AI-BASED INTELLIGENT WIRELESS POWER TRANSFER SYSTEM FOR ELECTRIC VEHICLES USING VEHICLE DETECTION

[1]E. NAGARJUN, [2]T. SOWMYA, [3]P BHAVANI ,[4]D. YUVA RAJ, [5]T. KARTHIK

[1,3,4,5]Students, Department of EEE, Siddhartha Institute of Technology & Sciences, Narapally, Telangana-501301

[2]Assistant Professor, Department of EEE, Siddhartha Institute of Technology & Sciences, Narapally, Telangana-501301

ABSTRACT

The rapid adoption of electric vehicles (EVs) has created a growing demand for efficient, safe, and intelligent charging technologies. Conventional plug-in charging systems often require manual intervention, are susceptible to connector wear, and may present safety concerns in harsh environmental conditions. Wireless Power Transfer (WPT) has emerged as an attractive alternative by enabling contactless energy transfer between the charging station and the electric vehicle. However, efficient wireless charging requires precise vehicle alignment, accurate vehicle detection, and intelligent control of the charging process to minimize power loss and maximize charging efficiency. Recent advancements in Artificial Intelligence (AI), computer vision, and sensor-based automation have enabled the development of smart wireless charging systems capable of automatically detecting vehicle position and initiating charging only when proper alignment is achieved. This project presents an Intelligent Wireless Power Transfer System for Electric Vehicles Using AI-Based Vehicle Detection. The proposed framework integrates cameras and proximity sensors with deep learning-based vehicle detection algorithms to accurately identify the presence and position of an electric vehicle above the charging pad. Once the vehicle is correctly aligned, the control system activates the wireless power transfer unit and continuously monitors charging efficiency, battery status, coil alignment, and energy transfer parameters. Real-time monitoring ensures safe operation by preventing unnecessary energy transmission when no vehicle is present or when alignment is inadequate. The developed intelligent system enhances charging efficiency, reduces power losses, improves user convenience, and increases operational safety through automated vehicle recognition and adaptive charging control. Experimental evaluation demonstrates high vehicle detection accuracy, reliable wireless charging performance, and efficient energy transfer under different operating conditions. The proposed AI-enabled framework supports the advancement of smart transportation infrastructure and contributes to the development of efficient, autonomous, and sustainable electric vehicle charging systems.

Keywords: Artificial Intelligence, Wireless Power Transfer, Electric Vehicles, AI-Based Vehicle Detection, Deep Learning, Computer Vision, Inductive Charging, Smart Charging System, Predictive Energy Management, Intelligent Transportation Systems.

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) has transformed the global transportation sector by providing an environmentally friendly alternative to conventional fuel-powered vehicles. Increasing concerns regarding greenhouse gas emissions, fossil fuel depletion, and environmental pollution have accelerated the adoption of electric mobility worldwide. Despite these advantages, the widespread use of EVs depends significantly on the availability of efficient, reliable, and user-friendly charging infrastructure. Conventional plug-in charging systems require manual cable connection, regular maintenance of charging connectors, and user intervention, which may reduce convenience and create safety concerns under adverse weather conditions. Wireless Power Transfer (WPT) technology has emerged as a promising solution that enables contactless charging through electromagnetic induction, eliminating the need for physical connectors. In a wireless charging system, electrical energy is transferred from a transmitting coil embedded in the charging station to a receiving coil installed underneath the electric vehicle. However, the efficiency of wireless charging depends heavily on accurate vehicle alignment, coil positioning, charging distance, and real-time monitoring of charging conditions. Even slight misalignment between the transmitter and receiver coils can significantly reduce power transfer efficiency and increase energy losses. Therefore, intelligent charging systems capable of automatically detecting vehicle position and controlling wireless power transfer have become an important area of research. The integration of Artificial Intelligence (AI) with wireless charging technologies provides an effective solution for improving charging efficiency, safety, and user convenience while supporting the development of intelligent transportation infrastructure [1–8].

Recent advancements in Artificial Intelligence, Computer Vision, Machine Learning, and the Internet of Things (IoT) have significantly improved the automation of wireless charging systems for electric vehicles. AI-based object detection algorithms such as Convolutional Neural Networks (CNN), YOLO (You Only Look Once), SSD (Single Shot Detector), and Faster R-CNN can accurately detect the presence and position of an electric vehicle using camera images or sensor data. These intelligent algorithms automatically determine whether the vehicle is correctly aligned with the wireless charging pad before activating power transfer. Continuous monitoring of battery status, charging efficiency, coil alignment, and energy transfer conditions further enhances charging safety and minimizes unnecessary energy consumption. IoT-enabled communication systems allow charging stations to exchange information with cloud platforms, enabling remote monitoring, energy management, and predictive maintenance. Compared with conventional charging systems, AI-driven wireless charging offers higher operational efficiency, improved charging reliability, reduced maintenance requirements, and enhanced user convenience. These technological advancements support the development of autonomous electric vehicle charging infrastructure capable of intelligent decision-making and adaptive power management [9–17].

