International Journal of Engineering Science Invention Research & Development; Vol. 12, Issue 10, April 2026
www.ijesird.com, E-ISSN: 2349-6185

IOT- BASED CHARGEBOT PHYGITAL STATION

Mr. Vivek Sharma[1], Mahak Mayani[2], Mayank Jain[3], Snehal Gajraj[4], Taniya Khan[5]
#1 Assistant Professor, Department of EE, Swami Keshvanand Institute of Technology, Management and Gramothan ,2,3,4,5 B.Tech Student, Department of EE, Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur, Rajasthan, India

***Abstract*- Because the population is increasing very rapidly, the demand for fuel has also increased considerably, and the conventional sources of fuel are drying up. Fuel is something without which one cannot think of surviving, mainly in the transportation department, as vehicles need fuel to work. But their excessive use results in severe environmental pollution, which is very injurious to the living organisms like human beings, animals, and plants. In order to discard all these issues, with advancements in technology, more and more electric vehicles have been adopted. The electric vehicle runs entirely on electrical energy and produces extremely less pollution as compared to conventional fuel-based automobiles, and hence, this may be considered an eco-friendly substitute to conventional automobiles. The ChargeBot prototype represents a leap to the next generation of electric vehicle charging systems: wireless, supplied by renewable energy, and connected in a digital manner. Further, benefitting from its design, it can be used in smart cities and residential areas to offer a cleaner, smarter, and more reliable alternative to conventional methods of charging. By blending the concept of renewable energy and smart digital tracking, enabled via IoT, it is possible that ChargeBot may speedily promote the usage of EVs.**

***Keywords*- Electric Vehicles , Automation, Wireless EV Charging, Renewable Energy, Smart cities..**

I. INTRODUCTION

This project is a prototype for the wireless charging of electric vehicles, where IoT plays a crucial role. It represents the development of a smart and sustainable electric vehicle charging station that utilizes solar photovoltaics (PVs) as an energy power source. This project is the integration of IoT monitoring, RFID authentication, and the capability of wireless charging. The system consists of a control unit based on a microcontroller (ESP32), a solar power generation unit, a battery storage system, and an RFID module for secure access and all information about the system. The demand for electric vehicles is rising as the automotive industry transitions quickly from IC engine vehicles to electric vehicles. As a result, there are also more charging stations. This project uses an inductive coupling to wirelessly charge the car using a wireless charging system. All we have to do is park the vehicle on the charging station. Wireless power transmission is the process of moving electrical energy from a source to a load remotely without the use of wires or cables. Nikola Tesla's greatest invention was the wireless power transfer concept. There is no need for human interaction with this system. Wireless power transmission might be one of the technologies that is one step forward towards the future [20]. This project can open up new possibilities of wireless charging that can be used in our daily lives. Wireless power transfer (WPT) using magnetic resonance is the technology that could set humans free from the annoying wires. In fact, the WPT adopts the same basic theory, which has already been developed for at least 30 years with the term inductive power transfer[33]. WPT technology has been developing rapidly in recent years. At milliwatts to kilowatts power level, the power transfer distance increases from several millimeters to several hundred millimeters with a load efficiency above 90%. The advances make the WPT very attractive to electric vehicle (EV) charging applications in both static and dynamic charging scenarios.

A. LITERATURE REVIEW

IoT in Electric Vehicle Charging Systems

The role of IoT in EV charging infrastructure is making a revolution in place of conventional charging of electric vehicles, as many studies have highlighted. The Internet of Things makes it possible to monitor in real-time charging and electrical parameters such as current, voltage, and power, as well as battery condition and energy consumption. Many researchers have proposed smart charging systems for EVs, using the concept of the Internet of Things that utilizes microcontrollers like MSP430, ESP8266, ESP32, and Arduino, along with cloud platforms for data storage and visualization. These systems facilitate remote access, enhance energy management, and support charging station predictive maintenance.

To improve safety and reduce human interference, automation in EV charging has been widely explored. The literature shows how to accurately connect the chargers to vehicles by guided positioning systems, robotic arms, and the use of automated charging docks.

Robotic charging systems enhance convenience, especially in public charging stations, and also minimize the damage caused by human consumers or handlers. Various sensors like proximity sensors, cameras, and limit switches ensure precise alignment and safe operation, which is integrated into the system.

Inductive coupling and resonant magnetic coupling are the techniques for wireless power transfer (WPT) of electric vehicles, and this is the focus of many researchers. IoT increases the system efficiency and reliability by monitoring charging status and ensuring efficient power transfer in the vehicles. Challenges like cost, losses of power, and alignment of coils are still under research. These studies establish a basis for hybrid systems that integrate wired and automated robotic charging solutions.

