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Solar powered wireless EV charging system with Auto boost power and Foreign object detection

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Abstract—this study proposes an innovative solution for an automated system that will allow the contactless charging of electric vehicles with enhanced safety and control. The system integrates solar energy with battery backup (hybrid energy) that will supply continuous charging to the vehicle. The system is controlled by an Adriano that ensures the seamless switching of the energy sources, depending on the environmental conditions. TheArduinoUnomicrocontrollerwillcontinuouslymonitor and control the voltage levels by regulating the switching relay. The energy is transferred through coils wirelessly between the transmitter and receiver. The receiver captures the energy and rectifies it to DC and subsequently boosts it to around 12.6V to optimally charge a battery. Safety is enhanced by an integrated metal detection system, which will prevent system operation and contactless charging in the presence of foreign metallic objects between the coils. Other features include a USB socket for vehicle to grid applications, and an LCD for the display of the system's parameters as it is being charged. There are substantial improvements to existing systems in the areas of safety and dependency on traditional energy sources. The system is also economical and sustainable, fulfilling the requirements for an advanced system of eco friendly, automated integrated transport EV charging systems.

Index Terms—Wireless Power Transfer, Electric Vehicles, Solar Energy, Adriano, Boost Converter, Metal Detection

I. Introduction

In our modern, rapidly urbanizing world with the growing number of megacities, the demand for efficient, sustainable transportation systems is critical. Fuel-powered vehicles contribute large amounts of greenhouse gases, and their transportation emissions are among the most damaging to

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the environmentcausingairpollutionandinpresentscenario, it is also leading to scarcity of fuel. The quest for lower impact transportation around the world has accelerated the adoptionofelectricvehicles.EV'stailpipeemissionsarezero, but there are still indirect emissions associated with the electricity generated from fossil fuel powered power plants. EV's strengths include low greenhouse emissions and a reduced dependencyonfossilfuels.Numerousdisadvantages, however, alsoplaguethesystems.Theseincludeaninsufficientcharging infrastructure, limited number of charging stations and long chargingtimes.Complicationsresultingfromtraditionalwired chargingsystemsrequirevehiclestobeparkedtocharge and are an inefficient loss of time. Systems tighten charging flexibility and cables are easily broken if left to wear. These systems also pose large safety concerns. To avoid the disadvantagesofthetraditionalwiredchargingsystems, theidea ofwirelesspowertransfer (WPT) hasstartedtobeadopted as an efficient method of charging electric vehicles. Wireless charging allows electricity to be charged without physical contact and significantly increases the mechanical wear of the systems. Now, there are studies focused on integrating solar energy into wireless chargers so that the additional sources available are more consistent with the design principle of sustainable energy, as opposed to the conventional use of the electrical grid [7].Moreover, beyondthat, sophisticatedpower management systems have been proposed that involve the dynamic switching of energy sources and may help maintain system integrity, MIR [8]. In many practical charging setups, uninterrupted operation becomes difficult during fluctuations in power availability. Because of this, combining backup supply and automatic switching methods has become important in recent EV charging research. And on the safety side, metal body detection helps to protect against dangers that may arise when any stray conductive materials penetrate between the coils [9]. The work presents a design for an adaptive wireless charging system for electric vehicles solar, battery backups, and the safety between the switch relay intelligent solar integration, and metal detection. The design also incorporates real-time control and monitoring with an Adriano, along with a boost converter to improve the charging of the respective batteries. A charging system with this design aims to improve the charging of electric vehicles, improve safety, and improve the use of sustainable energy. Current EV charging stations have a number of shortcomings, such as a dependence on grid energy, al ask of safety, poor energy management, and alackofreal-timecontrolandmonitoring.Byintegrating renewable energy and control systems, the design overcomes these weaknesses and provides a more efficient, safer, and more user-friendly charging system.

II. Literature Review

Developing electric vehicles (EVs) and wireless EV charging is an exciting opportunity. Advantages to wireless EV charging include no wear and tear on cables and connectors and improved charging infrastructure. It is expected that there will always be some mechanical wear on cables and connectors. Efforts are being made to design charging coils to optimize charging frequency which will improve mechanical efficiency.

