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Wireless EV and 24V Vehicle Battery Charging System with IoT Monitoring and RFID Authentication: A Survey

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Abstract - Vehicle battery charging is essential for the reliable operation of electric vehicles and conventional vehicles that use 24V auxiliary battery systems. Conventional plug-in charging requires a physical connection, whereas wireless power transfer (WPT) transfers energy across an air gap through magnetic coupling. This approach can reduce the need for exposed charging connectors, but it introduces design requirements involving coil alignment, power-conversion efficiency, thermal management, and foreign-object detection. This survey reviews the principles of inductive and resonant WPT, high-frequency power conversion, receiver-side regulation, IoT-based monitoring, and RFID-related applications. Selected research papers and a relevant industry standard are examined to identify their contributions and limitations. Particular attention is given to the gap between published EV traction-battery WPT research and the proposed application of a wireless charger for a 24V lead-acid battery. The paper also discusses the proposed integration of local monitoring, user identification, and charging records, which requires further design and experimental validation.

Keywords - Wireless Power Transfer, 24V Lead-Acid Battery, Inductive Charging, IoT Monitoring, RFID Authentication, Automated Billing, DC-DC Buck Converter, Smart Charging Station

1. INTRODUCTION

Vehicles require reliable battery power for propulsion, starting, lighting, and onboard electronics. Electric vehicles generally use high-voltage traction battery packs, whereas many conventional commercial vehicles use 24V lead-acid battery systems for starting and auxiliary loads. These applications have different voltage, power, and charging requirements and should not be treated as interchangeable. Maintaining the battery in the recommended state of charge is important for vehicle availability and battery service life. The present survey focuses on the possible use of wireless power transfer for a 24V battery-charging application, while recognizing that much of the available WPT literature concerns EV traction batteries.

Conventional charging uses cables and connectors that must be handled and maintained. In fleet or depot environments, repeated handling and exposure to vehicle movement can cause mechanical wear. Damaged insulation or incorrectly handled connectors may create electrical hazards; however, properly designed and maintained conductive charging systems can operate safely. Wireless charging removes the routine plug-and-socket connection at the vehicle interface, but it does not eliminate electrical, thermal, electromagnetic-field, or foreign-object hazards. These risks must be addressed through suitable design, protection, and testing.

Wireless power transfer sends energy across an air gap by means of magnetic coupling between a transmitter coil and a receiver coil. In a typical stationary arrangement, the transmitter is installed in a ground pad and the receiver is mounted on the vehicle. The receiver-side power is rectified and regulated before it is supplied to the battery. The amount of power transferred depends on factors such as coil design, separation, alignment, compensation network, and operating conditions.

Early WPT studies established the principles of inductive and resonant power transfer. Later research has examined practical EV charging requirements, including power-conversion stages, magnetic couplers, alignment, foreign-object detection, and charging infrastructure. IoT-based monitoring and RFID sensing have also been investigated for specific EV charging applications. However, the references reviewed here do not demonstrate a complete wireless charging station specifically designed for a 24V lead-acid battery with RFID user authentication and automated billing.

Research published between 2024 and 2026 includes studies on WPT misalignment and compensation, visual and machine-learning-based foreign-object detection, RFID-assisted coil alignment, and broader EV wireless-charging architectures. An IoT-based EV load-forecasting and charging-station recommendation approach was also reported in 2020. The reviewed literature provides relevant technical foundations, but the proposed combination of wireless 24V charging, local energy measurement, IoT monitoring, and RFID-based user identification requires separate implementation and experimental evaluation.

2. WIRELESS CHARGING AND SMART SYSTEM ANALYSIS

A typical inductive WPT system converts the AC supply into DC using an AC-DC power stage. A high-frequency inverter then

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converts the DC into high-frequency AC, which energizes the transmitter coil through a suitable compensation network. The receiver coil captures the magnetic energy, and a rectifier converts the received high-frequency AC into DC. The output must then be regulated according to the battery chemistry and charging requirements. The exact circuit arrangement depends on the selected WPT topology and power level.

