

## Solar Energy Harvesting Driven Wireless EV Charging Station Using IoT

V.Vidhya Gowri<sup>1</sup>, Sanjana D<sup>2</sup>, Rithika M<sup>3</sup>, Pavish G<sup>4</sup>, Deva Ganesh S<sup>5</sup>

<sup>1</sup>Assistant Professor, Electronic and Communication Engineering, Jansons Institute of Technology, Coimbatore (641659), Tamilnadu, India

<sup>2,3,4,5</sup> UG – Electronics and Communication Engineering, Jansons Institute of Technology, Coimbatore (641659), Tamil Nadu

**Emails:** vidhyagowri.v@jit.ac.in<sup>1</sup>, sanjanadhanasekaran01@gmail.com<sup>2</sup>, rithicandy0@gmail.com<sup>3</sup>, pavishgj@gmail.com<sup>4</sup>, devaganeshsakamuri@gmail.com<sup>5</sup>

### Abstract

The modern world has led to rapid growth of Electric Vehicles. The increased dependency on EV has also increased the demand for an efficient, sustainable and smart Electric vehicle charging method for it. The current status of the EV is traditional wired charging method that encounters challenges like continuous safety concerns, grid-based reliance and cable dependency sources etc. This paper has been designed to provide a solution by developing a solar energy harvesting charging station with the incorporation of Internet of Things (IoT) technology. It enables an eco-friendly solution using inductive wireless power transfer. This method reduces the risk in failure of mechanical parts operating with the help of wire connections. The big advantage of this project is that it provides real time monitoring of the system and the operational metrics. The data's can be accessed from anywhere and at any time in remote conditions using a cloud-based interface. It enables effective energy management of the system. A working prototype of the proposed solution has been built to test in the real-world situations. The results demonstrate the viability of combining solar energy harvesters with wireless charging module simultaneously ensuring the Realtime monitoring through IoT. This approach promotes an advancement of sustainable EV smart charging infrastructure with more future innovations.

**Keywords:** Electric Vehicle Charging, Internet of Things (IoT), Smart Charging Infrastructure, Solar Energy Harvesting, Sustainable, Wireless Power Transfer

### 1. Introduction

As electric vehicles and intelligent gadgets grow rapidly, the need for dependable and efficient charging infrastructure has grown a lot. Using wired charging methods requires physical links and cables, which can wear out, be unsafe, and be a hassle to use. Because of this, wireless charging technologies are getting more attention as a possible alternative. Wireless power transfer lets energy get without having to make direct electrical connections. Inductive coupling is one of the most popular methods to charge wirelessly because it is straightforward safe, and effective for short-distance

power transfer. At the same time, renewable energy sources like solar power are a clean and long-term way to make electricity. Eco-friendly charging systems that decrease reliance on traditional sources of power can be developed by blending solar energy harvesting with wireless charging technology. Furthermore, the integration of Internet of Things (IoT) technology enables ongoing system performance monitoring and control. Important metrics like voltage, current, battery illness, and charging efficiency can be monitored at the aid of IoT-based monitoring platforms. The design of a

solar-powered wireless charging station with Internet of Things monitoring capabilities is the main goal of this project. The system's objectives are to increase energy efficiency, make remote monitoring possible, and offer a dependable charging option for contemporary energy applications.

## 2. Literature Review

In recent years, plenty of researchers look into the integration of renewable sources of energy and wireless power transfer. Wireless charging technologies have been widely studied for applications such as electric vehicles, smartphones, and medical devices [1-10]. Inductive coupling has proven to be one of the most practical methods for transferring power over short distances. Previous studies have explored the use of solar panels for powering charging systems in order to reduce the dependence on grid electricity. Solar-based charging stations provide sustainable energy generation while minimizing environmental impact. Researchers have also proposed different methods to improve the efficiency of wireless power transfer systems through coil design optimization and power management techniques. Furthermore, IoT-based monitoring systems have been integrated into energy management applications to provide real-time data analysis and remote system control. By combining wireless power transfer, solar energy harvesting, and IoT monitoring, advanced charging infrastructures can be developed to support smart energy systems and future electric mobility solutions.

