



Wireless Power & Data Link for Electric Vehicle Charging

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Abstract. The rapid adoption of electric vehicles (evs) has intensified the demand for efficient, safe, and user-friendly charging technologies. Conventional plug-in charging systems present limitations related to physical wear, safety risks, and user inconvenience. This paper presents a comprehensive study of wireless power and data transfer systems for EV applications, focusing on the integration of inductive power transfer (IPT) with real-time communication mechanisms. The proposed approach enables simultaneous energy transmission and bidirectional data exchange between the ground infrastructure and the vehicle, ensuring optimized charging control, alignment detection, and system monitoring. Key design considerations such as coupling efficiency, misalignment tolerance, electromagnetic compatibility, and communication reliability are analyzed. Furthermore, the paper explores system architectures, compensation techniques, and control strategies to enhance overall performance. Simulation and experimental insights demonstrate that the integrated wireless system achieves high efficiency while maintaining robust data communication. The proposed framework contributes to the advancement of autonomous and intelligent charging infrastructure, supporting the future development of smart transportation systems.

Keywords: Fake news detection, machine learning, deep learning, ensemble learning, social media analytics, TF-IDF.

I. Introduction

The global shift toward sustainable transportation has significantly accelerated the development and deployment of electric vehicles (EVs). As EV adoption increases, the need for efficient and convenient charging solutions becomes critical. Traditional conductive charging methods, which rely on physical connectors, suffer from several drawbacks including mechanical degradation, safety concerns in harsh environmental conditions, and limited automation capability. These challenges have motivated the exploration of wireless power transfer (WPT) technologies as a viable alternative. Wireless power transfer for EVs primarily utilizes inductive coupling to transmit energy from a ground-based.

transmitter coil to a receiver coil mounted on the vehicle. This contactless approach enhances user convenience, improves safety, and enables dynamic charging scenarios where vehicles can be charged while in motion. However, efficient power transfer alone is insufficient for modern EV systems, which require continuous monitoring, control, and communication between the charging infrastructure and the vehicle. To address this requirement, wireless data transfer is integrated alongside power transfer, forming a unified system capable of simultaneous energy delivery and information exchange.



This integration supports critical functionalities such as battery status monitoring, charging optimization, alignment detection, authentication, and fault diagnostics. The coexistence of power and data transfer introduces technical challenges including electromagnetic interference, signal integrity degradation, and system complexity. Recent advancements in power electronics, communication protocols, and control algorithms have enabled the development of hybrid systems that effectively combine wireless power and data transfer. Techniques such as load modulation, frequency shifting, and dedicated communication channels are being explored to achieve reliable data transmission without compromising power efficiency. This paper focuses on the design and analysis of an integrated wireless power and data transfer system for EV applications. It investigates key parameters influencing system performance, proposes suitable architectures, and evaluates their effectiveness through theoretical and practical considerations. The objective is to contribute toward the realization of intelligent, efficient, and fully automated EV charging infrastructure, which is essential for the future of smart mobility.

II. Basic Operation of EV Inductive Chargers

Electric Vehicle (EV) inductive charging, also known as wireless power transfer (WPT), operates on the principle of electromagnetic induction to transfer energy without physical electrical contacts. This technology eliminates the need for conductive cables and enhances safety, reliability, and user convenience. At the core of the system are two main components: a primary (transmitter) coil embedded in the ground charging pad and a secondary (receiver) coil mounted underneath the EV. When the system is activated, electrical energy from the power source is first converted into high-frequency alternating current using a power electronic converter, typically consisting of a rectifier and an inverter. The high-frequency AC is then supplied to the transmitter coil, which generates a time-varying magnetic field around it.

This alternating magnetic field propagates through the air gap and induces a voltage in the receiver coil based on the principle of mutual inductance. The induced AC voltage in the receiver coil is then converted back into DC using a rectifier and regulated to meet the battery requirements through a DC-DC converter. This regulated DC power is used to charge the EV battery. To improve efficiency and compensate for the air gap between coils, both transmitter and receiver circuits are equipped with compensation networks (typically series or parallel capacitors). These networks create resonance at the operating frequency, significantly enhancing power transfer capability and reducing reactive losses.

