

Automatic Dynamic E-Vehicle Charging System Using Wireless Power Transfer Technology

Sudip Kr. Bid¹, Priyanka Dutta², Alpha Kujur³, Koushik Sahoo⁴, Ashish Rana⁵, Samir Samanta⁶, Subrata Dhara⁷

^{1,2,3,4,5,6,7} Electrical Engineering, Swami Vivekananda School of Diploma

¹ sudip.bid@gmail.com

Abstract - The rapid adoption of electric vehicles (EVs) has created a growing demand for efficient and convenient charging technologies. Conventional charging methods require vehicles to remain stationary for extended periods, limiting operational flexibility and user convenience. This paper presents the design and development of an Automatic Dynamic E-Vehicle Charging System based on Wireless Power Transfer (WPT) technology. The proposed system employs electromagnetic induction to transfer energy wirelessly from a transmitting coil embedded beneath a charging platform to a receiving coil mounted on an electric vehicle. An Arduino-based control system, integrated with infrared sensors and relay modules, automatically detects vehicle presence and initiates the charging process. The system continuously monitors charging conditions to ensure safe and reliable operation. Experimental implementation demonstrates the feasibility of automated wireless charging for future smart transportation systems. The proposed approach offers enhanced user convenience, improved safety, reduced charging downtime, and potential integration with smart-city infrastructure.

Key Words: Electric Vehicle, Wireless Power Transfer, Dynamic Charging, Electromagnetic Induction, Arduino, Smart Transportation, Battery Charging System.

I. INTRODUCTION

The growing use of electric vehicles (EVs) as a sustainable substitute for traditional internal combustion engine vehicles is drastically changing the global transportation industry. Increased concerns about environmental pollution, fossil fuel exhaustion, and emissions of greenhouse gases are driving up the development of EV technologies globally. Global EV deployment has increased significantly in recent years, according to the International Energy Agency (IEA), underscoring the critical need for effective charging infrastructure to facilitate this shift [18].

EVs still have issues with battery capacity, charging time, charging accessibility, and driving range despite their advantages for the natural world and economy. Long charging times and direct electrical connections are

necessary for conventional plug-in charging systems, which can limit car usage and decrease user convenience [20]. Researchers have been concentrating more on Wireless Power Transfer (WPT) technologies, which allow contactless charging via electromagnetic coupling, as a solution to these problems [9], [10].

Static and dynamic charging systems are two general categories for wireless charging systems. While dynamic charging enables vehicles to collect energy while traveling or passing through a charging zone, static charging happens when a vehicle is parked at an authorized charging location [3], [12]. Dynamic wireless charging has the potential to lower battery size specifications, greatly lessen range anxiety, and increase the overall effectiveness of electric modes of transportation [1], [4].

Recent advancements in inductive power transfer technologies have demonstrated promising results in terms of charging efficiency, system reliability, and smart-grid integration [2], [7]. Researchers have investigated various aspects of wireless charging, including coil design optimization [15], power electronic converters [11], charging infrastructure development [13] and administration of the transportation system [8]. The future viability and intelligence of future charging platforms are also anticipated to be improved by cutting-edge technologies including Vehicle-to-Grid (V2G) systems [17], artificial intelligence-based charge management, and renewable energy integration [19].

Despite significant advancements in wireless EV charging, issues such as power transfer efficiency, electromagnetic interference, infrastructure costs, coil alignment sensitivity, and standardization continue to prevent widespread adoption [6], [14], and [16]. As a result, there is an increasing demand for inexpensive prototype systems that can show that automated wireless charging solutions are feasible.

An Automatic Dynamic E-Vehicle Charging System based on wireless power transfer and microcontroller-

based automation is proposed in this study. The system uses an Arduino controller to regulate charging, an IR sensor to identify vehicles, and inductive coupling to transmit power wirelessly. Developing an affordable prototype, analyzing its operational efficiency, and proving the viability of automatic dynamic charging for upcoming smart transportation applications are the goals of this endeavor.

II. LITERATURE REVIEW

One of the most promising approaches to solving the problems with charging electric vehicles is wireless power transmission technology. To increase user comfort, network compatibility, and charging efficiency, a great deal of research has been done.

One of the first extensive research on inductive power transmission methods for applications related to transportation was offered by Covic and Boys [10]. By investigating magnetic coupling principles and system topologies, their work laid the groundwork for contemporary wireless charging solutions. In a similar vein, Li and Mi [9] examined wireless power transfer methods for EV applications and emphasized how they could enhance operational convenience and charging flexibility.