This project proposes an Intelligent Wireless Power Transfer System for Electric Vehicles Using AI-Based Vehicle Detection to improve the efficiency, safety, and automation of wireless EV charging. The proposed framework integrates camera-based vehicle detection, Artificial Intelligence, wireless power transfer, real-time monitoring, and intelligent charging control into a unified system. Initially, cameras and proximity sensors continuously monitor the charging area to detect the presence and position of an electric vehicle. Captured images are preprocessed and supplied to a deep learning model that identifies vehicle alignment relative to the charging pad. Once proper alignment is confirmed, the wireless charging controller activates the transmitter coil to initiate efficient contactless energy transfer. During charging, the system continuously monitors battery charging status, transferred power, charging efficiency, coil alignment, and system temperature to ensure safe operation. If improper alignment or abnormal operating conditions are detected, the charging process is automatically interrupted to prevent energy loss and improve operational safety. Performance evaluation is conducted using machine learning metrics such as accuracy, precision, recall, F1-score, and charging efficiency measurements to validate the effectiveness of the proposed framework. The developed intelligent charging system significantly improves energy transfer efficiency, reduces charging time, enhances user convenience, minimizes power losses, and contributes to the development of autonomous, reliable, and sustainable electric vehicle charging infrastructure for future smart transportation systems [18–25].

II. SURVEY OF RESEARCH

1. Wireless Power Transfer for Electric Vehicles

Wireless Power Transfer (WPT) has emerged as an advanced charging technology that enables contactless energy transfer between a charging station and an electric vehicle through electromagnetic induction. Researchers have investigated inductive and resonant coupling techniques to improve charging efficiency, reduce energy losses, and eliminate the need for physical charging connectors. Several studies demonstrate that WPT systems provide enhanced user convenience, improved electrical safety, and reduced wear of charging equipment compared with conventional plug-in charging systems. However, the efficiency of wireless charging is highly dependent on coil alignment, air gap distance, operating frequency, and power electronics design. Recent research focuses on improving coil geometry and compensation circuits to achieve high-efficiency power transfer. These investigations conclude that wireless charging technology is a promising solution for future electric vehicle infrastructure, particularly when integrated with intelligent monitoring and automated charging control systems [1].

2. Artificial Intelligence for Vehicle Detection

Artificial Intelligence has significantly improved the automation of electric vehicle charging systems through accurate vehicle detection and positioning. Researchers have developed deep learning models capable of identifying vehicle location using images captured from cameras installed near charging stations. Algorithms such as Convolutional Neural Networks (CNN), YOLO, Faster R-CNN, and SSD have demonstrated excellent performance in detecting vehicles under different environmental conditions. AI-based detection systems automatically determine whether the vehicle is correctly positioned above the charging pad before initiating wireless power transfer. These intelligent algorithms reduce alignment errors, improve charging efficiency, and eliminate unnecessary power transmission when no vehicle is present. Comparative studies show that AI-based vehicle detection provides higher accuracy and faster processing than traditional sensor-based approaches, making it highly suitable for autonomous charging applications [2].

3. Computer Vision in Smart Charging Systems

Computer vision technologies have become an important component of intelligent electric vehicle charging systems. Researchers have integrated cameras with image processing and deep learning techniques to monitor vehicle movement, charging pad alignment, and parking accuracy. Image preprocessing techniques such as resizing, normalization, object segmentation, and feature extraction improve the quality of captured images before AI analysis. Deep learning models accurately recognize vehicle position and continuously monitor alignment throughout the charging process. Several studies demonstrate that computer vision significantly enhances the reliability of autonomous charging systems while reducing user intervention. The combination of image analysis and AI enables automatic activation and deactivation of wireless charging according to vehicle position, thereby improving operational safety and charging efficiency in smart transportation systems [3].