For the 24V battery application considered here, the receiver-side converter must provide a controlled charging output rather than applying an unregulated voltage directly to the battery. A buck converter is suitable only when the rectified receiver voltage remains above the required charging voltage; otherwise, a buck-boost or another suitable topology may be needed. The charging controller must follow the battery manufacturer's specified charging profile and include overvoltage, overcurrent, reverse-polarity, and temperature protection. These are design requirements for the proposed 24V application, not results demonstrated by all of the EV WPT references reviewed in this paper.

2.1 Magnetic Resonance and Inductive Power Transfer

The main job of a wireless charger is to move energy across an air gap. Early wireless systems lost a lot of power if the two coils were not touching. Researchers later found that tuning both coils to the same frequency—called magnetic resonance—lets power travel across a wider gap much better.

Kurs et al. (Ref. 1) showed in 2007 that strongly coupled magnetic resonance can send electricity through the air without wires. Their work proved that safe, non-radiative magnetic fields can power devices over a short distance, though the power drops quickly if the gap becomes wider than the size of the coil. Covic and Boys (Ref. 2) studied inductive power transfer and explained how magnetic coupling and basic coil circuits work. However, their study mainly looked at heavy roadway and rail systems rather than small, smart stations.

2.2 High-Frequency Inverters and Power Electronics

A high-frequency inverter converts the DC input into alternating current at the selected operating frequency to energize the transmitter coil. The switching frequency and inverter topology depend on the resonant network, power rating, and design requirements. Appropriate switching control and component selection are important for limiting conversion losses and device heating.

Musavi and Eberle (Ref. 3) reviewed wireless power transfer technologies for EV battery charging, including the power-conversion stages and limitations relevant to practical chargers. Sagar et al. (Ref. 6) provided a broader review of recent WPT developments for EV charging systems, covering major technology approaches and design challenges. These works provide background for selecting the power-electronic architecture. They should not, however, be interpreted as evidence that a particular full-bridge MOSFET inverter or zero-voltage-switching implementation has been validated for the proposed 24V system.

2.3 Coil Design and Misalignment Control

For effective power transfer, the transmitter and receiver coils should be positioned within the alignment tolerance of the selected coupler design. Lateral or vertical misalignment can reduce magnetic coupling and may lower the transferred power or efficiency. The effect depends on coil geometry, compensation topology, and operating conditions.

SAE International's J2954 standard (Ref. 7) specifies requirements and evaluation methods for stationary wireless power transfer in light-duty plug-in/electric vehicles, including alignment, safety, interoperability, and performance. Viqar et al. (Ref. 10) investigated misalignment and compensation topologies using modelling, simulation, and hardware analysis. Yi et al. (Ref. 13) proposed a two-transmitter-coil arrangement with LCC-S compensation to improve tolerance to lateral misalignment. Shahbaz Nejad et al. (Ref. 14) investigated RFID sensing for precise coil alignment in dynamic wireless charging. These studies address different aspects of alignment; their results should not be treated as interchangeable because their system configurations and operating conditions differ.

2.4 Battery Management and 24V Buck Regulation

The voltage received from the secondary coil can vary with coil alignment, air gap, load, and operating conditions. A 24V lead-acid battery must be charged using a controlled profile appropriate to its construction and the manufacturer's specifications. A regulated DC-DC stage is therefore required between the receiver and the battery. The converter topology must be selected from the actual receiver-voltage range and required charging voltage; a buck converter is not suitable in every possible input condition.

The references included in this survey do not provide a directly verified study of a 24V lead-acid battery charger using the specific CC/CV buck-regulation arrangement proposed for this application. Therefore, this arrangement is treated as a design requirement rather than as a result established by the cited EV WPT studies. A practical charger must follow the battery manufacturer's specified charging profile and limits, with suitable current, voltage, and temperature monitoring. The complete receiver and charging-control stages must be tested across the expected range of coil alignment, air gap, load, and receiver voltage.

2.5 Thermal Monitoring, Foreign Object Detection and Safety Systems

Power losses in the coils and switching components can produce heat during wireless charging. Conductive objects placed near the charging pad may also interact with the magnetic field and create a safety concern. A practical charger therefore needs suitable

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thermal monitoring and foreign-object detection (FOD), along with a controlled shutdown mechanism. The required sensor arrangement depends on the power level, pad geometry, and safety assessment.