In addition to power transfer, modern inductive charging systems often incorporate communication mechanisms between the charger and the vehicle. This enables functions such as alignment detection, charging control, battery status monitoring, and safety interlocks.

However, the performance of inductive chargers depends on several critical factors:

- Coil alignment: Misalignment reduces coupling efficiency.
- Air gap distance: Larger gaps decrease power transfer capability.

- Operating frequency: Higher frequencies improve efficiency but may increase losses and electromagnetic interference.
- Coupling coefficient: Determines how effectively energy is transferred between coils.

III. Proposed System

The proposed system consists of two main sections: the primary side (transmitter) and the secondary side (receiver). The primary side includes an AC supply, rectifier, high-frequency inverter, and transmitter coil. The secondary side consists of a receiver coil, rectifier, filter, and EV battery.

The AC input is converted into DC using a rectifier and then into high-frequency AC using an inverter. This high-frequency signal is supplied to the primary coil, which generates a time-varying magnetic field. The receiver coil captures this magnetic field and induces voltage.

To enhance efficiency, a resonant compensation network such as series-series (SS) or LCC is used. In addition to power transfer, a communication module is integrated into the system. Data is transmitted along with the power signal using modulation techniques such as Amplitude Shift Keying (ASK) or Frequency Shift Keying (FSK). At the receiver side, filters separate the power and data signals. The power is used for charging the battery, while the data is processed using a demodulator and controller.

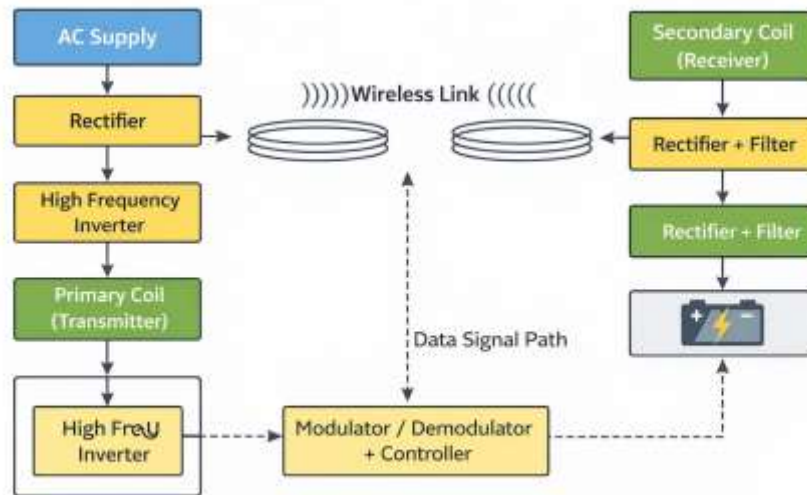


Fig. 3.1. Block Diagram of Proposed Wireless Power Transfer System

The block diagram of the proposed system illustrates the complete flow of power and data between the charging station and the electric vehicle.



The system begins with an AC supply, which is converted into DC using a rectifier. This DC is then converted into high-frequency AC using an inverter. The high-frequency signal is transmitted through the primary coil, creating a magnetic field.

The secondary coil receives this magnetic field and induces voltage, which is converted into DC using a rectifier and filter. This DC power is used to charge the EV battery. A data communication path is integrated into the system using a modulator and demodulator. This allows simultaneous transmission of control signals, battery status, and other parameters. The proposed system not only enables wireless power transfer but also introduces adaptive control, smart alignment detection, and simultaneous data communication. These enhancements improve efficiency, reduce system complexity, and ensure safe and reliable operation. The design is cost-effective and suitable for real-time applications, making it a significant improvement over conventional systems.

Simultaneously, data communication is integrated into the same inductive link by superimposing data signals onto the power signal using modulation techniques such as Amplitude Shift Keying (ASK) or Frequency Shift Keying (FSK). These data signals carry essential information including battery status, charging requirements, system parameters, and feedback signals.

At the receiver end, appropriate filtering techniques are employed to separate the power and data components. The data is then demodulated and processed by a controller, which uses this information to regulate and optimize the charging process. This ensures efficient, reliable, and safe operation of the overall system, making it suitable for modern wireless charging applications.