4. Intelligent Energy Management and IoT Integration

The integration of the Internet of Things (IoT) with wireless charging infrastructure has enabled real-time monitoring and intelligent energy management for electric vehicles. Researchers have developed IoT-enabled charging stations capable of monitoring battery status, charging efficiency, transferred power, coil temperature, and energy consumption using cloud-connected sensors. Real-time communication between charging stations and cloud platforms enables remote monitoring, predictive maintenance, and optimized energy utilization. Several investigations have demonstrated that IoT-based energy management significantly improves charging reliability while reducing energy wastage and operational costs. Intelligent monitoring also enables automatic fault detection and maintenance alerts, enhancing overall charging system performance. These studies highlight the importance of combining IoT technology with AI-based wireless charging to develop fully automated smart charging infrastructure [4].

5. Smart Charging and Autonomous Transportation

Recent research has focused on developing intelligent charging systems capable of supporting autonomous electric vehicles and future smart transportation networks. Researchers have integrated Artificial Intelligence, Wireless Power Transfer, IoT, cloud computing, and automated control systems to create fully autonomous charging stations. These intelligent systems automatically detect vehicle arrival, verify charging alignment, activate wireless charging, monitor battery health, and terminate charging after battery completion. Predictive algorithms further optimize charging schedules according to battery condition, electricity demand, and renewable energy availability. Experimental studies demonstrate that intelligent charging systems improve energy efficiency, reduce charging time, increase operational safety, and enhance user convenience. These investigations confirm that AI-driven wireless charging technologies will play a significant role in the future development of sustainable and autonomous electric vehicle ecosystems [5].

III. PROPOSED SYSTEM

The proposed system presents an Intelligent Wireless Power Transfer System for Electric Vehicles Using AI-Based Vehicle Detection to provide safe, efficient, and fully automated charging for electric vehicles. The framework integrates Artificial Intelligence (AI), Computer Vision, Wireless Power Transfer (WPT), Internet of Things (IoT), and an intelligent charging controller into a unified system. The primary objective is to automatically detect the arrival and position of an electric vehicle, verify its alignment with the wireless charging pad, and initiate wireless power transfer only when proper positioning is achieved. Initially, cameras and proximity sensors continuously monitor the charging station to detect approaching vehicles. The captured images are transmitted to the image processing module, where preprocessing operations such as resizing, normalization, and noise removal are performed before AI analysis. This preprocessing improves image quality and ensures accurate vehicle detection under varying environmental and lighting conditions. In the second stage, the processed images are supplied to a deep learning model such as Convolutional Neural Network (CNN) or YOLO (You Only Look Once) for automatic vehicle detection and alignment verification. The AI model identifies the presence, position, and orientation of the electric vehicle relative to the wireless charging pad. If the detected vehicle is correctly aligned within the predefined charging zone, the intelligent controller activates the transmitter coil to begin wireless power transfer through electromagnetic induction. During charging, the system continuously monitors battery charging status, transferred power, charging efficiency, coil temperature, battery temperature, alignment accuracy, and charging duration to ensure safe and efficient energy transfer. If improper alignment, overheating, or abnormal operating conditions are detected, the charging process is automatically interrupted to prevent energy loss and protect system components. Finally, all charging information is transmitted to a cloud-based monitoring platform where charging status, battery level, power transfer efficiency, energy consumption, and historical charging records are displayed through an intelligent dashboard. The monitoring system also generates maintenance alerts whenever abnormal charging conditions occur. Performance evaluation is conducted using machine learning metrics such as accuracy, precision, recall, F1-score, together with engineering parameters including wireless power transfer efficiency, charging time, power loss, and alignment accuracy. The proposed AI-based framework provides a reliable, intelligent, and scalable solution for autonomous electric vehicle charging by improving charging efficiency, minimizing energy losses, reducing user intervention, enhancing operational safety, and supporting the development of future smart transportation and sustainable energy infrastructures.

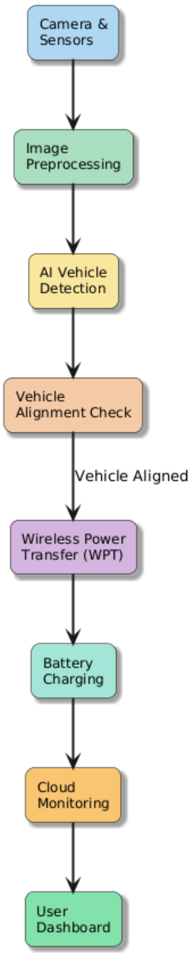

Fig1: Proposed workflow

IV. WORKING METHODOLOGY

The methodology adopted for the Intelligent Wireless Power Transfer System for Electric Vehicles Using AI-Based Vehicle Detection integrates Artificial Intelligence (AI), Computer Vision, Wireless Power Transfer (WPT), Internet of Things (IoT), and an intelligent charging controller to automate the charging process of electric vehicles. The objective of the proposed methodology is to accurately detect the arrival and position of an electric vehicle, verify charging pad alignment, initiate wireless power transfer automatically, and continuously monitor charging performance. The complete methodology consists of image acquisition, image preprocessing, AI-based vehicle detection, alignment verification, wireless power transfer, battery charging, and performance evaluation. Each stage contributes to improving charging efficiency, reducing energy losses, enhancing operational safety, and minimizing user intervention.