Miller et al. [11] examined primary-side power flow control techniques for wireless EV charging systems and showed how sophisticated power electronics can enhance system stability and charging efficiency. Budhia et al. [15] demonstrated that appropriate coil design greatly improves power transfer performance by concentrating on the optimization of magnetic structures and coil shapes. Mou and Sun [16] conducted a more thorough analysis of the development of wireless power transmission systems and determined important areas for further study.

There has been a lot of research interest in the switch from statically to dynamical charging. Dynamic inductive charging was discussed by Lukic and Pantic [12], who highlighted its potential to lower battery size and charging downtime. In a thorough analysis comparing static and dynamic wireless charging systems, Panchal et al. [3] came to the conclusion that dynamic charging can greatly increase vehicle range and energy efficiency.

In a more recent study, Song et al. [4] examined in-motion wireless power transfer devices and examined the difficulties of charging moving cars. The practical application of dynamic wireless charging infrastructure

was assessed by Hutchinson et al. [5], who also documented its possible advantages for upcoming transportation networks. By giving a summary of dynamic inductive charging systems and going over the financial and technical obstacles to commercialization, Mohamed et al. [1] built on these findings.

In their thorough analysis of inductive power transfer systems, Aydin et al. [2] emphasized the significance of coil alignment, resonance compensation, and system efficiency. In their study of wireless power transfer systems specifically used in electric vehicles, Triviño et al. [7] highlighted the importance of interoperability and standardization in large-scale adoption. Efficiency improvement was noted as a crucial research challenge by Ahmad et al. [13], who also provided a thorough analysis of EV wireless charging systems.

Khalid et al. [8] looked at transportation system management techniques incorporating dynamic wireless charging vehicles and talked about how they affected energy management and traffic operations. After conducting a thorough analysis of dynamic wireless charging systems, Shanmugam et al. [6] came to the conclusion that more study is needed to enhance infrastructure integration and charging dependability.

The relationship between power systems and charging infrastructure has also been studied. In order to improve system performance, Esteban et al. [14] examined different power supply topologies utilized in wireless charging systems. In their investigation of Vehicle-to-Grid (V2G) technologies, Habib et al. [17] showed how bidirectional power flow from EV batteries can support grid stability. Yilmaz and Krein [20] examined electric vehicle charging infrastructure and topologies, offering insightful information about the difficulties in designing and implementing chargers.

Sustainable charging options have received more attention in recent research. In their overview of current developments in wireless EV charging, Deb et al. [19] emphasized the incorporation of smart-grid technology, intelligent charging algorithms, and renewable energy sources. The need for sophisticated charging infrastructure to service the fast-growing global EV industry was further highlighted by the International Energy Agency [18].

Even while the literature now in publication shows that wireless charging technologies have advanced significantly, a number of concerns still need to be addressed, such as infrastructure scalability, high

installation costs, electromagnetic compatibility problems, and charging efficiency losses at wider air gaps. While little study has been done on low-cost educational prototypes, the majority of earlier studies concentrate on industrial-scale systems and sophisticated commercial implementations. By creating and testing an Automatic Dynamic E-Vehicle Charging System with inexpensive parts and microcontroller-based control, this work seeks to close this gap and offer a useful illustration of wireless charging concepts for upcoming intelligent transportation applications.

III. METHODOLOGY

A. Research Methodology

In order to create an Automatic Dynamic E-Vehicle Charging System using Wireless Power Transfer (WPT) technology, this study takes an experimental and prototype-based approach. A low-cost wireless charging prototype that can automatically identify an electric vehicle and start the charging process without making direct electrical contact is designed, implemented, tested, and its performance evaluated as part of the methodology.

The suggested system combines wireless energy transmission, sensor, and control modules to show that dynamic charging is feasible for upcoming electric vehicle applications. System design, hardware integration, software development, and experimental testing make up the entire technique.

B. System Architecture

The proposed charging system consists of four major subsystems:

1. Vehicle Detection Unit
2. Control and Monitoring Unit
3. Wireless Power Transfer Unit
4. Battery Charging Unit

An infrared (IR) sensor is used by the Vehicle Detection Unit to determine whether a car is in the charging zone. An Arduino UNO microcontroller is used by the Control and Monitoring Unit to process sensor inputs and regulate the charging process. The transmitter and receiver coils that make up the Wireless Power Transfer Unit use electromagnetic induction to transfer energy. Before delivering the power to the battery, the Battery Charging Unit corrects and controls it.