IV. Advanced Data Communication Between Electric Vehicles and Evse: A Case Study Approach.

This case study focuses on the real-time data transfer process between an Electric Vehicle (EV) and Electric Vehicle Supply Equipment (EVSE) during a typical charging session. The communication between EV and EVSE plays a critical role in ensuring efficient, safe, and optimized charging.

In the proposed scenario, when an EV is connected to the EVSE, an initial handshake process is established using a standardized communication protocol. The EV transmits essential parameters such as battery state of charge (SoC), voltage limits, and charging requirements. In response, the EVSE evaluates these parameters and determines the appropriate charging mode and power level.

Unlike conventional charging systems, the case study highlights a system where both power and data are transmitted simultaneously using an integrated communication channel. Data signals are superimposed onto the power signal using modulation techniques such as Amplitude Shift Keying (ASK) or Frequency Shift Keying (FSK), enabling efficient utilization of the same physical interface.

During the charging process, continuous bidirectional data exchange takes place. The EV sends real-time updates regarding battery condition, temperature, and charging status, while the EVSE dynamically adjusts the charging parameters to ensure optimal



performance and safety. This dynamic interaction improves charging efficiency and reduces the risk of overcharging or overheating.

Furthermore, the system incorporates intelligent monitoring features, where data collected during charging is transmitted to a central controller or cloud-based system for analysis. This enables predictive maintenance, usage tracking, and performance optimization. The case study also considers fault scenarios such as misalignment, communication failure, or abnormal current conditions, where the system responds by reducing power or safely terminating the charging process.

Overall, this case study demonstrates that advanced data transfer mechanisms between EV and EVSE significantly enhance system intelligence, efficiency, and reliability, making them essential for next-generation smart charging infrastructure.

A. Communication Initialization Phase

During the initial stage, a secure communication link is established between the Electric Vehicle (EV) and the EVSE. This phase involves identification, authentication, and parameter exchange before the charging process begins. Unlike conventional systems, the proposed approach ensures faster initialization using optimized handshake protocols.

The EV transmits basic information such as battery capacity, state of charge (SoC), and charging preferences, while the EVSE responds with system capabilities and available power limits. This structured communication ensures compatibility and reduces connection delay.

B. Real-Time Data Exchange and Control

Once the communication link is established, a continuous and synchronized bidirectional data exchange takes place between the EV and EVSE to ensure efficient charging control. The EV continuously transmits real-time parameters such as battery temperature, state of charge (SoC), voltage levels, current demand, and overall battery health. In response, the EVSE analyzes this incoming data and dynamically adjusts the charging voltage, current, and power levels to match the battery requirements.

To further enhance system performance, the proposed system integrates intelligent adaptive control algorithms that respond to both electrical and environmental variations. These algorithms continuously monitor fluctuations in load conditions, coil alignment, and external disturbances, and accordingly fine-tune system parameters to maintain stable and efficient operation.

Additionally, a feedback-based control loop is implemented, where real-time data is used to predict charging behavior and prevent potential issues such as overheating, overcharging, or voltage instability. This predictive capability improves system reliability and extends battery lifespan.

The system also supports low-latency communication, ensuring rapid response to changing conditions and minimizing delays in control actions. By combining real-time



monitoring, adaptive control, and predictive feedback mechanisms, the proposed system achieves improved energy efficiency, faster charging rates, and enhanced operational safety compared to conventional charging systems.

C. Integrated Power and Data Transmission

In the proposed system, both power and data are transmitted through a common interface. Data signals are superimposed on the power signal using modulation techniques such as ASK or FSK. This eliminates the need for separate communication channels, thereby reducing system complexity.

At the receiving end, advanced filtering and demodulation techniques are used to separate and process the data signals without affecting power transfer efficiency. This integration makes the system compact and cost-effective.

Furthermore, the proposed system improves signal integrity by incorporating robust encoding and noise-resistant modulation schemes, ensuring reliable data transfer even in the presence of electromagnetic interference. A synchronization mechanism is also implemented to maintain proper timing between power and data signals, preventing distortion during transmission. This coordinated integration enhances communication accuracy while maintaining high power transfer efficiency, making the system more stable and suitable for real-time applications.