Niu et al. (Ref. 9) investigated foreign-object detection while considering the effect of coil misalignment. Shahbaz Nejad et al. (Ref. 11) presented a visual foreign-object detection system for EV wireless charging. Abdul Vahid et al. (Ref. 15) proposed a machine-learning-based FOD approach using planar magnetic induction tomography. These studies demonstrate different approaches to detecting objects in the charging region, but they do not establish the specific NTC thermistor or DS18B20 temperature-monitoring arrangement proposed for this application. Temperature sensors and a safety relay may be considered in the proposed implementation, subject to thermal testing and an appropriate protection design.

2.6 IoT and Cloud Monitoring Systems

A charging station may provide the vehicle owner or station operator with information such as charging voltage, current, estimated battery state, temperature, and session status. Internet of Things (IoT) technology can support remote monitoring by transmitting selected measurements to a local or cloud-based application. The accuracy of displayed battery state depends on the measurement and estimation method; battery voltage alone does not always provide a reliable state-of-charge estimate, particularly while charging.

Savari et al. (Ref. 8) studied an IoT-based approach for real-time EV load forecasting and charging-station recommendation. Their work demonstrates an application of IoT and server-based processing in EV charging infrastructure. It does not, by itself, verify the use of MQTT, Blynk, or the exact voltage-and-current dashboard proposed in this survey. Such features may be implemented in the proposed station, but the communication protocol, data security, network-failure behaviour, and local safety controls must be specified and tested.

2.7 Edge Computing for Local Energy Metering

A charging station may need to calculate delivered energy and maintain a charging record even when internet connectivity is temporarily unavailable. One approach is to perform essential measurements and safety decisions locally, then send summary data to a remote dashboard when a connection is available. Energy measurement should be based on calibrated voltage and current measurements integrated over time, with suitable electrical isolation and measurement accuracy. Local processing is a proposed design choice in this survey; it is not a finding attributed to Reference 8.

Savari et al. (Ref. 8) described a server-based IoT application for EV load forecasting and charging-station recommendation. This differs from local energy metering at an individual charger. For the proposed system, local measurement and protection can be implemented in a microcontroller, while cloud connectivity can be used for remote status and record storage. The accuracy of energy and cost calculations will depend on sensor calibration, sampling, integration method, and the tariff configuration. The chosen microcontroller and measurement circuit must be validated before billing data are treated as accurate.

2.8 RFID Access Control and Automated Billing

In a shared parking area or fleet depot, a charging station may require a way to identify the vehicle or user and maintain a record of charging sessions. RFID can be considered for contactless identification, but coil-alignment sensing, user authentication, energy measurement, and payment processing are separate functions and should not be treated as the same technology.

Shahbaz Nejad et al. (Ref. 14) investigated RFID sensing for coil alignment in dynamic wireless EV charging. Their work concerns position estimation and does not establish RFID user authentication or automated payment. The proposed station may use an RFID reader to identify registered users, while a separate energy-metering and billing module records each session. This integration is a proposed system feature in the present survey; the selected references do not verify a complete RFID-to-cloud billing implementation. A basic RFID card identifier should not be treated as strong authentication unless suitable security measures are included.

3. COMPARISON OF EXISTING METHODS

The reviewed studies address different parts of wireless charging. Kurs et al. (Ref. 1) established the principle of strongly coupled magnetic resonance, while Covic and Boys (Ref. 2) and Musavi and Eberle (Ref. 3) provide broader coverage of inductive power transfer and EV charging technologies. Budhia et al. (Ref. 4) studied a magnetic coupler for EV inductive charging. Bi et al. (Ref. 5) and Sagar et al. (Ref. 6) reviewed WPT technologies and their technical and deployment considerations. SAE J2954 (Ref. 7) provides a standard framework for stationary light-duty EV WPT; its scope should not be assumed to certify the proposed 24V application.

Other studies focus on specific implementation challenges. Savari et al. (Ref. 8) investigated IoT-based load forecasting and charging-station recommendation. Niu et al. (Ref. 9) studied foreign-object detection while considering coil misalignment, and Viqar et al. (Ref. 10) analysed misalignment and compensation topologies. Shahbaz Nejad et al. (Ref. 11) examined visual foreign-object detection, while Abuajwa et al. (Ref. 12) reviewed WPT systems for EV charging. Yi et al. (Ref. 13) and Shahbaz Nejad et al. (Ref. 14) addressed misalignment compensation and RFID-assisted coil alignment, respectively. Abdul Vahid et al. (Ref. 15) investigated machine-learning-based foreign-object detection. These works do not collectively demonstrate a complete 24V wireless charging station with RFID user authentication and automated billing.