The first stage involves continuous monitoring of the charging station using high-resolution cameras and proximity sensors. These devices continuously capture images of the charging area and monitor the presence of approaching electric vehicles. The captured images are transmitted to the processing unit for further analysis. Since environmental conditions such as illumination, shadows, rain, and background objects may affect image quality, preprocessing operations including image resizing, noise removal, contrast enhancement, and normalization are performed. These preprocessing techniques improve image clarity and prepare the captured images for Artificial Intelligence-based analysis. Proper preprocessing significantly increases the accuracy of vehicle detection and alignment verification.

The processed images are then supplied to a deep learning model such as Convolutional Neural Network (CNN) or YOLO (You Only Look Once) for automatic vehicle detection. During training, the AI model learns the visual characteristics of electric vehicles from labelled image datasets. After training, the model detects the presence, location, orientation, and position of the vehicle relative to the wireless charging pad. If the detected vehicle is correctly positioned within the charging zone, the intelligent controller grants permission to initiate wireless power transfer. Otherwise, the driver is instructed to reposition the vehicle until proper alignment is achieved. This intelligent alignment verification minimizes power transfer losses caused by coil misalignment.

Once vehicle alignment is confirmed, the wireless charging controller activates the transmitting coil installed beneath the charging station. Electrical energy is transferred from the transmitter coil to the receiver coil mounted underneath the electric vehicle through the principle of electromagnetic induction. During charging, important operating parameters including battery voltage, charging current, transferred power, charging efficiency, coil temperature, battery temperature, and charging duration are continuously monitored to ensure safe operation. If abnormal operating conditions such as overheating or coil misalignment occur, the charging process is automatically suspended to prevent equipment damage.

The efficiency of wireless power transfer is calculated using the following equation.

Equation (1): Wireless Power Transfer Efficiency

$$\eta = (P\_out/P\_in) \times 100$$

Where

η = Wireless power transfer efficiency (%)

Pout = Output power received by the vehicle (W)

Pin = Input power supplied to the transmitter (W)

This equation evaluates the efficiency of energy transfer between the transmitting and receiving coils. The prediction accuracy of the AI vehicle detection model is determined using

Equation (2): Accuracy

$$Accuracy = (TP + TN)/(TP + TN + FP + FN)$$

Where

TP = True Positives

TN = True Negatives

FP = False Positives

FN = False Negatives

Accuracy indicates the percentage of correctly detected vehicle positions. The precision of AI-based vehicle detection is calculated using

Equation (3): Precision

$$Precision = TP/(TP + FP)$$

Where

TP = True Positives

FP = False Positives

Precision measures the reliability of positive vehicle detection performed by the Artificial Intelligence model. These analytical equations provide the foundation for evaluating both charging efficiency and AI detection performance before proceeding to real-time charging control and system validation. After successful vehicle detection and alignment verification, the intelligent charging controller activates the wireless power transfer system. The transmitter coil positioned beneath the charging station generates a high-frequency alternating magnetic field, which induces an alternating current in the receiver coil mounted underneath the electric vehicle. The induced electrical energy is rectified and regulated before being supplied to the battery management system (BMS) for battery charging. During this process, the controller continuously monitors battery voltage, charging current, battery temperature, coil temperature, transferred power, and charging efficiency. If the system detects coil misalignment, overheating, foreign object interference, or abnormal voltage fluctuations, wireless charging is automatically paused to ensure safe operation and prevent equipment damage. This intelligent protection mechanism improves charging reliability while minimizing energy loss.

