[2], DR. D.L.Bhuyar[3], Prof. Jaisinh Nimbalkar[4]

[1] Student, Department of Electronics and Telecommunication Engineering, CSMSS Chh. Shau College of Engineering, Chhatrapati Sambhajinagar.

.[2] Principal, Department of Electronics and Telecommunication Engineering, CSMSS Chh. Shau College of Engineering, Chhatrapati Sambhajinagar

[3] HOD, Department of Electronics and Telecommunication Engineering, CSMSS Chh. Shau College of Engineering, Chhatrapati Sambhajinagar

[4]Assistant Professor, Department of Electronics and Telecommunication Engineering, CSMSS Chh. Shau College of Engineering, Chhatrapati Sambhajinagar.

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Abstract - The rapid adoption of electric vehicles (EVs) has intensified the demand for efficient, reliable, and intelligent charging infrastructure. Conventional plug-in charging systems present limitations such as physical connector wear, user inconvenience, safety concerns, and inefficient energy utilization. To address these challenges, this work proposes an IoT-based wireless electric vehicle charging station integrated with smart grid technology**,** aimed at enhancing charging efficiency, automation, and grid interoperability.

The proposed system employs wireless power transfer (WPT) based on electromagnetic induction or resonant magnetic coupling to enable contactless energy delivery between the charging pad and the vehicle-mounted receiver. IoT-enabled control architecture is incorporated to facilitate real-time monitoring, remote operation, fault detection, and data analytics. Key operational parameters such as charging power, voltage, and current, battery state of charge (SoC), temperature, and system efficiency are continuously sensed and transmitted to a cloud-based platform using wireless communication protocols such as Wi-Fi or MQTT.

***Key Words*:** Smart grid, IOT, Wireless, Esp32, Electric Vehicle, GSM

1. INTRODUCTION

Integration with smart grid technology allows bidirectional communication between the charging station and the utility grid, enabling intelligent load management, demand response, and dynamic pricing. The system can automatically schedule charging during off-peak hours, optimize power flow based on grid conditions, and support renewable energy sources such as solar power. Additionally, user authentication, billing automation, and usage analytics are implemented through a mobile or web-based interface, improving user experience and operational transparency.

The proposed IoT-based wireless EV charging station enhances safety by eliminating exposed conductive elements, reduces maintenance requirements, and supports scalable deployment within smart cities. Experimental results demonstrate improved energy efficiency, reduced charging downtime, and effective grid load balancing. This system represents a sustainable and intelligent solution for next-generation EV charging infrastructure aligned with smart grid objectives.

The rapid growth of electric vehicles (EVs) has emerged as a key solution to reduce greenhouse gas emissions, dependency on fossil fuels, and urban air pollution. Governments and industries worldwide are actively promoting the adoption of EVs as part of sustainable transportation initiatives. However, the widespread deployment of EVs faces significant challenges, particularly in terms of charging infrastructure, charging convenience, grid load management, and energy efficiency. Conventional plug-in charging systems often suffer from limitations such as cable wear, user inconvenience, safety concerns, and inefficient energy utilization during peak demand periods.

Wireless power transfer (WPT) technology offers a promising alternative to traditional wired charging systems by enabling contactless energy transfer between the charging station and the electric vehicle. Wireless EV charging improves user convenience, enhances safety by eliminating exposed conductors, and reduces mechanical degradation of connectors. When integrated with Internet of Things (IoT) technology, wireless charging stations can be intelligently monitored, controlled, and optimized in real time, enabling seamless communication between vehicles, charging infrastructure, and grid operators.

The integration of IoT with smart grid technology plays a crucial role in addressing the challenges of large-scale EV charging. A smart grid enables bidirectional communication between energy producers, consumers, and storage systems, allowing dynamic energy management, demand response, and efficient load balancing. IoT-enabled sensors, controllers, and communication modules facilitate real-time data acquisition related to charging status, energy consumption, grid conditions, and user authentication. This data-driven approach enhances system reliability, reduces energy wastage, and supports predictive maintenance of charging infrastructure.