Mons and colleagues [1] detail the various methods of wireless charging that focus on the critical need for coil alignment and impedance tuning in order for the method to become more mature and commercially viable. Additionally, there is a giant push for using the solar energy as the primary resource to power the EV chargers. A hybrid solar-battery system was developed by Rodriguez et al. [2] to power Leon Musk's EV charging grid, with the system being less dependent on the national grid and providing a more stable energy resource. Additionally, in order to reduce the

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charging time for EVs, Gupta et al. [3] developed a method of using boost converters to convert the DC voltage.

One major concern with wireless charging is the lack of safety. Without safety features built in, there are potential hazards to not only the equipment, but to people as well, if a If a metal object is placed between the charging coils, the system detects its presence and interrupts wireless power transmission to prevent overheating, power loss, and potential safety hazards..

[4] Tackled this with sensor-driven systems that detect foreign objects, shutting things down before anything goes wrong. Monitoring and control matter a lot, too.Parketal. [5] Built a microcontroller-based system that tracks voltage and current in real time, letting you manage charging smarter and keeping users in the loop. Wilson et al. [6] introduced relay-based circuits to flip between different power sources smoothly, so the system never pauses unexpectedly. On top of that, An and et al. [7] expanded the charging setup to include USB ports—handy for keeping phones and other devices charged on the go.

There's a bigger focus now on making wireless charging systems run mostly on solar energy, shrinking reliance on the power grid. Researchers are recommending smarter power management—dynamic switching between sources so charging stays steady even when conditions change. Safety features like metal detection keep the system safe, making sure nothing hazardous sneaks between the coils.

This study proposes an adaptive wireless charging system for EVs that covers pretty much everything: solar panels, backup batteries, relays for smart switching, metal detection, real-time monitoring with Adriano and LCD displays, plus a boost converter to make battery charging efficient. The goal? Better charging efficiency, stronger safety measures, and a push toward sustainable energy for EVs.

Traditional EV charging setups have real weak spots: too muchgridreliance, missingsafetychecks, poorenergyeffi- cadency, and no real-time monitoring. These flaws drag down reliability and sustainability. The system described here takes all those issues head-on. It combines renewable, backup batteries, relay switching, metal detection, and real-time mon- itoring into one strong wireless EV charging package.

Yatnakar and Norman [9] surveyed wireless charging tech and how to best situate stations, highlighting the need to blend renewable energy and communication models for good rollouts. Their work, though, sticks to theory—no real-world validation. Ahmad et al. [10] dug into different wireless charging methods, pointing out issues like coil misalignment and the push for standards, but they didn't verify their ideas in practice.

Requital. [11] Focused on dynamic wireless charging using resonant inductive power, testing coil designs and alignment using ANSYS simulations. Promising stuff but still only in the lab. Yucca et al. [12] built a system to measure station performance and electromagnetic emissions, nailing transfer efficiency, although it only works for static charging and needs intricate instrumentation.

Kumar et al. [13] developed a combined framework with renewable and battery storage for smoother optimization and reliability, but they never really address wireless power transfer efficiency or real-time operation. Erdogmus [14] brought in the concept of a digital twin for EV-grid integration, blending wireless charging and renewables. It offers advanced monitoring and simulation but is complex and puts a heavy load on computers. N. R. et al. [16] improved EV charging design to boost power quality and management, aiming for stability but not really

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digging into wireless energy transfer.

Vakiti and Subhadra [17] explored IoT-based wireless power transmission for EVs—real-time monitoring and remote control—but you need solid network connectivity, and scaling up or keeping things secure is tricky. Manikandan et al. [18] built an IoT-enabled wireless battery management system, tracking voltage and charge to keep things safe—though they only tested it on a small scale. Swarnkar et al. [19] put together a solar-powered wireless charging system based on resonant magnetic coupling plus MPPT techniques, with MATLAB simulations showing better efficiency and a stable voltage.

Looking at all this, the literature shows big steps forward in wireless power, renewable, IoT monitoring, and smart controls. But most studies focus on one piece at a time—efficiency, control, infrastructure—and don't really pull everything together. The approach offered here aims to do just that, integrating solar energy, battery backup, smart relay switching, metal detection, and real-time monitoring into a full wireless EV charging solution.