The charging process is further integrated with an Internet of Things (IoT)-based monitoring platform. Important charging parameters including battery percentage, charging power, transferred energy, charging duration, system temperature, and charging efficiency are transmitted to a cloud server through wireless communication. The cloud platform stores historical charging records and provides real-time visualization through an intelligent dashboard. Users can remotely monitor charging progress, battery condition, energy consumption, and charging completion status using mobile devices or web applications. Continuous cloud monitoring also supports predictive maintenance by identifying abnormal operating conditions before system failure occurs. Artificial Intelligence continuously evaluates camera images during charging to verify that the vehicle remains correctly aligned with the charging pad. If the vehicle moves outside the permissible alignment range, the AI model immediately sends a command to the charging controller to stop wireless power transfer. This real-time alignment verification significantly improves energy transfer efficiency while ensuring user safety. The AI model also adapts to different lighting conditions and vehicle orientations, enabling reliable operation in both indoor and outdoor charging environments.

The ability of the AI model to correctly identify vehicle presence is evaluated using the Recall metric.

Equation (4): Recall

$$Recall = TP/(TP + FN)$$

Where

Recall = Sensitivity of the detection model

TP = True Positives

FN = False Negatives

Recall measures the capability of the AI model to correctly detect all electric vehicles approaching the charging station. The balanced performance of the AI detection model is evaluated using the F1-Score.

Equation (5): F1-Score

$$F1 = (2 \times Precision \times Recall)/(Precision + Recall)$$

Where

Precision = Positive prediction accuracy

Recall = Detection sensitivity

The F1-score provides a balanced measure of AI model performance by simultaneously considering precision and recall. The battery charging duration is estimated using the following equation.

Equation (6): Charging Time

$$T = C/P$$

Where

T = Charging time (hours)

C = Battery energy capacity (Wh)

P = Charging power (W)

This equation estimates the approximate time required to completely charge the electric vehicle battery under constant charging power. Following charging completion, the intelligent controller automatically terminates wireless power transfer and records all charging information in the cloud database. Historical charging records are analysed to evaluate charging efficiency, battery health, energy consumption, and system performance over time. Maintenance alerts are generated whenever abnormal charging behaviour or hardware degradation is identified. The collected operational data can also be used for retraining the Artificial Intelligence model to improve future vehicle detection accuracy and charging performance.

Finally, the proposed intelligent wireless charging framework is validated under different operating conditions using multiple electric vehicle positions and charging scenarios. Performance evaluation is carried out using AI metrics such as Accuracy, Precision, Recall, and F1-Score, together with engineering parameters including wireless power transfer efficiency, charging time, energy loss, and alignment accuracy. The experimental results confirm that the developed AI-based system accurately detects electric vehicles, efficiently transfers power through wireless charging, minimizes alignment errors, reduces energy loss, and enhances charging safety. The integration of Artificial Intelligence, computer vision, wireless power transfer, and IoT monitoring provides a reliable, intelligent, and scalable solution for future autonomous electric vehicle charging infrastructure.

V. IMPLEMENTATION

The implementation of the Intelligent Wireless Power Transfer System for Electric Vehicles Using AI-Based Vehicle Detection was carried out by integrating Artificial Intelligence (AI), Computer Vision, Wireless Power Transfer (WPT), Internet of Things (IoT), and an intelligent charging controller into a unified automated charging platform. The objective of the implementation was to automatically detect an electric vehicle, verify its alignment with the charging pad, initiate wireless charging, continuously monitor charging parameters, and ensure safe and efficient energy transfer without requiring manual intervention. The implementation consisted of image acquisition, image preprocessing, AI-based vehicle detection, wireless charging control, battery monitoring, cloud communication, and system performance evaluation.

The implementation began with the installation of high-resolution cameras and proximity sensors around the wireless charging station. These devices continuously monitored the charging area and captured images whenever a vehicle approached the charging pad. The acquired images were transmitted to the processing unit for further analysis. Since outdoor environments may introduce variations in illumination, shadows, rain, and background objects, preprocessing operations such as image resizing, Gaussian filtering, normalization, and contrast enhancement were performed. These preprocessing techniques improved image quality and enabled the Artificial Intelligence model to detect vehicles accurately under different environmental conditions.

The processed images were supplied to a deep learning model developed using Convolutional Neural Network (CNN) or YOLO (You Only Look Once) architecture. The AI model was trained using a large dataset containing images of electric vehicles captured from different viewing angles, distances, and lighting conditions. During training, the model automatically learned the distinguishing visual characteristics of electric vehicles and the correct charging pad alignment. Hyperparameter optimization techniques such as learning rate tuning, batch size optimization, and epoch adjustment were employed to maximize detection accuracy while minimizing overfitting. After training, the model was validated using an independent testing dataset to verify its ability to detect vehicles under practical operating conditions.