## 3. Problem Statement

Photovoltaic panels, a power conditioning circuit, a battery storage unit, a wireless power transfer module, and an Internet of Things monitoring platform are some of the essential parts of the suggested system. Sunlight is shown by the solar cells, which then transform it into electrical energy. A charge controller is then used to control this energy in order for saving level voltage levels and prevent the battery from being overcharged. The portable power source circuit's transmitter coil receives the battery's stored energy. A magnetic field is created around a transmitter coil when alternating current passes through it. This magnetic field is shown by a nearby receiver coil, using electromagnetic induction

to make it back into electrical energy. Before being sent to a load or jumping device, the received energy is corrected and regulated. To track variables like voltage, current, battery level, and pushing status, a web of Issues module is related to the system. Users can use a mobile or web application to remotely monitor system performance by delivering the information acquired to a cloud platform.

## 4. Proposed System Overview

The proposed approach serves as an IoT-enabled wireless charging station who runs on solar power. A photovoltaic panel, charge controller, battery storage unit, wireless power transmitter and receiver coils, and a microcontroller-based Internet of Things monitoring unit make up the system. The photovoltaic panel collects solar energy, that is then managed by a charge controller and stored in a rechargeable battery. The transmitter coil get the stored energy or yields an alternating magnetic field. Solar voltage, power level, and charging current are all continually tracked by an IoT-based microcontroller. The data compiled is sent to a cloud server so that users can view the system's performance from a distance. This monitoring feature aids in maintaining effective operation and improve energy management.

## 5. System Architecture

### 5.1. Solar Energy Harvesting Unit

The solar energy harvesting unit consists of a photovoltaic (PV) panel that converts sunlight into electrical energy. A MPPT-based charge controller is used to extract maximum power from the PV panel under varying solar conditions and to regulate the output for safe charging of the storage unit.

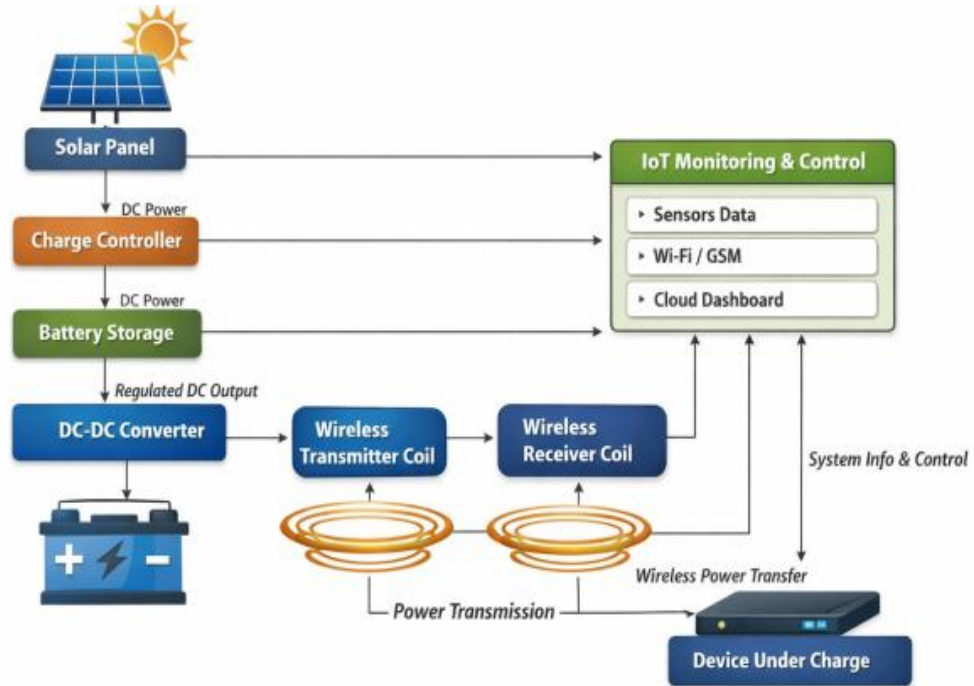
### 5.2. Energy Storage and Power Conditioning

The harvested solar energy is stored in a rechargeable battery or supercapacitor, ensuring continuous power availability during low or no sunlight conditions. A DC-DC converter is employed to provide a stable and regulated voltage suitable for the wireless charging module and control circuitry.