Phygital is the combination of physical and digital, where physical hardware and digital platforms are integrated into one system, such as mobile applications and web dashboards. Much literature provides real-time information, digital payments, booking of slots, and notification of emergencies about battery status, which improves user interest in the phygital system. To enhance the overall user experience, EV charging applications provide users the ability to interact with the charging system through apps, QR codes, or touch interfaces.

According to a literature survey, it is provided that IoT, phygital (physical+digital) systems, and automation are the key enablers for next-generation EV charging infrastructure. Smart charging, wireless power transfer, cloud connectivity, and automation are provided in previous research. The proposed IoT-based ChargBot Phygital Station builds on these studies to provide a scalable, intelligent, and efficient solution that can be used in future smart cities and sustainable transportation systems.

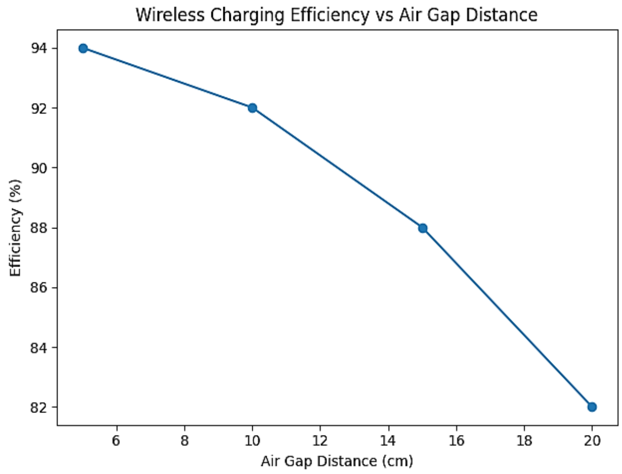

Fig.1 Variation of wireless power transfer efficiency with air gap distance (illustrative trend based on reported behavior in [25], [26])

B. *MOTIVATION*

Convenient, safe, secure, and intelligent charging infrastructure is becoming necessary, which is the driving force behind the development of an IoT-based wireless charging system for electric vehicles. Electric shock, damaged cables, and shoddy connections may result from conventional charging systems where a plug-in system needs physical connectors, continuous maintenance, human interference, and wear and tear of cables.

Electromagnetic induction, or resonant coupling, is the technique of transferring power to the wireless charging of electrical vehicles, which eliminates physical connectors.

Energy optimization is the key motivation. IoT-based systems can integrate with smart grids such as solar and wind energy, balance loads, and manage power dynamically to reduce peak demand and improve overall efficiency. This (WTP) is crucial as the number of electric vehicles continues to grow.

II. IMPLEMENTATIONS

A. *(16×2) LCD Display with I2C module*

Fig.2 LCD with I2C module

The LCD module applied in the system uses the I2C communication protocol, which needs only two lines for communication: SDA and SCL. It decreases the usage of ESP32 GPIO pins by providing an I2C interface for efficient serial communication capable of real-time display of battery voltage, battery percentage, and battery temperature. It also shows RFID authentication status and charging state.

B. *Rectifier and Filter*

A bridge rectifier is used to convert the AC voltage from the received coil into a DC voltage. Four diodes are connected to create a full wave rectification. A filter capacitor is connected to smooth the ripples from the rectified signal to produce a stable DC voltage. A resistor voltage divider reduces the voltage to a safe range for measurement with the ESP32 ADC.

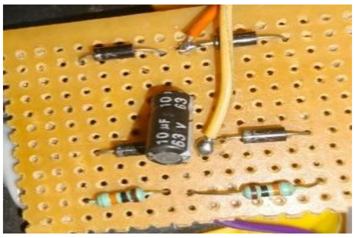

Fig.3 Rectifier circuit

C. *DC Barrel Jack - Female*

The DC Jack is a power interface connector that is used to supply external regulated DC voltages. It allows auxiliary or backup power input if needed.

Fig.4 DC Jack

D. *SMPS - Switched Mode Power Supply*

The SMPS is a device for high-efficiency power conversion that takes AC voltage inputs and provides a DC output. It supplies power to circuits and charging modules in a stable and isolated condition.

E. *TP4056 Li-ion Lithium Battery Charging Module*

USB charging TP4056 is a linear charge control IC used primarily to charge Lithium-ion batteries while ensuring safe charging with protection such as over-charging, constant current/constant voltage, and thermal protection.