Automatic charging initiation, real-time monitoring, and safe charging process operation are made possible by the integration of these subsystems.

C. Wireless Power Transfer Mechanism

The proposed system operates based on the principle of electromagnetic induction. When alternating current flows through the transmitter coil, a time-varying magnetic field is generated around the coil. The receiver coil, positioned within the magnetic field, experiences an induced electromotive force (EMF) according to Faraday's Law of Electromagnetic Induction.

The induced voltage is expressed as:

$$E = -N \frac{d\phi}{dt}$$

where:

- E = Induced electromotive force (V)
- N = Number of turns in the receiver coil
- ϕ = Magnetic flux linkage (Wb)
- $\frac{d\phi}{dt}$ = Rate of change of magnetic flux linkage

The induced alternating voltage is converted into direct current using a rectifier circuit and subsequently supplied to the rechargeable battery for charging.

D. System Operation

By using an infrared sensor to continuously monitor the charging location, the suggested charging system runs autonomously. The sensor notifies the Arduino controller when a car enters the charging area. The relay module is then turned on by the Arduino, which powers the transmitter coil and produces an alternating magnetic field. This magnetic energy is captured by the receiver coil and transformed into electrical energy. The induced AC voltage is then rectified and controlled before being utilized for charging the battery. The LCD panel shows the charging status information during this procedure, and when the car exits the charging zone, charging automatically stops. This automated process increases user convenience by doing away with manual involvement.

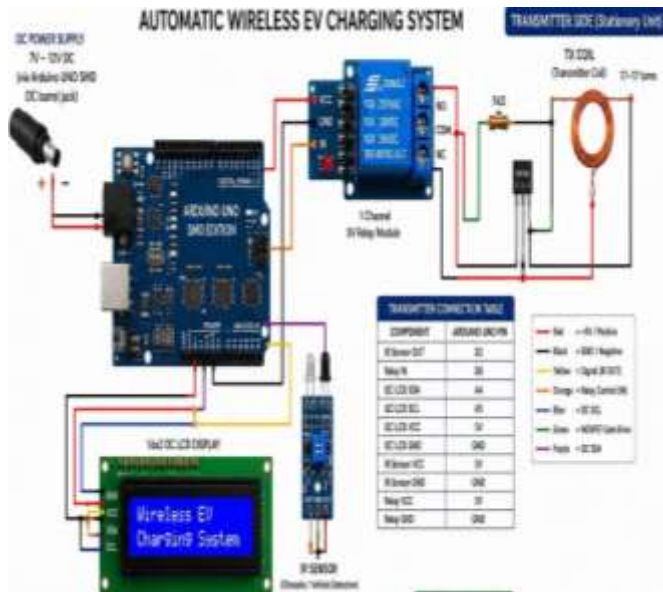


Fig -1: Circuit diagram

E. Algorithm for Automatic Charging Control

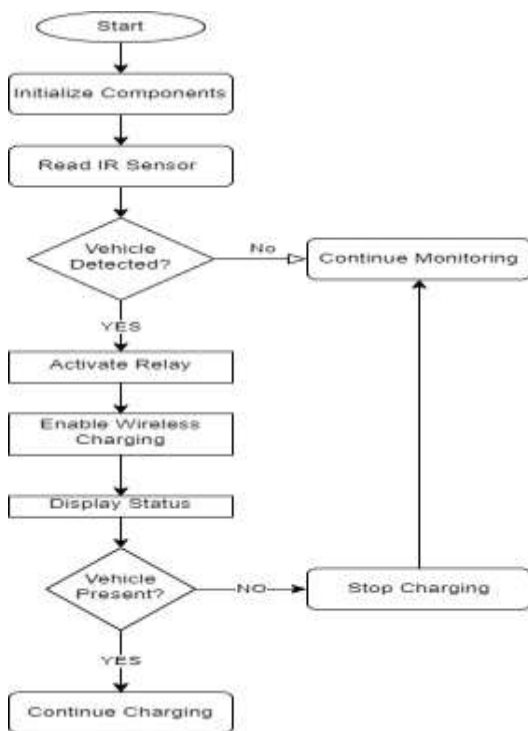


Fig- 2: Flowchart

F. Prototype Development

An Arduino UNO, IR sensor, relay module, LCD display, copper coils, DC power supply, and a miniature electric car were used to build a laboratory-scale prototype. The receiver coil was fastened to the vehicle model, and the transmitter coil was placed underneath the charging station.