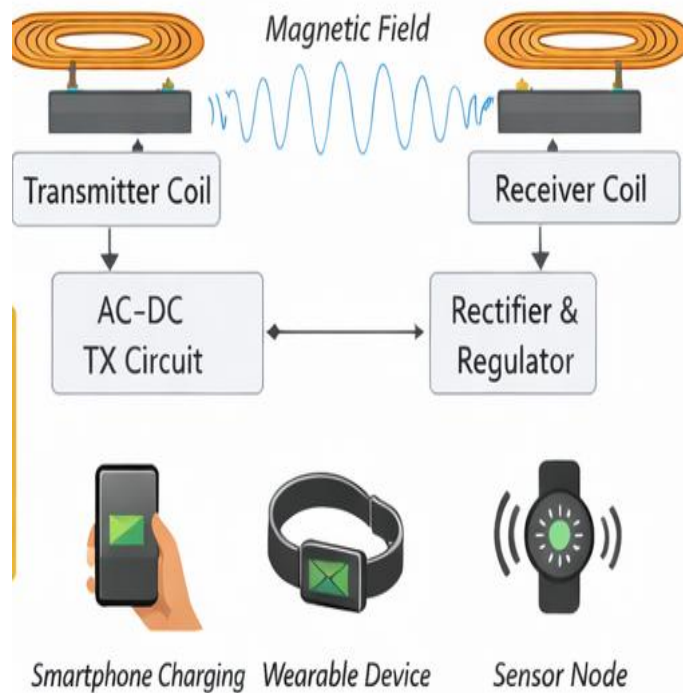
### 5.3. Wireless Charging Module

The wireless charging module operates using resonant inductive coupling. A transmitter coil generates an alternating magnetic field when powered, which induces a voltage in the nearby

receiver coil. This enables efficient, contactless power transfer for charging low-power electronic devices.



**Figure 1** Solar Energy Harvesting Driven Wireless Charging System



**Figure 2** Wireless Charging Principle

## 6. Methodology

The first stage of the proposed wireless charging station's operation is solar energy harvesting. Solar energy panels produce direct current, or DC, electricity when exposed to sunlight. A charge controller absorbs this power, stabilizes the output voltage, and safeguards the battery. The battery ensures a steady supply of power even in the absence of solar radiation since it is an energy storage device. An oscillator circuit or inverter uses the stored power to create alternating current for the transmitter coil. Through inductive coupling, the magnetic field of the transmitter coil releases voltage in her receiving coil. The received AC power is converted to DC using a rectifier circuit, which is then filtered to create an output voltage that is stable. Finally, batteries or electronic gadgets are charged using the controlled power. The Internet of Things monitoring system captures operational data from sensors and transmits it to an internet portal. This makes it possible to monitor system parameters in real time and contributes to increased system efficiency shown in Figure 1.

### 6.1. Power Harvesting Process:

Solar energy is harvested using a photovoltaic (PV) panel that converts incident sunlight into electrical energy. The generated power is regulated through an MPPT-based charge controller to ensure maximum energy extraction under varying solar conditions. The regulated output is then stored in a rechargeable battery, providing a stable energy source for continuous system operation.

### 6.2. Wireless Power Transfer Mechanism:

The stored energy is supplied to the wireless

charging transmitter through a power conditioning circuit. An alternating current flowing through the transmitter coil generates a magnetic field, which induces a voltage in the receiver coil based on resonant inductive coupling [11-20]. The induced voltage is rectified and regulated to charge low-power electronic devices wirelessly.

### 6.3. Control Strategy:

An IoT-enabled microcontroller [19], [30] continuously monitors system parameters such as solar voltage, battery level, charging current, and load status using voltage and current sensors. Based on these parameters, the controller manages power flow between harvesting, storage, and wireless charging units. Real-time data is transmitted to a cloud platform, enabling remote monitoring and efficient energy management.

### 7. Hardware and Software Implementation

#### 6.4. Components Used:

The hardware setup includes a solar photovoltaic (PV) panel for energy harvesting, a charge controller with MPPT for efficient power regulation, and a rechargeable battery for energy storage. A DC–DC converter is used for voltage regulation. The wireless charging system consists of transmitter and receiver coils, rectifier circuitry, and protection components. Voltage and current sensors are employed to monitor system parameters, and an IoT-enabled microcontroller [19], [30] (ESP8266/ESP32) is used for control and communication.