D. Maximum Efficiency Control

The proposed system incorporates a maximum efficiency control mechanism to ensure optimal power transfer under varying operating conditions. In practical scenarios, factors such as coil misalignment, air gap variations, and load fluctuations can significantly reduce system efficiency. To address these challenges, the system continuously monitors key parameters such as voltage, current, and power in real time.

Based on this feedback, adaptive control techniques are applied to dynamically adjust the operating frequency and maintain resonance between the primary and secondary coils. This helps in minimizing power losses and improving energy transfer efficiency. Additionally, the charging current is regulated according to battery requirements, ensuring safe and efficient operation.

This approach significantly enhances system performance compared to conventional fixed-parameter systems, making it more reliable and suitable for modern wireless charging applications.

E. Data Logging and Cloud Integration

To support advanced applications, the system enables data logging and cloud connectivity. Charging data, usage patterns, and system performance metrics are stored and analyzed for future optimization.

This feature allows remote monitoring, smart billing, and integration with IoT-based energy management systems, making the proposed solution suitable for modern smart grid applications.



F. Intelligent Monitoring and Safety Mechanism

The proposed system incorporates intelligent monitoring features to ensure safe, stable, and reliable operation during the charging process. Key parameters such as voltage, current, battery temperature, and charging status are continuously monitored in real time. This continuous observation helps in early detection of abnormal conditions such as overcurrent, overheating, overvoltage, or system faults.

In case any irregularity is detected, the system responds immediately by either adjusting the charging parameters or safely terminating the charging process to prevent damage to the battery and equipment. This automatic protection mechanism enhances the safety of both the EV and EVSE.

Furthermore, the system utilizes collected data for basic predictive analysis, which helps in identifying performance trends and potential issues in advance. This supports better maintenance planning and improves overall system reliability.

the system ensures continuous coordination between power transfer and data communication, which helps in maintaining overall system stability. The use of real-time feedback allows the system to adapt quickly to changing conditions during operation. This not only improves charging efficiency but also enhances user safety. As a result, the proposed system provides a reliable and intelligent solution for modern wireless charging applications. the system responds immediately by either adjusting the charging parameters or safely terminating the charging process to prevent damage to the battery and equipment. This automatic protection mechanism enhances the safety of both the EV and EVSE.

TABLE I
Communication Messages Between EV and EVSE (Proposed)

Message Type	Communication Direction	Description
Initialization Request	EV → EVSE	Sends EV identification and charging request
Authentication Response	EVSE → EV	Confirms user and system authentication
Charging Parameter Data	EV → EVSE	Provides battery status, SoC, and limits
Control Command	EVSE → EV	Adjusts voltage/current based on conditions
Status Update	EV → EVSE	Sends real-time battery and system data
Fault Alert	EV/EVSE ↔ Both	Indicates abnormal conditions or errors
Session Termination	EVSE → EV	Ends charging process safely

V. Future Scope and Advanced Features in Wpdl Systems

The proposed Wireless Power and Data Link (WPDL) system can be further enhanced by incorporating advanced features and design improvements to meet future require-

ments of efficient and intelligent charging systems. One important aspect is the integration of data and power coils in a compact structure, which helps in reducing system size while maintaining stable communication and efficient energy transfer.

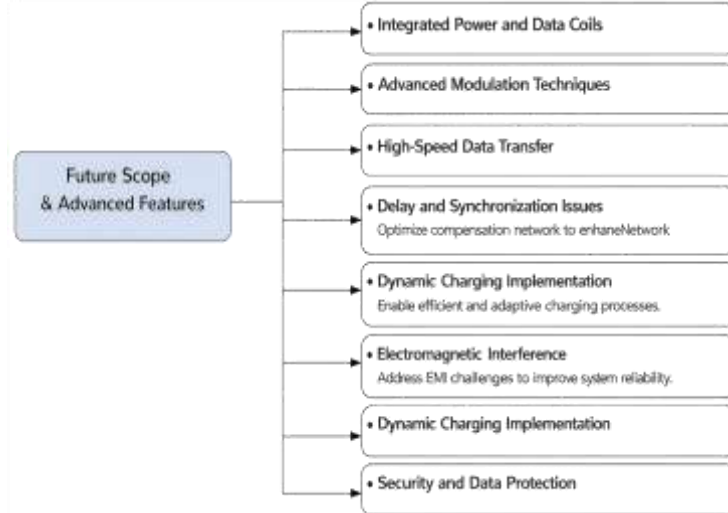


Fig. 5.1. Diagram of future scope and advanced features of WPDL.