Fig.5 Li-ion Lithium Battery Charging Module

F. *Solar Panel Module 6V 2W 0.35A 80A Round Polycrystalline*

The solar panel receives the power provided by the sun. It then transforms the power into electrical energy using the photovoltaic effect. The solar panel is considered to be the main source of renewable energy and is required to run the charging station.

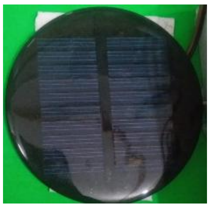

Fig.6 Solar panel

G. *RC522 13.56MHz RFID Card Reader Module*

The RFID reader works on the principle of detecting radio frequency electromagnetic waves from an RFID tag, thereby allowing the system to use it for authenticating vehicles before access is granted to the charging point.

Fig.7 RFID module and Card

H. ESP WROOM 32 MCU Module

The ESP32-WROOM is a high-performance microcontroller that is used for acquiring data, processing the data, performing control actions, and communicating wirelessly in the field of IoT-based monitoring and system automation. The microcontroller is enabled with Wi-Fi and Bluetooth communication.

Fig.8 ESP32 controller

I. LM35 Temperature Sensor

The device is a precision integrated circuit temperature sensor. It is capable of producing linear voltage outputs that are proportional to temperatures expressed in degrees Celsius. It allows for accurate thermal monitoring of the battery during charging operations.

Fig.9 LM35 sensor

J. LED (Light Emitting Diode)

An LED is a semiconductor device and emits light when biased. It is typically used as a visual status indicator for the visualization of power availability or charging activities.

Fig. 10 LED

K. Magnetic Flux Linkage between Transmitter and Receiver Coils

The transmitter coil produces a high frequency alternating magnetic field when it is "energized". The magnetic flux is picked up by the receiving coil, which induces AC voltage using the principle of electromagnetic induction.

L. Diode - 1N4007

General-purpose silicon rectifier diode 1N4007 has been used in the bridge rectifier stage for conversion of induced AC voltage into DC voltage. It allows current to flow in one direction and enables full-wave rectification to take place, keeping DC output stable for the charging circuit.

M. Blynk IoT Platform (Displayed Parameters)

The cloud platform is used to ensure the real-time monitoring of the parameters of the system with the help of Wi-Fi communication supported by the ESP32 board's microcontroller. In this case, the parameters are monitored in real-time, such as battery voltage, battery percentage, battery temperature with the use of the LM35 sensor, RFID vehicle identification, and charging status, via the human interface of the mobile application.

III. PROBLEM FORMULATION

A. Low Power Transfer Efficiency & Distance Limitations

Similarly, with an increase in distance between transmitting (ground side) and receiving (vehicle side) coils, there is a substantial decrease in the efficiency of wireless charging

B. Thermal Management & Safety Issues

Due to overheating of the coil and high power transfer, it can reduce system lifespan, material degradation, heating of power electronics, and safety hazards. Overvoltage, overcurrent, and the necessity for continuous temperature monitoring and protection mechanisms are the risks included in the system.

C. Real-time Monitoring & Data Gaps

Various implementations of these systems may not include continuous monitoring of parameters such as the state of charge, battery health, and overall energy consumption, leading to gaps between this data, hindering intelligent decisions.

D. Electromagnetic Interference

There has to be proper shielding and safety measures in place in order to protect the electronic devices, communication equipment, and medical devices around the wireless power transfer system, as it would interfere by generating an electromagnetic field.

E. Cybersecurity & Data Privacy

Cyber-attacks, unauthorized access, and data breaches have been introduced due to the inclusion of IoT modules. Secure communication, encryption, and authentication are important for the security and privacy of any user.

F. Grid Load Management

Simultaneous charging of various EVs can increase demand or peak load conditions, which potentially destabilizes the power grid.

IV. WORKING

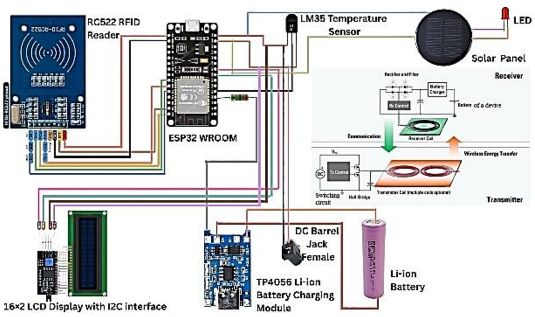

Fig. 11 Circuit Diagram

The process of the IoT based ChargeBot Phygital Station starts by the Solar Panel Module (6V, 2W, 0.35A Round Polycrystalline), which converts solar energy into DC electrical energy. The DC electrical energy, then, is supplied to the TP4056 Li-ion Lithium Battery Charging Module, which regulates the usage in the charging of the 18650 Li-ion 2600mAh Rechargeable Battery.