#### 6.5. Microcontroller / Controller Logic:

As the controlling unit, the microcontroller connects with sensors to gauge charging current,

**Table 1 System component and Specifications**

Component	Specification	Description
Solar Panel	20 W, 12 V	Converts solar energy into electrical energy
Charge Controller	MPPT based	Maximizes power extraction from PV panel
Energy Storage	12 V Li-ion Battery	Stores harvested solar energy
DC–DC Converter	Buck Converter	Regulates voltage for wireless module
Microcontroller	ESP32 / ESP8266	System control and IoT communication
Wireless Module	Resonant Inductive	Enables contactless power transfer

solar output, and battery status. To ensure safe and effective functioning, it regulates distributing power between the storage unit and the wireless charging module using real-time data. Periodically, the controller also manages IoT communication, transmitting system data to a cloud platform for remote monitoring and analysis [21-30].

### 6.6.Simulation or Firmware Tools:

The IDE, or Arduino IDE, with embedded C/Arduino programming is utilized to create the microcontroller's firmware. Cloud systems like ThingSpeak for Blynk, or Firebase are used to implement IoT data visualization and centralized access. Simulation tools such as Proteus or MATLAB/Simulink for performance analysis can support circuit behavior and system validation.

### 7. Performance Metrics

- Power Transfer Efficiency:

Ratio of power received at the wireless receiver to the power transmitted, indicating the effectiveness of wireless energy transfer.

- Charging Time:

Time required to charge the device wirelessly under available solar and stored energy conditions.

- Transmission Distance:

Maximum effective separation between transmitter and receiver coils while maintaining stable power transfer shown in table 2 and 3.

**Table 2 Operating Parameters of the Proposed System**

Parameter	Value	Unit
Solar Panel Voltage	18–21	v
Battery Voltage	11.1–12.6	v
Wireless Operating Frequency	85 -200	kHz
Transmission Distance	Up to 5	cm
Load Power	5 - 10	W

**Table 3 Wireless Power Transfer Performance**

Distance(cm)	Received Power (W)	Efficiency (%)
1	9.5	88
2	8.7	85
3	7.9	83
5	6.8	80

### 8. Energy Utilization

Measure of how efficiently harvested solar energy is stored and used for wireless charging with minimal losses.

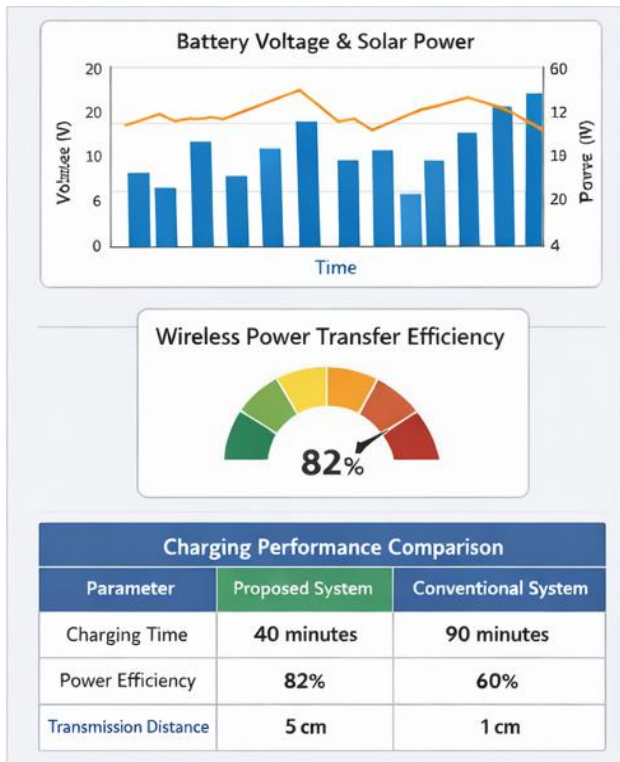
### 9. Results and Discussion

#### 9.1.Experimental Results:

A powered by sunlight wireless charging system prototype was created and put through multiple testing scenarios. In the presence of sunlight, the solar panel effectively produced electrical energy and used the charge controller to charge the battery. Stable voltage and current levels were noted at the receiver side throughout testing. Using inductive coupling, a wireless power transfer module efficiently transferred energy over a short distance. Real-time system metrics, such as battery voltage, output current, and charging status, may be seen on the IoT monitoring platform. The experimental findings verify that a realistic and sustainable charging solution may be achieved by pairing solar energy harvesting with wireless power transfer technology. Additionally, the system provides the benefit of remote monitoring via Internet of Things connectivity [31-40].