III. Objectives

The proposed work aims to overcome the limitations of existing electric vehicle charging systems by developing an efficient, safe, and sustainable wireless charging solution. The key objectives of this project are outlined below:

- **To develop a contactless energy transfer system for charging electric vehicles:** This objective focuses on developing a system that enables energy transfer without physical connections through inductive coupling. It involves designing transmitter and receiver coils, ensuringproperalignment, andachievingefficientpower transfer. By eliminating the need for cables, the system reduces mechanical wear and improves user convenience.
- **System with an integrated Solar Energy and a Battery Back Up for Uninterrupted and Consistent Availability:** This system has the major sustainable goal of using the sun as the main source of power. In the case that the sun is not available such as in the case of the night timer in the case of inadequate sunlight, this system will incorporate battery as the system's power source. This system will provide an increased level of reliability and reduced requirements for the use of the power system.
- **To develop an automatic power source switching mechanism using Adriano:** In this system an intelligent system will be used that will be incorporated with the Adriano controller, which in the case of power source delivers, will be done interlocked to each other. In the case of the system or battery having inadequate power, the system will rely on solar power. The power system will enable the system to operate optimally in an is color manner.
- **To improve system safety using a metal detection mechanism:** Integrating a metal detection sensor for detecting unwanted metallic objects in-between the coils, alertsthesystemforapossibletransferofpower,avoiding overheatingandotherpossibledangers.Itincreasessafety and reliability for the end user.

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- **Real-time monitoring of voltage and other system:** The system utilizes voltage monitoring units, along with a micro controller that continuously checks possible system inputs and outputs. System performance is continually monitored and is displayed in real time through an LCD. Analysis, management, and other data fault monitoring are enhanced through this capacity.

IV. System Design

The proposed wireless electric vehicle (EV) charging system uses renewable energy sources integrated with wireless power transfer technology and smart control systems to ensure charging safety, efficiency, and flexibility. The system design is aimed at addressing the shortcomings of traditional wired systems by providing contactless energy transfer with safety and monitoring capabilities.

A. Existing System

The conventional electric vehicle charging systems rely on a connection with the grid (or power supply) through wired connectors. These systems include charging connectors that expand due to erosion with many uses and become inconvenient to the user. The charging systems often require vehicles to be halt and idle for very long periods of time in order to receive power. The systems also have the rigidity to be relatively unchanging to environmental and operational inconveniences, and rely on non-renewable energy instead of incorporating renewable energy sources such as solar into the system. The systems have in adequate monitoring to give any real-time appreciation of the current state of charge, voltage, or overall system performance.

The systems present a significant risk of overheating and short circuits, highlighting the need to prioritize safety features. Furthermore, wired charging systems generally lack mechanisms such as foreign object detection. These systems also provide limited support for smart power management and portable charging functionalities.

B. Proposed System

To overcome the limitations of existing systems, the proposed design uses a hybrid wireless charging setup that combines solar energy, battery backup, and intelligent control mechanisms. A solar panel is used as the primary energy source, while a storage battery provides backup power to maintain continuous operation under varying environmental conditions. A relay-based switching circuit is used to automatically select between the solar power and battery supply based on power availability. The overall operation is controlled using an Arduino microcontroller, which monitors voltage conditions and manages the system in real time.

Wireless power transfer is achieved using transmitter and receiver coils positioned at a distance of approximately 2–3 mm. The transmitter coil generates an alternating magnetic field, which induces voltage in the receiver coil and enables energy transfer without direct physical contact. The received signal is then rectified and boosted using a DC–DC boost converter to obtain the required voltage level for charging applications.

For safety purposes, a metal detection mechanism is incorporated to identify foreign metallic objects placed between the transmitter and receiver coils and stop system operation under such conditions. Metallic objects within the magnetic field can generate eddy currents, which may result in heating, power losses, and potentially unsafe operating conditions. The presence of metal

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can also disturb the magnetic field and reduce the efficiency of power transfer. By detecting such objects and interrupting wireless power transmission, the system provides safer and more stable operation.

Furthermore, the system incorporates an LCD display for real-time monitoring of voltage parameters and includes a USB charging module to facilitate the charging of auxiliary electronic devices. These features improve the usability and monitoring capabilities of the proposed system.

Compared with conventional wired charging systems, the proposed system aims to improve efficiency and safety while reducing reliance on conventional energy sources and increasing charging flexibility. The integration of solar power and battery backup provides a reliable and sustainable power supply under different environmental conditions. Wireless energy transfer eliminates the need for physical connectors, thereby improving user convenience and reducing mechanical wear associated with repeated plugging and unplugging.