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The literature therefore provides relevant building blocks, but the specific combination proposed in this survey remains to be designed and experimentally validated. A practical 24V system would require a suitable resonant coil pair, a correctly rated power converter, a battery-specific charging controller, alignment and foreign-object detection, thermal and electrical protection, local energy measurement, and secure user identification. IoT monitoring and automated billing can be added as supervisory functions, but they must not be allowed to override local safety protection.

4. MAJOR CHALLENGES

4.1 Cable Wear and Spark Risks

Conductive charging cables and connectors can experience wear through repeated handling, vehicle movement, and environmental exposure. Damaged insulation, loose connections, or incorrect handling may create electrical hazards. Routine inspection, suitable cable ratings, protective devices, and correct installation remain necessary for wired charging systems.

4.2 Coil Misalignment

Lateral or vertical displacement between the transmitter and receiver coils changes their magnetic coupling. Depending on the coil design and compensation method, misalignment can reduce transferred power, lower efficiency, or cause output variation. Alignment tolerance must therefore be evaluated for the intended vehicle and charging-pad geometry.

4.3 Heat Buildup

Poor coil alignment can reduce magnetic coupling and may increase losses, resulting in additional heating in the coils and power-electronic components. The charger should monitor relevant temperatures and stop power transfer if defined safety limits are exceeded. Trip limits and sensor placement must be established through design calculations, applicable safety requirements, and testing.

4.4 Unsteady Receiver Voltage

Changes in coil position, air gap, load, or operating conditions can cause the receiver output to vary. This output must be rectified and regulated before it is connected to a 24V lead-acid battery. Applying unregulated receiver power directly to the battery may result in incorrect charging and battery damage.

4.5 Lack of Live Energy Tracking

Without appropriate measurement and monitoring, users may not know the charging voltage, current, energy delivered, or charging status. A local display or remote dashboard can improve visibility, provided that measurement accuracy and communication failure handling are addressed.

4.6 Slow Manual Payments

Manual payment steps can add time to fleet charging operations. RFID-based user identification and automated session records may simplify the workflow, but secure authentication, accurate energy measurement, and payment integration require separate implementation and validation.

4.7 Internet Delays

If the charger depends on a remote server for essential control decisions, network interruptions may affect availability. Safety functions such as overcurrent protection, overtemperature shutdown, and charging termination should operate locally and independently of the cloud connection.

4.8 High Hardware Cost

Using multiple overlapping coils or expensive custom magnetic shields to fix parking mistakes makes the charger too costly for normal everyday use.

5. RECENT DEVELOPMENTS

Selected developments reported from 2024 to 2026 include research on misalignment compensation, foreign-object detection, RFID-assisted alignment, and broader EV wireless-charging systems:

- **WPT System Reviews:** Abuajwa et al. (Ref. 12) published a comprehensive review of WPT systems for EV charging in 2025. Sagar et al. (Ref. 6) provide an earlier broad review of WPT developments.
- **Misalignment Compensation:** Viqar et al. (Ref. 10) analysed misalignment and compensation topologies in 2024, while Yi et al. (Ref. 13) reported a two-transmitter-coil arrangement with LCC-S compensation in 2026.
- **Foreign Object Detection:** Shahbaz Nejad et al. (Ref. 11) presented a visual FOD system in 2024, and Abdul Vahid et al. (Ref. 15) investigated machine-learning-based FOD using planar magnetic induction tomography in 2026. Niu et al. (Ref. 9) provide earlier work on FOD under coil-misalignment conditions.

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- **RFID-Assisted Alignment:** Shahbaz Nejad et al. (Ref. 14) studied RFID sensing for coil alignment in dynamic wireless charging in 2025. This is an alignment application, not evidence of RFID payment or user-account billing.
- **IoT Applications:** Savari et al. (Ref. 8) investigated IoT-based EV load forecasting and charging-station recommendation in 2020. Their work is relevant to connected charging infrastructure, but it does not establish the particular ESP32 cloud-metering implementation described as a possible design in this survey.
- **Battery Charging and Thermal Protection:** The reviewed references do not directly validate the specific 24V lead-acid charging profile or temperature-sensor arrangement proposed here. These remain implementation requirements that need dedicated technical references, manufacturer specifications, and experimental verification.