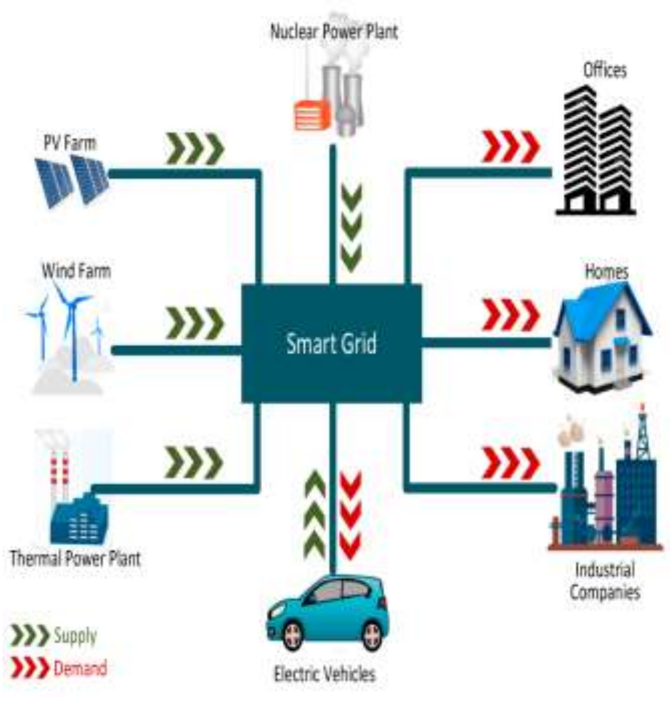

Fig.1: An illustration of the roles of EVs and other suppliers/consumers in the smart grid.

In conclusion, the IoT-based wireless EV charging station using smart grid technology represents an advanced and sustainable solution for future electric mobility. By combining wireless power transfer, IoT intelligence, and smart grid capabilities, the system addresses key limitations of conventional EV charging infrastructure and supports the global transition toward efficient, reliable, and environmentally friendly transportation systems.

2. Ligature Review

2.1 Introduction

The rapid growth of electric vehicles (EVs) has intensified the demand for efficient, user-friendly, and intelligent charging infrastructures. Conventional plug-in charging systems present challenges such as cable wear, safety risks, limited automation, and poor integration with smart energy management systems. To address these limitations, researchers have increasingly focused on IoT-based wireless EV charging systems integrated with smart grid technologies. These systems combine wireless power transfer (WPT), Internet of Things (IoT) platforms, and smart grid concepts to enable safe, efficient, monitored, and optimized EV charging.

This literature review presents a detailed discussion of prior research related to wireless EV charging, IoT-enabled monitoring and control, and smart grid integration, highlighting key contributions, methodologies, and research gaps.

Kurs et al. (2007) demonstrated the feasibility of strongly coupled magnetic resonance for mid-range wireless power transfer, laying the theoretical groundwork for modern EV wireless charging systems. Building on this, Sample, Meyer, and Smith (2011) proposed practical implementations of inductive charging systems with improved efficiency and alignment tolerance for vehicular applications.

Bi et al. (2016) conducted a comprehensive review of high-power wireless charging for EVs, emphasizing coil design, compensation networks, and electromagnetic compatibility. Their work highlighted efficiency levels exceeding 90% under optimal alignment, making WPT suitable for real-world EV charging scenarios.

Gungor et al. (2013) explored IoT-based smart grid communication architectures, emphasizing the role of sensors, embedded controllers, and cloud platforms in enabling bidirectional information flow between consumers and utilities. Their framework directly supports IoT-enabled EV charging management.

Zhang et al. (2018) proposed an IoT-based EV charging station architecture using embedded controllers, cloud servers, and mobile applications. Their system allowed real-time monitoring of charging status, energy consumption, and fault conditions. However, their work focused primarily on wired charging infrastructure.

In a related study, Patil et al. (2017) implemented an IoT-enabled wireless charging prototype using microcontrollers and Wi-Fi modules. Their work demonstrated remote monitoring of voltage, current, and charging time but lacked advanced grid interaction and demand-response features.