The intelligent relay-based switching mechanism further enhances system flexibility by enabling the selection of an appropriate energy source according to availability. In addition, the metal detection mechanism helps prevent potential safety hazards by interrupting power transmission when a foreign metallic object is detected. Real-time monitoring through the microcontroller and LCD display enables improved system control and performance evaluation, ultimately contributing to greater efficiency, reliability, and convenience in the charging process.

V. Hardware and Software Requirements

A. Hardware Requirements

The hardware implementation of the proposed system consists of power generation, control, sensing, and wireless transmission components. Each component is carefully selected based on its performance, efficiency, and compatibility with the overall system requirements.

- **Solar Panel:** The solar panel acts as the primary power source, providing an output of 6V–12V DC with a power range of 5W–20W depending on sunlight conditions. It converts solar energy into electrical energy using photovoltaic cells.
- **Battery:** A rechargeable 12V battery (lead-acid or lithium-ion) with a capacity ranging from 1.3Ah to 7Ahisusedasabackupsourcetoensurecontinuousoperation during low or no sunlight conditions.
- **Adriano Uno:** Based on the ATmega328P microcontroller and operating at 5V with a 16 MHz clock frequency, Adriano Uno is chosen due to its low cost, ease ofprogramming, anduser-friendlydevelopmentenvironment.Itsbuilt-inUSBinterfaceenablesrapidprototyping, while sufficient I/O pins and library support make it suitable for real-time monitoring and control of system components.
- **Relay Module:** A 5V single-channel relay module capable of handling loads up to 10A is used for automatic switching between solar and battery power sources based on real-time voltage conditions.
- **Transmitter Coil:** A copper coil with multiple turns (typically 20–50 turns) operating at high frequency (20 kHz–100 kHz) is used to create a varying magnetic field that enables

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wireless transfer of power.

- **Receiver Coil:** A similar copper coil is placed near the transmitter coil to capture the magnetic field and induce AC voltage through electromagnetic induction.
- **Oscillator/Driver Circuit:** This circuit converts DC input into high-frequency AC signals required for wireless transmission and is typically implemented using transistor-based or IC-based driver circuits.
- **Rectifier Circuit:** The alternating signal received at the output is converted into direct current using a full-wave rectifier circuit built with fast recovery diodes such as1N4007.
- **Filter Circuit:** To obtain a stable DC output, filter capacitors typically in the range of 470µF to 1000µF are used to smooth out the fluctuations and minimize ripple in the rectified signal.
- **Boost Converter:** A DC-DC step-up converter (e.g., MT3608 module) is used to increase the voltage up to approximately 12.6V required for EV battery charging.
- **Voltage Sensors:** Voltage sensing circuits based on a resistor divider network are used to measure DC voltages up to 25V, enabling continuous monitoring of both input and output levels.
- **Metal Detection Sensor:** An inductive proximity sensor is used to detect metallic objects within a short range (2–5 cm), ensuring safe operation by preventing power transfer in unsafe conditions.
- **LCD Display (16x2):** This 16×2 LCD runs on 5V and helps display important measurements like system status and voltage readings.
- **USB Charging Module:** This module has an output of 5V DC with a maximum current of 1A and acts as a mobile phone charger.

B. Software Requirements

This section covers the tools to design the control and monitor the system along with the simulation of the proposed model.

- **Adriano IDE:** Used for programming the Adriano Uno in Embedded C/C++. It supports code uploading, serial monitoring, and debugging features.
- **MATLAB/Semolina:** This tool is used to develop and simulate the wireless power transfer model. It helps to visualize the system in order to check design and analyze the voltage, system efficiency, and performance.
- **Embedded Programming:** Used to implement control logic for automatic power source switching, voltage monitoring, and safety mechanisms.
- **Serial Communication:** UART-based communication (9600baudrate) is used for debugging and real-time data monitoring.

VI. Methodology

The proposed wireless electric vehicle (EV) charging system is based on hybrid architecture of renewable solar energy and a battery backup with manual source switching, wireless power

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transfer, and real-time monitoring. The system consists of two main parts: a charging station that serves as the transmitting unit, and a vehicle-based prototype serving as the receiving unit. Therefore, the system is based on the principle of electromagnetic induction, which involves the transfer of energy from a source to a load without a physical conducting link.