The battery will be used for storing the required amount of power, which is utilized by the ESP WROOM 32 MCU Module and the wireless transmission circuit. The 2N2222 NPN transistor, which is enabled by the control circuit, will be able to provide the required current for the transmitter coil. As soon as it is enabled, a magnetic field will be generated by the transmitter coil. Consequently, a voltage will be generated within the receiver coil by electromagnetic induction based on the magnetic link between the two coils. The induced A.C. voltage is converted into Direct Current using the Rectifier and Filter circuit and is then supplied for charging purposes. A 9V battery, Hi-Watt type (6F22), can be used as an auxiliary supply during testing. Before charging is activated, authentication takes place using the RC522 13.56MHz RFID Card Reader Module. When the RFID tag serial number is valid, the ESP32 will verify the serial number, matching it with the corresponding vehicle number. Only authorized users can use the charging facility.

Fig.12 Block Diagram

The LM35 temperature sensor continuously monitors the temperature of the battery, while the voltage of the battery is monitored through an analog sensing system. The ESP32 then uses the readings from the sensor and the voltage to compute the percentage of the battery. The system displays real-time values like battery voltage, battery temperature, RFID, vehicle number, and charging state on these displays using an LCD Display with an (16×2) I2C interface. At the same time, it sends these values via Wi-Fi, and in the software platform, values like battery voltage, battery temperature, battery percentage, RFID, and vehicle number can be seen. There is also an LED indicating the charging status.

Hence, a system that incorporates features of renewable energy, wireless charging, authentication, monitoring, and IoT communication is developed.

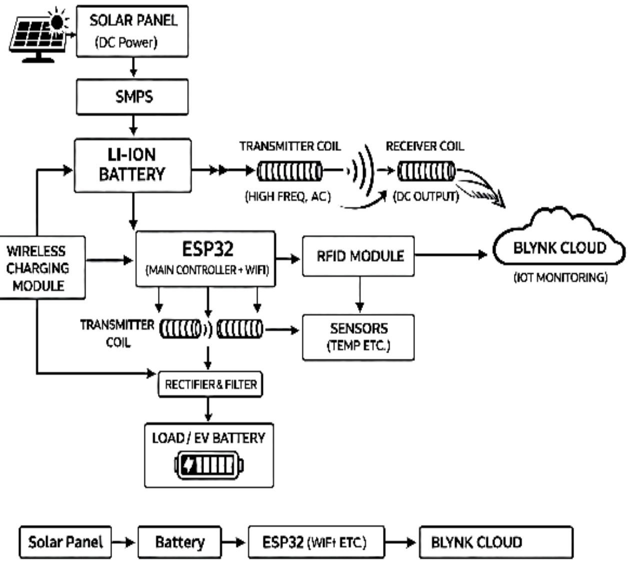

Fig.12 Block Diagram

V. METHODOLOGY

If a wired charging system is built at various charging stations. Wired charging stations have more disadvantages, such as requiring more space, having different types of sockets, requiring a small substation, having a converter circuit installed at every charging station, having a limited range of wire, and also requiring more time for charging. All these problems are solved by a wireless electrical vehicle charging system. The traditional wired or plug-in charging systems are not user-friendly and environment-friendly. To reduce the charging time, a large number of batteries can be used, or the drained batteries can be swapped with the charged batteries when needed. There is energy waste due to line loss when the coil is conducted for a long time. Its service life will be decreased because of continuous working[16].

VI. RESULT

Fig.13 Complete Project Photo

This project is a prototype, where all components are working at a low rating.

Firstly, we observed that the solar panel was able to charge the Li-ion battery properly under sunlight conditions through the TP4056 module. This battery supplied power to the ESP32 and the transmitter circuit, and the system is working smoothly without any power drops during our testing. For authentication of the system, the RFID module was checked using different RFID cards. When a registered card was scanned, the charging process started immediately. However, when an unregistered card was used, the system did not allow charging; this confirmed that the access control feature was functioning correctly. Testing of wireless charging starts after placing the transmitting and receiving coils close. We noticed that the receiver coil was able to pick up the induced voltage, which was then converted into DC using the bridge rectifier circuit. The output was stable at short distances, although the efficiency reduced slightly when the distance between the coils increased. The LM35 temperature sensor continuously displayed temperature readings on the 16×2 LCD along with battery voltage and charging status. During extended operation, small temperature variations were observed, and the system was able to monitor them properly.