Fang et al. (2012) presented a detailed survey on smart grid concepts, identifying EVs as both loads and potential distributed energy resources. Their study emphasized the importance of intelligent scheduling and real-time pricing mechanisms for EV charging.

Sortomme and El-Sharkawi (2011) proposed optimal charging algorithms for EVs to minimize grid impact and charging costs. Their work demonstrated that coordinated charging significantly reduces peak demand compared to uncoordinated charging.

When combined with wireless charging, smart grid control becomes even more critical due to efficiency variations and alignment-dependent power transfer, as noted by Covic and Boys (2013).

Li et al. (2019) proposed a smart wireless EV charging system using IoT sensors and cloud-based energy management. Their system dynamically adjusted charging power based on grid conditions and vehicle battery state-of-charge (SoC). Simulation results showed improved grid stability and reduced peak load.

Huang et al. (2020) developed an IoT-enabled wireless charging station integrated with renewable energy sources and smart meters. Their architecture supported real-time monitoring, fault detection, and user billing, demonstrating the practical feasibility of smart wireless charging stations.

More recently, Al-Saadi et al. (2021) introduced a smart grid–connected wireless EV charging framework employing machine learning algorithms for load forecasting and charging optimization. Their results indicated improved energy utilization and reduced operational costs.

Yan et al. (2013) analyzed cybersecurity challenges in smart grids and emphasized the need for secure communication protocols, authentication mechanisms, and data encryption. These concerns are equally applicable to IoT-based wireless EV charging systems.

Subsequent studies by Khan et al. (2020) proposed lightweight security frameworks for IoT-enabled charging stations, ensuring secure data transmission without excessive computational overhead.

3. Proposed System

3.1. System Overview

The proposed system presents an IoT-enabled wireless electric vehicle (EV) charging station integrated with a smart grid energy management framework**.** The charging station is powered through multiple heterogeneous energy sources**,** namely solar energy**,** wind energy**, and** utility grid power (MSEB)**.** An ESP32 microcontroller acts as the central control and communication unit, enabling intelligent source selection, real-time monitoring, and automated charging operation.

The primary objective of the system is to ensure efficient, reliable, and uninterrupted EV charging by dynamically selecting the optimal power source based on voltage availability**,** while minimizing dependency on the conventional grid. The system further enhances user convenience and safety by employing infrared (IR) sensors for vehicle detection, which automatically initiates the charging process when an EV 0i10s present.

3.2. Architecture of the Proposed System

The proposed system consists of the following major subsystems:

1. Renewable Energy Generation Unit
   - Solar Power System
   - Wind Power System
2. Utility Grid Interface (MSEB Supply)
3. Power Conditioning and Source Selection Unit
4. Wireless EV Charging Module
5. IoT Monitoring and Control Unit (ESP32)
6. Vehicle Detection and Safety Unit (IR Sensor)

Each subsystem cooperates under the smart grid paradigm to deliver optimized energy flow and intelligent control.