A. Charging Station

The charging station generates electrical power and transfers it wirelessly to the receiver unit to enable efficient charging. The components that make this system work are the solar panel, the rechargeable battery, the manual switch, the relay module, the Adriano Uno, the voltage sensor, the metal detector, the oscillator circuit, the driver circuit, and the transmitter coil.

As illustrated in Fig. 1, the solar panel acts as a power generator by harnessing the sun's rays that strike the photovoltaic cells. The solar panel is able to provide the system a certain amount of power that can be expressed as:

$$P = V \times I \text{ (W)} \quad (1)$$

Where *V*is the panel voltage and *I* is the output current.

The manual switch is the system's primary input device for selecting the source of energy. If the range of brightness is satisfactory and sunlight is available, solar power is selected. However, battery power is selected if the conditions are cloudy, it is nighttime, or the solar output is minimal. These measures are taken to facilitate the operation of the station without in eruption.

The selected DC supply is received by the oscillator circuit, which is able to provide the high-frequency AC that is used for the relay of power. The transmitter unit's frequency of resonance is expressed as:

$$f = 2\pi\sqrt{LC} \text{ (Hz)} \quad (2)$$

Where *L* is coil inductance and *C* is resonant capacitance. The A C current drives the transmitter coil, causing the coil to produce a changing magnetic field and thus perform the power relay to the receiver coil. This mechanism is described

By the following equation:

$$M = k\sqrt{L_1 L_2} \text{ (H)} \quad (3)$$

Where *k* is the coupling coefficient, and $L_1$and $L_2$are the inductances of the transmitter and receiver coils respectively. The system also utilize same told election sensor to enhance safety. The purpose of this metal detecting sensor is to particularly improve safety. If, at any given moment, between the transmitter and receiver coils, some foreign metal objects are embedded, the system is blacked out owing to a possible

Hazard and heat overload of the system.

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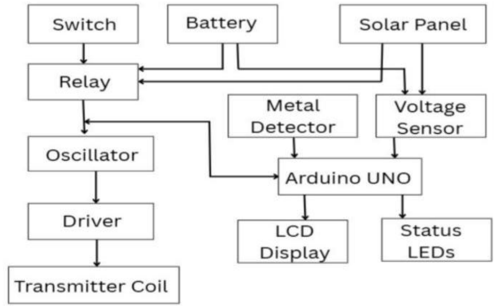

Fig.1: Block diagram of charging station

To ensure stable operation. Initially, the solar panel generates electrical energy, which is either directly used by the system or stored in the battery for later use. An Adriano continuously monitorsthevoltagelevelsandcontrolstherelaytoselect the most suitable power source. After selecting the appropriate power source, the DC supply is converted into a high-frequency AC signal using an oscillator-based inverter circuit, which is then fed to the transmitter coil. This coil generates a varying magnetic field around it. When the receiver coil is positioned within this field, an electromotive force (EMF) is induced in it, producing an AC voltage at the output.
The AC voltage generated at the receiver side is converted into DC, smoothed using a filter, and then increased to the required level suitable for charging. The system ensures continuous operation by switching between solar and battery sources as needed. Emerald ejection mechanism adds an extra layer of safety by preventing operation when foreign metallic objects are detected between the coils.
An Arduino and LCD display is used to monitor the process in real time. This allows control and analysis of system performance. Overall, the proposed system demonstrates an efficient, reliable, and sustainable approach for wireless electric vehicle charging.

VII Results and Discussions

The performance of the proposed contactless charging system for electric vehicles is evaluated through both hardware implementation and output observations. The obtained results demonstrate the effectiveness of wireless power transfer, system control, and real-time monitoring.

A. Hardware Prototype

The developed hardware prototype consists of separate transmitter and receiver units, representing the charging station and the electric vehicle prototype respectively. The transmitter unit, placed at the charging station side, is responsible for generating and transmitting power wirelessly, the receiver unit, placed on the vehicle prototype, captures the transmitted energy and converts it into electrical power suitable for charging.
Fig. 3 show the transmitter unit of the system. It includes a solarpanel, batterybackup, ArduinoUno, relaymodule, metal detection sensor, and transmitter coil. The system success-fully switches between power sources and generates a high-frequency magnetic field required for wireless power transfer.