The application of WPDL in dynamic charging systems, where vehicles are charged while in motion, represents an important future direction. This requires robust communication and precise synchronization to ensure continuous and efficient operation. Furthermore, security aspects such as protection against data loss, interference, and unauthorized access must be considered to ensure reliable system performance.

1. Integration of Power and Data Coils

Future WPDL systems aim to integrate power and data transfer coils into a compact structure. However, proper design is required to avoid interference between power and data signals, which can affect system performance.

2. Advanced Modulation Techniques

Advanced modulation techniques can improve data reliability and transmission speed. The challenge lies in selecting suitable techniques that provide high accuracy without increasing system complexity.

3. High-Speed Data Transfer

Increasing data transmission rate is essential for real-time control and monitoring. However, maintaining synchronization between power and data signals at high speeds remains a major challenge.

4. Delay and Synchronization Issues

Communication delay can affect system stability and control accuracy. Future systems must focus on minimizing latency and ensuring proper synchronization between transmitter and receiver.

5. Compensation Network Optimization

Optimizing compensation networks can enhance efficiency and reduce power losses. The challenge is to design networks that perform well under different load and alignment conditions.

6. Dynamic Charging Implementation

Applying WPDL in dynamic charging systems (charging while in motion) is a promising future scope. However, maintaining continuous communication and efficient power transfer during movement is difficult.

7. Electromagnetic Interference (EMI)

EMI can disturb both power and data transmission. Reducing interference and ensuring stable communication in noisy environments is a key challenge.

8. Security and Data Protection

Future systems must ensure secure data communication. Protecting the system from unauthorized access, data loss, and cyber threats is a major concern.

VI. WpdL For EV Chargers; Classification

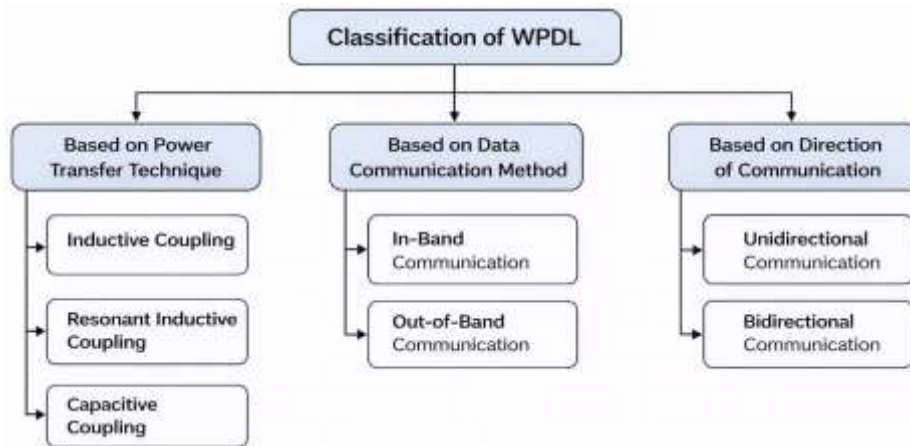


Fig.6.1. WPDL for EV Chargers Classification

The Wireless Power and Data Link (WPDL) system can be systematically classified based on three important aspects: power transfer technique, data communication method, and direction of communication. This classification helps in understanding different design approaches and selecting suitable configurations for efficient wireless charging and data exchange.

1. Based on Power Transfer Technique

This classification depends on how electrical energy is transferred between the transmitter and receiver.



a) Inductive Coupling

Inductive coupling is the most commonly used method, where power is transferred through a magnetic field generated between two coils placed in close proximity. It offers high efficiency and safety for short-distance applications such as wireless charging of electric vehicles.

b) Resonant Inductive Coupling

In this method, both transmitter and receiver coils are tuned to the same resonant frequency. This improves power transfer efficiency and allows energy transmission over relatively larger distances compared to basic inductive coupling. It is suitable for applications requiring better alignment tolerance.

c) Capacitive Coupling

Capacitive coupling transfers power through electric fields using conductive plates instead of coils. It is generally used for low-power applications and offers advantages such as compact design and reduced electromagnetic interference.