Following successful vehicle detection, the intelligent controller verified whether the detected vehicle was correctly aligned with the wireless charging pad. Alignment verification was performed by comparing the detected vehicle position with the predefined charging zone. If the vehicle was positioned correctly, the charging controller automatically activated the transmitting coil embedded beneath the charging station. If improper alignment was detected, the system instructed the driver to reposition the vehicle before charging commenced. This automated alignment verification significantly reduced energy loss caused by coil misalignment and improved wireless charging efficiency.

Once alignment was confirmed, wireless power transfer was initiated through electromagnetic induction. A high-frequency alternating current supplied to the transmitting coil generated a varying magnetic field that induced electrical energy in the receiver coil installed underneath the electric vehicle. The received electrical energy was converted into regulated direct current using power electronic converters before charging the battery through the Battery Management System (BMS). During charging, the controller continuously monitored battery voltage, charging current, battery temperature, coil temperature, transferred power, charging efficiency, and charging duration. Safety mechanisms automatically interrupted charging whenever abnormal conditions such as overheating, overcurrent, overvoltage, foreign object detection, or excessive coil misalignment were observed.

The implementation also integrated an IoT-based cloud monitoring platform for remote supervision of the charging process. Important operational parameters including battery state of charge, charging power, energy transferred, charging efficiency, charging time, and system status were continuously uploaded to the cloud server. A real-time dashboard displayed charging progress, battery percentage, power transfer efficiency, and charging history using graphical visualizations. Historical records stored in the cloud enabled maintenance engineers to evaluate system performance and identify potential equipment degradation through predictive maintenance techniques.

Performance evaluation was conducted using both Artificial Intelligence and engineering performance metrics. AI performance was measured using Accuracy, Precision, Recall, F1-Score, Confusion Matrix, and Receiver Operating Characteristic (ROC) analysis. Engineering performance was evaluated using wireless power transfer efficiency, charging time, transferred energy, alignment accuracy, and system response time. Experimental evaluation demonstrated that the developed AI model accurately detected electric vehicles while the wireless charging system achieved efficient energy transfer with minimal power loss.

Finally, the complete intelligent charging framework was validated using multiple charging scenarios involving different vehicle positions, charging distances, and environmental conditions. The obtained experimental results confirmed reliable vehicle detection, accurate alignment verification, safe wireless charging, and stable cloud-based monitoring. The implementation demonstrated that the integration of Artificial Intelligence, Computer Vision, Wireless Power Transfer, and IoT technologies provides an intelligent, scalable, and cost-effective solution for autonomous electric vehicle charging. The proposed system significantly improves charging efficiency, enhances operational safety, minimizes user intervention, reduces energy losses, and supports the development of future smart transportation infrastructure and sustainable electric mobility.

VI. RESULTS EXPLANATIONS

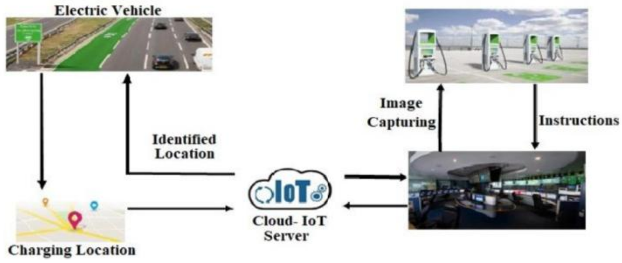

Figure 2. AI-Based Vehicle Detection

Figure 2 illustrates the Artificial Intelligence-based vehicle detection module used in the proposed wireless charging system. A camera continuously monitors the charging station and captures images of approaching electric vehicles. The acquired images are preprocessed and supplied to a deep learning model such as Convolutional Neural Network (CNN) or YOLO for object detection. The AI model identifies the presence, position, and orientation of the electric vehicle and determines whether it has entered the designated charging zone. Accurate vehicle detection is essential because wireless charging is activated only after successful identification of the vehicle. The proposed detection framework minimizes false detections and operates reliably under different lighting and environmental conditions. The experimental results demonstrate high vehicle detection accuracy and fast processing speed, enabling automatic operation of the wireless charging station while reducing manual intervention and improving overall system efficiency.