#### 9.2.Graphs and Tables:

Experimental results are presented using graphs and tables to illustrate key performance parameters such as solar voltage variation, battery state of charge, wireless power transfer efficiency, and charging time. These visual representations validate the system's stable operation and highlight the relationship between solar input, stored energy, and wireless output power shown in Figure 3.



**Figure 3 Battery Voltage and Solar Power**

### 9.3. Comparison with Conventional Systems:

As opposed to traditional grid-connected wired charging systems, the proposed method eliminates cable-related losses and reduces reliance on non-renewable energy sources. In contrast to grid-powered wireless chargers, the suggested approach offers superior functionality through real-time tracking and improved sustainability through solar power utilization. Everything being accounted for, the results show that the suggested system offers a smart, efficient, and environmentally friendly alternative to traditional charging systems shown in Table 3.

**Table 4 Performance Comparison with Conventional System**

Parameter	Proposed System	Conventional Wired Charging
Power Source	Solar Energy	Grid Power
Charging Method	Wireless	Wired

Power transfer efficiency	82%	60%
Charging Time	40 minutes	90 minutes
Cable Losses	Nil	Present

### Conclusion

The layout and setup of a solar-powered wireless charging station with Network of Things monitoring was reported in this study. The technology creates an effective charging solution by combining wireless power transfer, renewable energy generation, and real-time data monitoring. The suggested technology can successfully transfer power wirelessly while maintaining stable performance, according to experimental testing. Utilizing solar energy promotes eco-friendly energy practices and decreases reliance on traditional power sources. Future sustainable energy systems, smart devices, and electric vehicle charging could all benefit from the new approach.

### Future Scope

By increasing the solar panel capacity, applying higher-power resonant wireless charging modules, and combining modern energy storage systems, the suggested solar energy harvesting-driven wireless charging station can be further improved to accommodate EV-scale charging. Electric two-wheelers and auxiliary EV systems would be able to access wireless charging thanks to this extension. Another possible method is integration with the smart grid, which allows the system to function in a hybrid or grid-connected mode. So as to ensure regular charging and increased energy reliability, excess solar energy can be fed back into the grid and grid support services can be used when solar availability is limited. Furthermore, utilizing historical data, AI-based power optimization approaches may be employed in order to forecast energy generation and charging needs. Machine learning algorithms can optimize power allocation, charging schedules, and battery usage, thereby improving overall system efficiency, lifespan, and intelligent decision-making for future smart charging infrastructures.

### References

- [1]. S. Y. Hui, "Wireless power transfer: Recent developments and future trends," IEEE Trans. Power Electron., 2020.