2. Based on Data Communication Method

This classification focuses on how data is transmitted between the EV and EVSE.

a) In-Band Communication

In this method, data signals are transmitted along with the power signal using modulation techniques such as ASK or FSK. It eliminates the need for separate communication channels and reduces system complexity, making it suitable for compact and cost-effective designs.

3. Based on Direction of Communication

This classification is based on the flow of data between the transmitter and receiver.

a) Unidirectional Communication

In unidirectional communication, data flows only in one direction, typically from transmitter to receiver. It is simple and easy to implement but offers limited control and monitoring capabilities.

b) Bidirectional Communication

In bidirectional communication, data is exchanged in both directions between EV and EVSE. This enables real-time monitoring, feedback control, and efficient system operation. It is widely used in modern smart charging systems.

This ensures reliable communication even in the presence of noise and interference.

VII. Experimental Results & System Performance Evaluation

The web-based monitoring interface acts as a cloud-integrated visualization layer for the Wireless Power Delivery (WPD) system, developed using the Blynk IoT platform. It functions as a centralized unit that displays real-time system parameters such as voltage, current, power, and temperature.

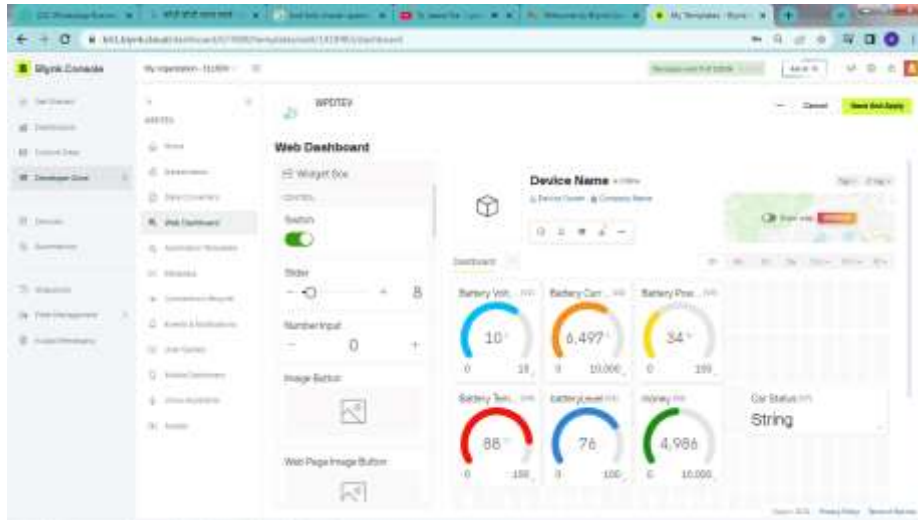


Fig.7.1.Web Dashboard

The interface uses interactive widgets to convert sensor data into clear visual indicators, enabling easy monitoring of system performance. The temperature parameter ensures safe operation, while battery level and cost estimation provide additional user-oriented insights.