Connector wires and insulated conductors made of copper were used to link the hardware components, which were put together on a project board. The Arduino IDE was used to create embedded applications that implemented the sensor monitoring and charging control logic.

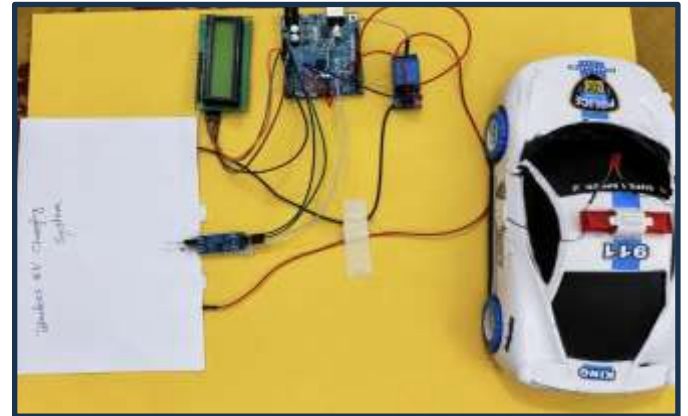


Fig- 2: Prototype Model

IV. RESULT

Table - 1 : Charging Performance

Coil Distance (cm)	Output Voltage (V)	Efficiency (%)
1	5.1	90
2	4.8	84
3	4.45	76
4	4.05	68
5	3.6	58

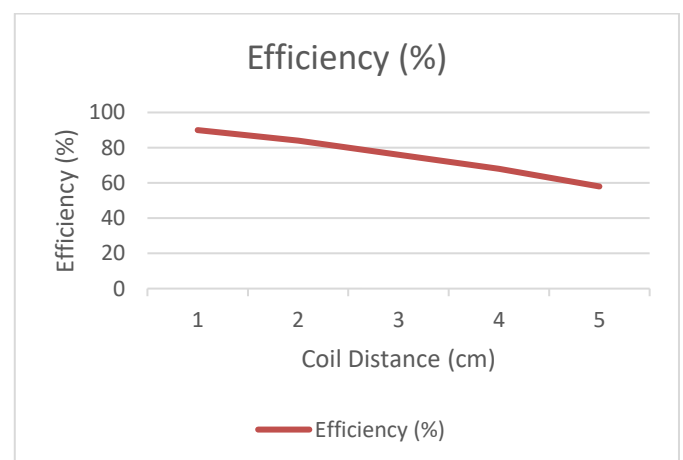


Fig- 3: Coil distance Vs Efficiency

I. DISCUSSION

The outcomes of the experiment verify that automatic wireless charging for electric cars is feasible. Throughout the testing procedure, dependable operation was ensured by the combination of Arduino-controlled charging automation and infrared vehicle identification.

Electromagnetic induction hypothesis is in line with the observed decrease in charging efficiency as coil separation distance increases. Lower induced voltage and power transfer efficiency come from a decrease in magnetic coupling between the coils as the air gap widens.

The suggested method is more convenient and requires less human involvement than traditional plug-in charging devices. Future smart transit networks, parking lots, and public charging stations can all benefit greatly from the automatic charging process.

But the prototype also draws attention to a number of real-world issues. Coil alignment and distance continue to have a significant impact on wireless charging efficiency. Widespread implementation would require significant infrastructure investment and optimization of power transfer technology.

II. CONCLUSION

An Automatic Dynamic E-Vehicle Charging System based on wireless power transfer technology was designed and implemented in this study. Using an Arduino-based control system, the built prototype effectively demonstrated wireless energy transmission, automated vehicle identification, and regulated battery charging.

The findings suggest that wireless charging can offer a useful substitute for traditional charging techniques by enhancing user experience, convenience, and safety. The basic ideas of dynamic EV charging were confirmed by the suggested method, which also achieved dependable functioning.

The system has limits with regard to synchronization sensibility, infrastructural demands, and recharging efficiency, despite its encouraging performance. Resonant inductive coupling, increased power transfer capacity, smart-grid integration, and practical testing with large-scale electric automobiles should be the main topics of future research.

Overall, the Automatic Dynamic E-Vehicle Charging System represents a significant step toward the

development of intelligent and sustainable charging infrastructure for future electric transportation systems.