- [2]. Z. Bi et al., "Wireless power transfer for electric vehicles," *IEEE Trans. Ind. Electron.*, 2020.
- [3]. F. Musavi and W. Eberle, "Wireless power transfer technologies for EV charging," *IEEE Trans. Power Electron.*, 2020.
- [4]. A. K. Shukla and K. Sudhakar, "Solar powered EV charging stations: A review," *Renew. Sustain. Energy Rev.*, 2020.
- [5]. P. Machura and Q. Li, "Wireless charging of electric vehicles: A review," *IEEE Trans. Transport. Electrific.*, 2021.
- [6]. Y. Li and X. Chen, "Hybrid solar-powered wireless charging systems," *IEEE Trans. Power Electron.*, 2022.
- [7]. J. Park et al., "Next-generation wireless charging systems," *IEEE Trans. Transport. Electrific.*, 2024.
- [8]. H. Zhang et al., "High-efficiency resonant wireless charging systems," *IEEE Access*, 2020.
- [9]. S. Kim and J. Park, "Resonant inductive wireless charging systems," *IEEE Trans. Ind. Electron.*, 2021.
- [10]. J. Hu et al., "Energy management for solar-powered charging stations," *IEEE Trans. Ind. Electron.*, 2020.
- [11]. P. Zhang et al., "Smart grid-connected renewable charging stations," *IEEE Trans. Smart Grid*, 2022.
- [12]. A. Verma and R. Singh, "Design of smart solar charging stations," *IEEE Access*, 2022.
- [13]. A. Singh and P. K. Jain, "Renewable-based smart charging infrastructure," *IEEE Trans. Ind. Electron.*, 2023.
- [14]. M. R. Khan et al., "Energy harvesting techniques for IoT applications," *IEEE Access*, 2020.
- [15]. R. K. Jha and P. S. Mehra, "Solar energy harvesting and power management," *IEEE Sensors J.*, 2020.
- [16]. J. P. Torreglosa et al., "Control strategies for solar-based charging," *IEEE Trans. Ind. Appl.*, 2021.
- [17]. L. Wu and J. Zhang, "Energy optimization of solar-powered charging stations," *IEEE Access*, 2022.
- [18]. R. Patel and S. Mehta, "Energy storage optimization for solar charging," *IEEE Trans. Energy Convers.*, 2023.
- [19]. M. A. Hannan et al., "Smart energy management systems," *IEEE Access*, 2021.
- [20]. A. R. Al-Ali et al., "IoT-based smart grid applications," *IEEE Systems J.*, 2021.
- [21]. S. Kumar and R. Mishra, "IoT-enabled renewable monitoring systems," *IEEE Sensors J.*, 2022.
- [22]. K. Ramesh and V. Kumar, "IoT-based wireless charging station," *IEEE Access*, 2023.
- [23]. T. Nguyen et al., "Solar-powered IoT systems," *IEEE Sensors J.*, 2023.
- [24]. S. Zhou et al., "AI-based power optimization in smart grids," *IEEE Trans. Smart Grid*, 2021.
- [25]. S. Kumar and R. Mishra, "AI-based energy prediction in solar systems," *IEEE Access*, 2023.
- [26]. A. Das and S. Banerjee, "Machine learning-based power management," *IEEE Access*, 2024.
- [27]. Y. Huang, Z. Zhao, and C. Qiu, "Wireless power transfer for IoT devices," *IEEE Internet of Things Journal*, vol. 7, no. 9, pp. 8307–8320, Sept. 2020.
- [28]. F. Yang and C. Mi, "Recent advances in inductive wireless power transfer," *IEEE Transactions on Industrial Electronics*, vol. 69, no. 10, pp. 1–12, Oct. 2022.
- [29]. H. Wang, Y. Liu, and Z. Zhang, "Wireless power transfer systems for smart devices," *IEEE Access*, vol. 10, pp. 88990–89005, 2022.
- [30]. M. Ali and H. Kim, "Wireless charging technologies for IoT and wearable devices," *IEEE Internet of Things Journal*, vol. 10, no. 5, pp. 1–12, May 2023.
- [31]. Y. Chen and Z. Li, "Smart grid-assisted solar charging infrastructure," *IEEE Transactions on Smart Grid*, vol. 14, no. 1, pp. 1–11, Jan. 2023.
- [32]. R. Ahmad and M. S. Alam, "Renewable-

powered charging infrastructure for smart cities,” IEEE Access, vol. 9, pp. 110221–110235, 2021.

- [33]. A. Mahmood, N. Javaid, and S. Razzaq, “Wireless charging technologies: A survey,” IEEE Communications Surveys & Tutorials, vol. 23, no. 2, pp. 1–25, 2021.
- [34]. J. Luo and Y. Zhang, “High-efficiency wireless power transfer using resonant coupling,” IEEE Access, vol. 11, pp. 44567–44579, 2023.
- [35]. C. Zhao and J. Wang, “Energy-efficient wireless power transfer system design,” IEEE Access, vol. 9, pp. 87934–87944, 2021.
- [36]. Y. Sun and J. Xu, “Wireless charging system design for portable devices,” IEEE Transactions on Consumer Electronics, vol. 67, no. 1, pp. 45–52, Feb. 2021.
- [37]. N. Tesla, A. Ahmed, and F. Blaabjerg, “Power electronics for wireless EV charging,” IEEE Access, vol. 10, pp. 13320–13335, 2022.
- [38]. K. Aditya and S. Williamson, “Advanced wireless charging techniques for electric vehicles,” IEEE Transactions on Transportation Electrification, vol. 8, no. 2, pp. 1–14, Jun. 2022.
- [39]. S. Ghosh and M. P. Dave, “IoT-based smart energy monitoring and control,” IEEE Sensors Journal, vol. 22, no. 19, pp. 1–10, Oct. 2022.
- [40]. J. Hu and K. J. Tseng, “Renewable energy integration for electric vehicle charging,” IEEE Transactions on Industrial Electronics, vol. 67, no. 8, pp. 1–10, Aug. 2020.