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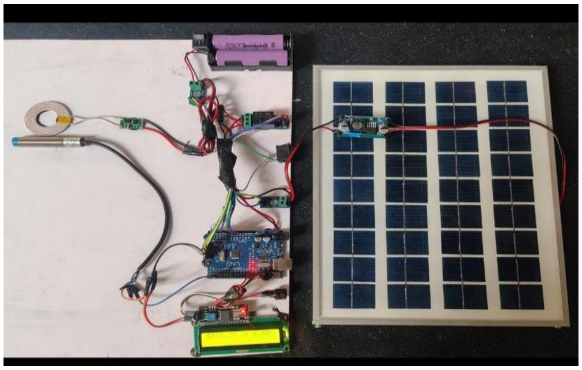

Fig. 3: Hardware prototype of transmitter unit

Fig. 4 illustrates the receiver unit. It consists of a receiver coil, rectifier, filter, boost converter, Adriano, and LCD display. The receiver effectively captures the transmitted energy and converts it into a stable DC voltage suitable for battery charging.

B. Receiver Side Voltage Output

Fig.5shows the voltage measured at the receiver side after rectification and boosting. The output voltage is regulated to approximately 12V–12.6V, which is suitable for charging applications. These findings verify that a stable output voltage has been achieved in efficient wireless power.

The setup also includes a USB charging module that givesaregulated5VDC output for charging small devices such as

Fig. 5: Voltageobservedatreceiverside

Mobile phones and accessories. This allows low-power devices to be charged along with EV charging. The module helps in maintaining stable voltage output and reduces the effect of overvoltage or voltage fluctuations on connected devices.

The readings shown in Table 1 indicate that the system operates properly under different

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conditions. The relay-based switching circuit was able to switch between solar supply and battery backup whenever required. It was also observed that the charging efficiency reduced when the distance between the coils increased or when slight misalignment occurred. Even with these variations, the setup continued to operate within the required range, showing the possibility of wireless EV charging applications.

Table 1: Experimental Results of Hardware Prototype

Parameter	Value	Observation
Input Voltage	12V	Stable switching observed
Output Voltage	5V	Induced from coil
Coil Distance	2–3 mm	Efficient transfer range
Switching	Manual	Solar/Battery selection
Metal Detection	Active	System stops on detection

VIII. Mat lab Based Quantitative Analysis

To validate the performance of the proposed hybrid wireless EV charging system, MATLAB-based analysis was performed using experimental and estimated data. The analysis mainly focuses on charging performance and wireless voltage behavior at the receiver side. These results help in understanding the system behavior under practical operating conditions.

A. Charging Performance Analysis

The system's charging behavior was analyzed by recording how the battery percentage changed over time. The corresponding values are listed in Table 2.
The corresponding graphical representation of the charging performance is shown in Fig. 6.
Table 2 and Fig. 6 show that the state of charge increases gradually with time, demonstrating consistent and effective wireless power transfer between the transmitter and receiver. During the early stage (0–12 minutes), the charging process progresses at a faster rate, as the system operates in the constant current region.

Table2: Charging Performance Data (12-minuteinterval)

Time (min)	Charging (%)
0	45
12	57
24	67
36	75
48	83

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Time (min)	Charging (%)
60	90
72	96
82	100

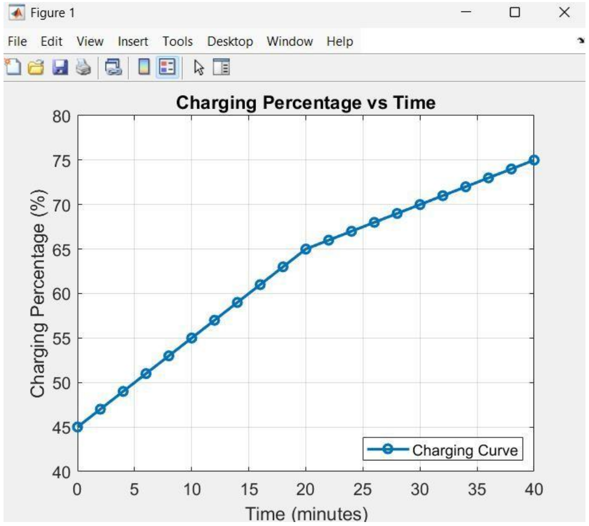

Fig.6: Charging percentage versus time

As the battery reaches beyond 50% charge, the charging rate gradually slows down, representing the transition into the constant voltage (CV) region. This non-linear charging behavior aligns with practical battery characteristics, where internal resistance increases with the state of charge, leading to a reduction in charging speed. Overall, the curve's upward trajectory shows steady system operation and energy transfer with minimal losses.