The ESP32 also sent real-time data to the Blynk application through Wi-Fi. Parameters such as battery voltage, temperature, percentage level, and RFID status were visible on the mobile interface during testing, and the data updated regularly.

VII. CONCLUSION

Presented here is the design and development, followed by experimental validation, of an IoT-based functional prototype ChargeBot Phygital Station that integrates renewable energy, wireless power transfer, secure authentication, and real-time IoT monitoring into a unified framework. In such a system, the effective conversion of solar energy to stored electrical energy was demonstrated using the Li-ion battery management system, and then controlled wireless transmission through magnetic flux linkage between transmitter and receiver coils. This ensures that only authentic vehicle users are able to commence charging safely through the implementation of RFID-based authentication. Continuous monitoring of the battery voltage and temperature using analog sensing was done with the LM35 sensor for enhancing operational safety and reliability. Real-time data acquisition by the ESP32 Wi-Fi module in the Blynk platform provided intelligent monitoring, which allowed for remote supervision of battery voltage, temperature, charging status, RFID identity, and vehicle number. The prototype proves the feasibility of the proposed system design. Although the scale at which the prototype is designed is small, the proposed system architecture shows promise to scale up to build a future generation of smart electric vehicle charging infrastructure meeting the criteria of sustainability and intelligence**.**

REFERENCE

[1] S. Deilami, A. S. Masoum, P. S. Moses, and M. A. S. Masoum, "Real-time coordination of plug-in electric vehicle charging in smart grids to minimize power losses and improve voltage profile," *IEEE Transactions on Smart Grid*, vol. 2, no. 3, pp. 456–467, Sept. 2011.

[2] Y. He, B. Venkatesh, and L. Guan, "Optimal scheduling for charging and discharging of electric vehicles," *IEEE Transactions on Smart Grid*, vol. 3, no. 3, pp. 1095–1105, Sept. 2012.

[3] A. Kurs *et al.*, "Wireless power transfer via strongly coupled magnetic resonances," *Science*, vol. 317, no. 5834, pp. 83–86, Jul. 2007.

[4] C. C. Chan, "The state of the art of electric and hybrid vehicles," *Proceedings of the IEEE*, vol. 90, no. 2, pp. 247–275, Feb. 2002.

[5] H. H. Wu, A. Gilchrist, K. Sealy, and D. Bronson, "A review on inductive charging for electric vehicles," *IEEE Transactions on Industrial Electronics*, vol. 62, no. 10, pp. 6538–6548, Oct. 2015.

[6] N. Tesla, "Apparatus for transmitting electrical energy," U.S. Patent 1,119,732, Dec. 1, 1914.

[7] M. Kezunovic and J. McCalley, "Smart grid and renewable energy integration," *IEEE Power and Energy Magazine*, vol. 8, no. 1, pp. 22–34, Jan.–Feb. 2010.

[8] M. A. Razzaque, M. Milojevic-Jevric, A. Palade, and S. Clarke, "Middleware for Internet of Things: A survey," *IEEE Internet of Things Journal*, vol. 3, no. 1, pp. 70–95, Feb. 2016.

[9] F. Restuccia, S. D'Oro, and T. Melodia, "Securing the Internet of Things in the age of machine learning and software-defined networking," *IEEE Internet of Things Journal*, vol. 5, no. 6, pp. 4829–4842, Dec. 2018.

[10] Blynk Inc., "Blynk IoT platform documentation." [Online]. Available: https://blynk.io

[11] Espressif Systems, "ESP32-WROOM-32 datasheet," Espressif Systems, 2023.

[12] Texas Instruments, "LM35 precision centigrade temperature sensors datasheet," Texas Instruments, 2022.

[13] NXP Semiconductors, "MFRC522 RFID reader IC datasheet," NXP Semiconductors, 2021.

[14] M. H. Qahtan, E. A. Mohammed, and A. J. Ali, "Charging station of electric vehicle based on IoT: A review," *Open Access Library Journal*, vol. 9, p. e8791, 2022, doi:10.4236/oalib.1108791.

[15] V. K. B. Veeresha *et al.*, "IoT-based wireless EV charging station using Arduino Uno," *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, vol. 14, no. 1, 2026, doi:10.17148/IJIREEICE.2026.14107.