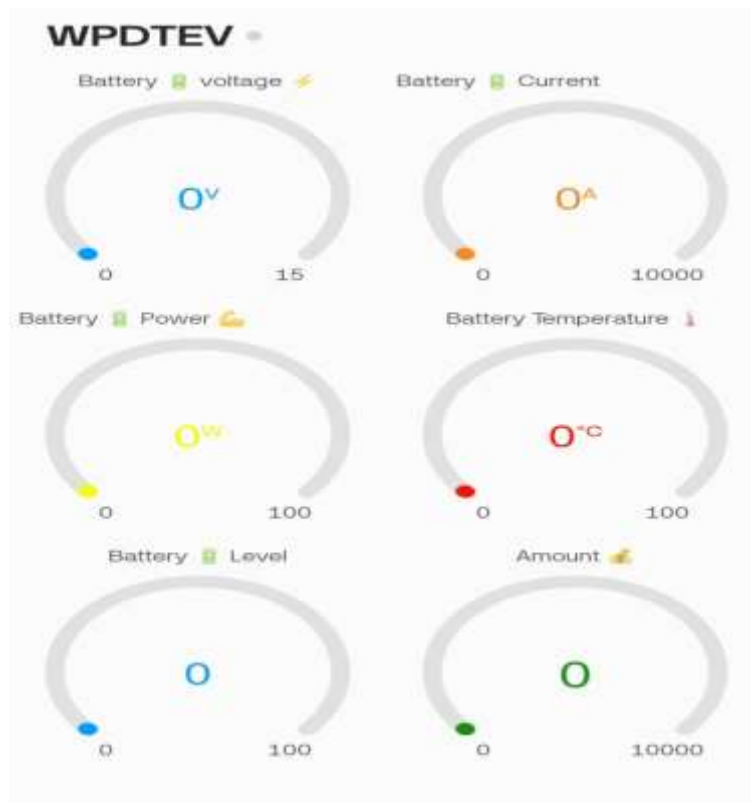


Fig.7.2. Mobile Based Real Time Control & Visualization



The mobile dashboard illustrates a portable and user-centric implementation of real-time monitoring for the wireless power delivery system. Built on the Blynk IoT platform, this interface allows users to access system data remotely through a smartphone, eliminating the need for physical supervision.

The dashboard is structured using circular gauge widgets that provide an intuitive representation of key parameters including voltage, current, power, temperature, battery percentage, and charging cost. Each gauge operates within predefined limits, ensuring accurate and bounded visualization of real-time values.

Unlike traditional monitoring systems, this mobile interface emphasizes accessibility and responsiveness. The real-time data synchronization ensures that any variation in system performance is immediately reflected on the user's device. The inclusion of cost tracking introduces an analytical dimension, enabling users to estimate energy usage and optimize efficiency.

Furthermore, the compact and interactive design of the mobile dashboard enhances user engagement while maintaining clarity and precision. This figure highlights the successful implementation of a smart monitoring ecosystem where wireless power transfer is seamlessly integrated with mobile-based IoT control.

VIII. Conclusion

The Wireless Power and Data Link (WPDL) system represents a transformative approach in modern engineering by enabling the simultaneous transmission of energy and information over a shared medium. Unlike conventional systems where power and communication are handled separately, WPDL integrates both functionalities, reducing system complexity, wiring requirements, and maintenance challenges. This integration is particularly valuable in applications such as electric vehicle dynamic charging, implantable biomedical devices, and harsh industrial environments where physical connections are impractical or unreliable.

This work analyzed key classifications of WPDL systems, including different power transfer mechanisms and communication strategies, while also addressing critical design challenges. One of the most significant technical concerns is the mutual interference between power and data signals, especially at high frequencies and varying load conditions. Additionally, issues such as coil misalignment, efficiency degradation over distance, latency in communication, and synchronization between transmitter and receiver directly impact system reliability and performance.

From a system design perspective, achieving an optimal balance between power transfer efficiency and data integrity remains a complex task. The use of resonant coupling, adaptive impedance matching, and advanced modulation techniques can significantly enhance system stability. Moreover, intelligent control strategies, such as real-time monitoring and feedback-based adjustment, can help maintain consistent performance under dynamic operating conditions.

A unique aspect of WPDL systems is their dependency on co-design, where electromagnetic, communication, and control subsystems must be developed together rather



than independently. This interdisciplinary requirement opens new research directions in areas like electromagnetic compatibility (EMC), joint optimization algorithms, and hybrid communication architectures. Furthermore, incorporating machine learning-based prediction models can improve alignment detection, fault diagnosis, and adaptive tuning of system parameters.

Looking ahead, the future of WPDL lies in scalable, high-power, and high-data-rate systems capable of supporting next-generation technologies such as autonomous electric vehicles, smart transportation infrastructure, and IoT-enabled energy networks. However, standardization, safety regulations, and cybersecurity remain key challenges that must be addressed before large-scale deployment.

In conclusion, WPDL technology holds immense potential to redefine how power and data are transmitted in integrated systems. With continued advancements in design optimization, intelligent control, and system integration, WPDL can become a cornerstone technology for efficient, contactless, and smart energy ecosystems of the future.

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