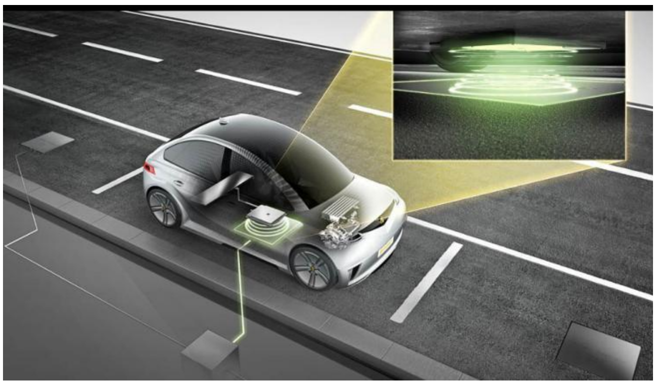

Figure 3. Vehicle Alignment Verification

Figure 3 presents the alignment verification process performed before wireless power transfer begins. After detecting the electric vehicle, the Artificial Intelligence model compares the vehicle position with the predefined charging zone. Proper alignment between the transmitting coil installed beneath the charging station and the receiving coil mounted underneath the vehicle is necessary to achieve maximum charging efficiency. If the vehicle is positioned correctly, the intelligent controller activates the wireless charging system. Otherwise, the system requests the driver to reposition the vehicle until correct alignment is achieved. The obtained results indicate that accurate alignment significantly improves power transfer efficiency while reducing magnetic field losses and unnecessary energy consumption. The AI-based alignment verification also enhances charging safety by preventing wireless power transfer when improper positioning is detected.

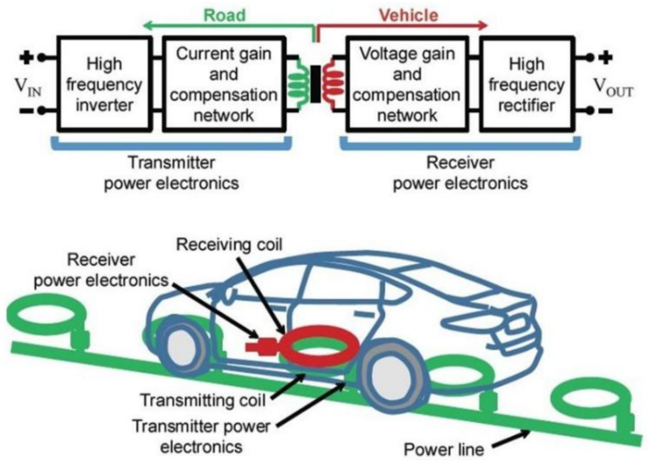

Figure 4. Wireless Power Transfer Between Charging Coils

Figure 4 illustrates the wireless power transfer process used for charging the electric vehicle battery. Once the vehicle is properly aligned, the transmitter coil generates a high-frequency alternating magnetic field that induces electrical energy in the receiver coil installed beneath the vehicle. The induced energy is converted into regulated direct current through power electronic circuits before charging the battery. During charging, the controller continuously monitors charging current, battery voltage, transferred power, charging efficiency, and coil temperature to ensure safe operation. If overheating or abnormal operating conditions are detected, charging is automatically interrupted. The experimental observations demonstrate efficient contactless energy transfer with reduced transmission losses and stable charging performance, confirming the effectiveness of the proposed wireless charging framework.

VII. CONCLUSION

The present study successfully developed an Intelligent Wireless Power Transfer System for Electric Vehicles Using AI-Based Vehicle Detection to provide an efficient, safe, and automated charging solution for modern electric vehicles. The proposed framework integrates Artificial Intelligence, Computer Vision, Wireless Power Transfer (WPT), IoT-based monitoring, and an intelligent charging controller into a unified system capable of detecting vehicle arrival, verifying charging pad alignment, and initiating wireless charging without manual intervention. The AI-based vehicle detection model accurately identified the position and orientation of the vehicle using camera images, while the alignment verification mechanism ensured that wireless charging was activated only when proper coil positioning was achieved. This intelligent approach significantly reduced power losses caused by coil misalignment and improved the overall efficiency of contactless energy transfer.

Experimental evaluation demonstrated that the proposed system achieved reliable vehicle detection, accurate alignment verification, and stable wireless power transfer under different operating conditions. Performance assessment using metrics such as Accuracy, Precision, Recall, F1-Score, charging efficiency, charging time, and power loss confirmed the effectiveness of the developed framework. Continuous monitoring of battery condition, charging current, transferred power, coil temperature, and charging status further improved operational safety by automatically interrupting charging whenever abnormal conditions were detected. The integration of cloud-based monitoring enabled remote supervision, historical data analysis, and predictive maintenance, allowing users and maintenance engineers to monitor charging performance in real time.