[16] P. Adith *et al.*, "Solar-based smart charging station with wireless power transfer for electric vehicles and monitoring using IoT," *International Advanced Research Journal in Science, Engineering and Technology*, 2025, doi:10.17148/IARJSET.2025.125335.

[17] A. Devkar, M. Nalawade, S. Patil, and A. Nichal, "Review paper on wireless EV charging integrated with IoT-based smart parking monitoring system," *International Journal of Research and Scientific Innovation*, vol. 12, no. 11, pp. 519–524, 2025, doi:10.51244/IJRSI.2025.12110050.

[18] H. Mandapati, S. B. Shaganti, N. Bura, T. S. Babu, T. M. Krishna, and N. Nwulu, "IoT-based wireless electric vehicle charging station," in *Lecture Notes in Networks and Systems*. Singapore: Springer, 2025, pp. 955–963, doi:10.1007/978-981-97-8329-8_70.

[19] H. Sahu, H. Arya, A. Penta, R. Kumar, and S. Saha, "IoT based smart parking ecosystem with connected wireless induction chargers," *SAE Technical Paper*, 2024, doi:10.4271/2024-26-0129.

[20] S. Sandeep, M. H. V., S. Chacko, and S. Kulal, "IoT based EV wireless charging station," *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, 2024, doi:10.17148/IJIREEICE.2024.12709.

[21] A. Devkar, M. Nalawade, S. Patil, and A. Nichal, "Review Paper on Wireless EV Charging Integrated with IoT-Based Smart Parking Monitoring System," *Int. J. Res. Sci. Innov.*, vol. 12, no. 11, pp. 519–524, 2025, doi:10.51244/IJRSI.2025.12110050. :contentReference[oaicite:5]

[22] H. Mandapati, S. B. Shaganti, N. Bura, T. S. Babu, T. M. Krishna, and N. Nwulu, "IoT-Based Wireless Electric Vehicle Charging Station," Lecture Notes in Networks and Systems, Springer, 2025, doi: 10.1007/978-981-97-8329-8_70.

[23] J. M. Miller *et al*., "Demonstrating dynamic wireless charging of an electric vehicle: The benefit of electrochemical capacitor smoothing," *IEEE Transactions on Power Electronics*, vol. 29, no. 4, pp. 1819–1825, Apr. 2014.

[24] A. Kurs et al., "Wireless Power Transfer via Strongly Coupled Magnetic Resonances,"*Science*, vol. 317, no 5834, pp. 83–86, 2007. doi: 10.1126/science.1143254.

[25] S. Lukic and Z. Pantic, "Cutting the cord: Static and dynamic inductive wireless charging of electric vehicles," *IEEE Electrification Magazine*, vol. 1, no. 1, pp. 57–64, Jun. 2013.

[26] J. M. Miller, O. C. Onar, and M. Chinthavali, "Primary-side power flow control of wireless power transfer for electric vehicle charging," *IEEE Transactions on Power Electronics*, vol. 29, no. 9, pp. 4592–4604, Sept. 2014.

[27] V. K. B. Veeresha, A. M. Patil, L. H., P. M. Mesta, and S. G. K., "IoT-Based Wireless EV Charging Station Using Arduino Uno," Int. J. Innov. Res. Electr., Electron., Instrum. Control Eng., DOI: 10.17148/IJIREEICE.2026.14107, 2026. :contentReference[oaicite:1]{index=1}

[28] C. C. Mi, G. A. Covic, and O. C. Onar, "Modern advances in wireless power transfer systems for roadway powered electric vehicles," *IEEE Transactions on Industrial Electronics*, vol. 63, no. 10, pp. 6533–6545, Oct. 2016.

[29] G. A. Covic and J. T. Boys, "Inductive power transfer," *Proceedings of the IEEE*, vol. 101, no. 6, pp. 1276–1289, Jun. 2013.

[30] J. M. Miller, "Design considerations for wireless charging of electric vehicles," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 147–156, Mar. 2015.

[31] SAE International, "SAE J2954 wireless power transfer for light-duty plug-in/electric vehicles," SAE Standard J2954, 2020.

[32] IEEE, "Internet of Things (IoT) for smart grid applications," *IEEE Communications Magazine*, 2018.

[33] S. Li and C. C. Mi, "Wireless Power Transfer for Electric Vehicle Applications," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 3, no. 1, pp. 4-17, March 2015, doi: 10.1109/JESTPE.2014.2319453.