References

- [1] A. A. S. Mohamed, M. M. Hassan, and M. A. Hannan, "An Overview of Dynamic Inductive Charging for Electric Vehicles," *Energies*, vol. 15, no. 15, pp. 1–25, 2022.
- [2] E. Aydin, A. S. Yilmaz, and M. Ermis, "Inductive Power Transfer for Electric Vehicle Charging Applications: A Comprehensive Review," *Energies*, vol. 15, no. 14, pp. 1–34, 2022.
- [3] C. Panchal, S. Stegen, and J. Lu, "Review of Static and Dynamic Wireless Electric Vehicle Charging System," *Engineering Science and Technology, an International Journal*, vol. 21, no. 5, pp. 922–937, 2018.
- [4] K. Song, Z. Li, and J. Jiang, "A Review of Dynamic Wireless Power Transfer for In-Motion Electric Vehicles," Intech Open, London, UK, 2016.
- [5] L. Hutchinson, B. Waterson, and P. Anvari, "Potential of Wireless Power Transfer for Dynamic Charging of Electric Vehicles," *IET Intelligent Transport Systems*, vol. 13, no. 1, pp. 3–13, 2019.
- [6] Y. Shanmugam, P. Venkatesh, and K. Ramachandran, "A Systematic Review of Dynamic Wireless Charging System for Electric Transportation," *IEEE Access*, vol. 10, pp. 100215–100235, 2022.
- [7] A. Triviño, J. Aguado, and S. de la Torre, "Wireless Power Transfer Technologies Applied to Electric Vehicles: A Review," *Energies*, vol. 14, no. 21, pp. 1–30, 2021.
- [8] M. Khalid, M. Alghamdi, and A. Alshahrani, "Transportation Systems Management Considering Dynamic Wireless Charging Electric Vehicles: Review and Prospects," *Transportation Research Part E: Logistics and Transportation Review*, vol. 158, pp. 102–120, 2022.
- [9] S. Li and C. C. Mi, "Wireless Power Transfer for Electric Vehicle Applications," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 4–17, 2015.
- [10] G. A. Covic and J. T. Boys, "Modern Trends in Inductive Power Transfer for Transportation Applications," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 1, no. 1, pp. 28–41, 2013.
- [11] J. M. Miller, O. C. Onar, and M. Chinthavali, "Primary-Side Power Flow Control of Wireless Power Transfer for Electric Vehicle Charging," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 147–162, 2015.
- [12] 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, 2013.
- [13] A. Ahmad, M. S. Alam, and R. Chabaan, "A Comprehensive Review of Wireless Charging

Technologies for Electric Vehicles,” *IEEE Transactions on Transportation Electrification*, vol. 4, no. 1, pp. 38–63, 2018.

[14] B. Esteban, M. Sid-Ahmed, and N. C. Kar, “A Comparative Study of Power Supply Architectures in Wireless EV Charging Systems,” *IEEE Transactions on Power Electronics*, vol. 30, no. 11, pp. 6408–6422, 2015.

[15] M. Budhia, G. A. Covic, and J. T. Boys, “Design and Optimization of Circular Magnetic Structures for Lumped Inductive Power Transfer Systems,” *IEEE Transactions on Power Electronics*, vol. 26, no. 11, pp. 3096–3108, 2011.

[16] X. Mou and H. Sun, “Wireless Power Transfer: Survey and Roadmap,” *IEEE Vehicular Technology Magazine*, vol. 10, no. 2, pp. 29–39, 2015.

[17] S. Habib, M. Kamran, and U. Rashid, “Impact Analysis of Vehicle-to-Grid Technology and Charging Strategies of Electric Vehicles on Distribution Networks,” *Journal of Power Sources*, vol. 277, pp. 205–214, 2015.

[18] International Energy Agency (IEA), *Global EV Outlook 2024: Trends in Electric Mobility*, Paris, France: IEA Publications, 2024.

[19] S. Deb, K. Kalita, and P. Mahanta, “Review of Recent Trends in Wireless Charging of Electric Vehicles,” *Renewable and Sustainable Energy Reviews*, vol. 156, pp. 111–128, 2022.

[20] M. Yilmaz and P. T. Krein, “Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-In Electric and Hybrid Vehicles,” *IEEE Transactions on Power Electronics*, vol. 28, no. 5, pp. 2151–2169, 2013.