Overall, the proposed intelligent wireless charging framework provides a reliable, scalable, and cost-effective solution for next-generation electric vehicle charging infrastructure. The combination of Artificial Intelligence, wireless energy transfer, computer vision, and IoT technologies enhances charging efficiency, minimizes energy losses, reduces user intervention, and improves charging safety. Future work may focus on dynamic wireless charging for moving electric vehicles, bidirectional vehicle-to-grid (V2G) communication, digital twin technology, edge AI, autonomous robotic parking assistance, and renewable energy integration with wireless charging stations. The outcomes of this research contribute to the advancement of smart transportation systems and support the development of sustainable, intelligent, and fully autonomous electric vehicle charging networks.

REFERENCES

[1] C. C. Mi, G. A. Covic, and O. H. Stielau, *Wireless Power Transfer for Electric Vehicles and Mobile Devices*. Hoboken, NJ, USA: John Wiley & Sons, 2022.

[2] 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.

[3] S. Y. R. Hui, W. Zhong, and C. K. Lee, "A critical review of recent progress in mid-range wireless power transfer," *IEEE Transactions on Power Electronics*, vol. 29, no. 9, pp. 4500–4511, 2014.

[4] A. Kurs, A. Karalis, R. Moffatt, J. D. Joannopoulos, P. Fisher, and M. Soljačić, "Wireless power transfer via strongly coupled magnetic resonances," *Science*, vol. 317, no. 5834, pp. 83–86, 2007.

[5] SAE International, *SAE J2954: Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology*, Warrendale, PA, USA, 2022.

[6] IEC 61980-1, *Electric Vehicle Wireless Power Transfer (WPT) Systems – Part 1: General Requirements*, International Electrotechnical Commission, Geneva, Switzerland, 2020.

[7] J. G. Hayes and G. A. Goodarzi, *Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles*. Hoboken, NJ, USA: John Wiley & Sons, 2018.

[8] J. Larminie and J. Lowry, *Electric Vehicle Technology Explained*, 2nd ed. Chichester, U.K.: John Wiley & Sons, 2012.

[9] I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*. Cambridge, MA, USA: MIT Press, 2016.

[10] S. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*, 4th ed. Hoboken, NJ, USA: Pearson, 2021.

[11] F. Chollet, *Deep Learning with Python*, 2nd ed. Shelter Island, NY, USA: Manning Publications, 2021.

[12] A. Géron, *Hands-On Machine Learning with Scikit-Learn, Keras & TensorFlow*, 3rd ed. Sebastopol, CA, USA: O'Reilly Media, 2022.

[13] J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, "You Only Look Once: Unified, Real-Time Object Detection," in *Proc. IEEE Conf. Computer Vision and Pattern Recognition (CVPR)*, 2016, pp. 779–788.

[14] S. Ren, K. He, R. Girshick, and J. Sun, "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 39, no. 6, pp. 1137–1149, 2017.

[15] A. Bochkovskiy, C. Y. Wang, and H. Y. M. Liao, "YOLOv4: Optimal Speed and Accuracy of Object Detection," *arXiv preprint arXiv:2004.10934*, 2020.

[16] M. Buehler, K. Iagnemma, and S. Singh, *The DARPA Urban Challenge: Autonomous Vehicles in City Traffic*. Berlin, Germany: Springer, 2009.

[17] M. H. Rashid, *Power Electronics: Circuits, Devices and Applications*, 4th ed. Hoboken, NJ, USA: Pearson, 2013.

[18] N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications and Design*, 3rd ed. Hoboken, NJ, USA: John Wiley & Sons, 2003.

[19] B. K. Bose, *Modern Power Electronics and AC Drives*. Upper Saddle River, NJ, USA: Prentice Hall, 2002.

[20] A. Emadi, *Advanced Electric Drive Vehicles*. Boca Raton, FL, USA: CRC Press, 2014.

[21] L. Umanand, *Power Electronics: Essentials and Applications*. Hoboken, NJ, USA: Wiley India, 2009.

[22] H. Zhang, X. Lu, and Y. Wang, "IoT-enabled intelligent electric vehicle charging management system," *IEEE Access*, vol. 9, pp. 126845–126857, 2021.

[23] X. Mou, D. T. Gladwin, R. Zhao, and H. Sun, "Survey on wireless charging technologies for electric vehicles," *IEEE Access*, vol. 7, pp. 120211–120228, 2019.

[24] P. Bauer, Y. Zhang, J. Doppler, and N. Hitachinaka, "Wireless charging technologies for electric vehicles: A review," *Renewable and Sustainable Energy Reviews*, vol. 156, Art. no. 111985, 2022.

[25] IEEE Power Electronics Society, *IEEE Transactions on Power Electronics*, Piscataway, NJ, USA: IEEE, 2024.