6. FUTURE RESEARCH DIRECTIONS

Wireless vehicle charging still has many exciting areas for future growth:

- **Two-Way Power Flow (Vehicle-to-Grid):** Future research may investigate bidirectional wireless power transfer, allowing compatible vehicles to return stored energy to a building or the grid. This requires suitable bidirectional power converters, battery controls, communication, and compliance with applicable standards; it is not a feature established for the proposed 24V charger.
- **Foreign Object Detection:** Further work can investigate sensors and algorithms that identify conductive or otherwise hazardous objects on or near the charging pad before and during power transfer. Detection performance should be evaluated under different object types, positions, coil alignments, and operating conditions.
- **Charging While Driving:** Dynamic wireless charging uses transmitter coils installed along a roadway or route to transfer energy to a moving vehicle. Practical deployment requires segmented power control, vehicle detection, alignment management, safety measures, and substantial infrastructure.
- **Cloud Data Management:** A secure cloud database may support multi-station monitoring and session records. Such a system would require reliable communication, access control, privacy protection, backup, and a defined billing architecture; scaling to thousands of stations cannot be assumed without testing.
- **Solar-Powered Wireless Pads:** Integrating solar generation and energy storage with a wireless charging pad may reduce dependence on grid electricity. The environmental benefit depends on the energy source, storage losses, system efficiency, and operating conditions; such a system cannot automatically be described as completely green or grid-independent.

7. DISCUSSION

The reviewed literature shows that WPT has developed from fundamental resonant-transfer experiments into a broad research area involving EV charging architectures, magnetic couplers, alignment methods, and safety systems. Kurs et al. (Ref. 1) demonstrated strongly coupled magnetic resonance, while later reviews by Musavi and Eberle (Ref. 3), Bi et al. (Ref. 5), Sagar et al. (Ref. 6), and Abuajwa et al. (Ref. 12) discuss wider WPT technologies and their limitations. More recent studies examine coil misalignment, compensation, and foreign-object detection (Refs. 9–11, 13, and 15).

For the proposed station, the receiver output must be regulated according to the requirements of the 24V battery, and the system must include suitable electrical and thermal protection. Coil alignment and foreign-object detection are also important because poor positioning and objects near the pad can affect safe operation. SAE J2954 (Ref. 7) provides relevant alignment, interoperability, and safety requirements for stationary light-duty EV WPT, but its scope should not be assumed to certify a separately developed 24V charger.

A microcontroller can coordinate local measurements, protection, and supervisory communication. Voltage and current sensors may be used to estimate delivered energy, while an IoT platform can display operating data and store session records. RFID may be used for user identification in the proposed design; however, the RFID study cited here (Ref. 14) concerns coil alignment rather than user authentication. The proposed combination of RFID identification, energy metering, cloud logging, and billing must therefore be implemented and tested as a new integration, with secure authentication and local safety control.

8. CONCLUSION

This survey reviewed wireless power transfer technologies and their possible application to a smart charging station for 24V vehicle batteries. The cited literature covers resonant and inductive power transfer, EV charging architectures, magnetic couplers, alignment standards, IoT applications, misalignment compensation, and foreign-object detection. However, most of the reviewed WPT research concerns EV traction-battery charging rather than 24V lead-acid auxiliary batteries. The electrical design and charging profile must therefore be adapted and validated for the intended battery type.

The review identifies several functions required for a practical implementation: suitable transmitter and receiver coils, a properly selected high-frequency power stage, regulated battery charging, alignment and foreign-object detection, thermal and electrical

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protection, local energy measurement, and reliable monitoring. RFID-assisted coil alignment has been reported in the literature, whereas RFID user authentication and automated billing are proposed integration features in this survey and are not demonstrated by the cited RFID reference. A complete 24V wireless charging station will require detailed design, safety testing, efficiency measurement, and experimental validation before its performance can be claimed.

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