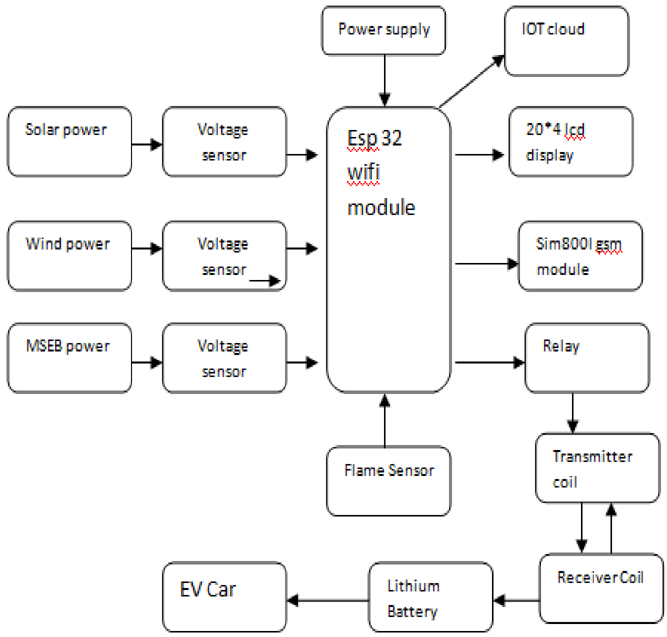

Fig 2. Block Diagram Of Proposed System

3.3. Energy Sources and Power Generation

3.3.1 Solar Energy System

The solar energy subsystem consists of photovoltaic (PV) panels that convert solar radiation into electrical energy. The generated DC power is regulated using DC–DC converters and charge controllers to maintain voltage stability. This energy is prioritized during daylight hours to promote sustainable operation and reduce grid dependency.

3.3.2 Wind Energy System

The wind energy subsystem utilizes a small-scale wind turbine coupled with a rectifier and voltage regulation unit. The AC output from the turbine is converted into DC power and conditioned before being fed into the power selection unit. Wind energy serves as an auxiliary renewable source, particularly effective during low solar availability.

3.3.3 Utility Grid (MSEB) Supply

The Maharashtra State Electricity Board (MSEB) supply acts as **a** backup and balancing source. It ensures uninterrupted charging when renewable sources are insufficient. The grid power is interfaced through isolation transformers and protection circuits to maintain safety and compliance with electrical standards.

3.4. Smart Grid Based Source Selection Mechanism

A key feature of the proposed system is its automatic energy source selection algorithm, which operates under smart grid principles.

- Voltage sensors continuously monitor the output voltage of solar, wind, and grid sources**.**
- The ESP32 compares the measured voltages in real time.
- The power source with the highest available and stable voltage is selected to supply the charging station.
- Automatic switching is achieved using relay modules or solid-state switches, ensuring seamless transition without interrupting charging operations.

This adaptive selection mechanism maximizes renewable energy utilization while maintaining charging reliability.

3.5. Wireless EV Charging System

The wireless charging subsystem is based on inductive power transfer (IPT) technology. It consists of:

- A transmitter coil connected to the selected power source.
- A receiver coil mounted on the electric vehicle.
- High-frequency inverters and resonant circuits to enable efficient power transfer.

Wireless charging eliminates physical connectors, thereby reducing wear and improving safety in outdoor or public environments.

3.6. Vehicle Detection and Automated Charging Control

An IR sensor module is installed at the charging bay to detect the presence of an electric vehicle.

- When a vehicle enters the charging zone, the IR sensor output changes state.
- The ESP32 interprets this signal and verifies vehicle presence.

- Upon successful detection, the system automatically enables the wireless charging circuit.
- If the vehicle is removed, the charging process is safely terminated to prevent energy loss or hazardous conditions.

This automation enhances operational efficiency and user convenience.

3.7. IoT Integration and ESP32 Control Unit

The ESP32 microcontroller serves as the **central** intelligence and IoT gateway of the system.

Key functions include:

- Monitoring voltage, current, and power parameters
- Controlling relays for source switching
- Managing wireless charging activation
- Processing IR sensor inputs
- Transmitting real-time data to a cloud server or mobile application via Wi-Fi

Users and administrators can remotely monitor system status, energy source usage, and charging activity through an IoT dashboard.

3.8. System Advantages

- Efficient utilization of renewable energy sources
- Reduced dependence on conventional grid power
- Automatic and intelligent power source selection
- Contactless and safe wireless charging
- Real-time IoT monitoring and control
- Environmentally sustainable and scalable design

4. CONCLUSIONS

The proposed IoT-based wireless EV charging station integrated with smart grid techniques provides a robust, sustainable, and intelligent charging solution. By combining renewable energy sources with grid power and implementing automated control using ESP32, the system ensures reliable EV charging while promoting green energy adoption. The inclusion of IR-based vehicle detection and wireless power transfer further enhances user safety, convenience, and operational efficiency, making the system suitable for future smart city and smart transportation infrastructures.

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