B. WirelessVoltageFluctuationAnalysis

The output voltage at the receiver side was analyzed to assess the stability and effectiveness of the designed inductive charging mechanism, which is used to transfer energy. The observed values are presented in Table 3.

Table3: Receiver Side Voltage Fluctuation

Time (s)	Voltage (V)
0	8.35
2	8.40
4	8.37

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Time (s)	Voltage (V)
6	8.40
8	8.38
10	8.39
12	8.37
14	8.40
16	8.37
18	8.38
20	8.39

The variation of voltage over time is illustrated in Fig.7.

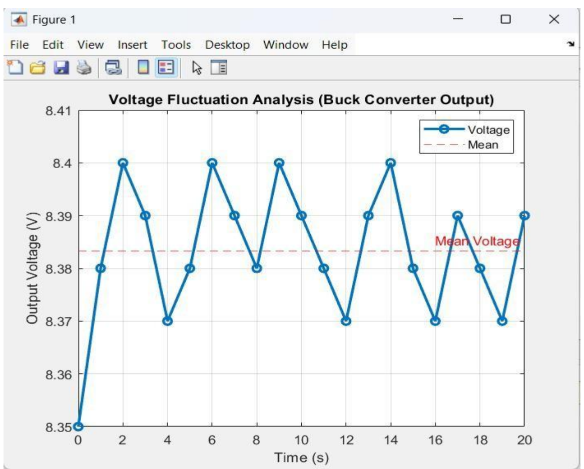

Fig.7: Voltage fluctuation analysis attr an smitter side

From Table 3 and Fig. 7, it can be observed that the output voltage remains almost constant, with an average value of approximately 8.38 V. The fluctuations are very small, typically within the range of ±0.02 V to ±0.03 V, indicating that the system maintains good stability.

These minor variations can be attributed to practical factors such as slight misalignment between the transmitter and receiver coils, variations in magnetic coupling, switching losses in power electronic components, and minor environmental disturbances. However, despite these factors, the system is able to maintain a stable output, which reflects effective resonance tuning and proper filtering. The consistent average voltage shown in Fig. 7 confirms steady-state operation. Voltage stability is an important parameter in wireless charging systems, as it directly affects charging efficiency, battery safety, and overall system reliability.

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C. Voltage Variation with Distance

The effect of coil separation distance on the output voltage was studied, and the observed values are listed in Table 4.

Table4: Voltage drop with increasing coil distance

Distance (mm)	Voltage (V)
0	8.40
1	7.80
2	6.50
3	5.00
4	3.50
5	2.00
6	0.50
7	0.00

From Table 4 and Fig. 8, it can be observed that increasing the gap between the transmitter and receiver coils results in a noticeable drop in the induced voltage, which in turn reduces the power transfer efficiency. Beyond a certain separation (around 6–7 mm), the voltage drops close to zero, indicating that wireless power transfer becomes negligible.

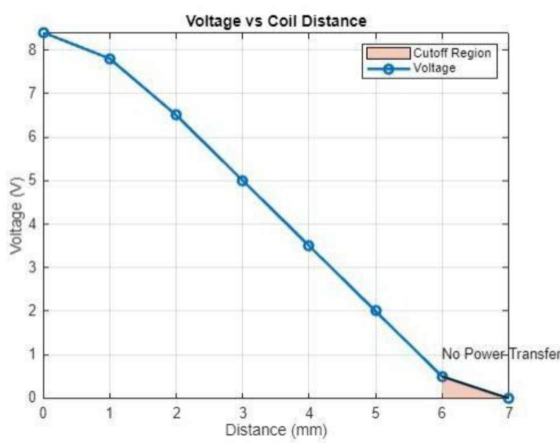

Fig. 8: Output voltage vs coil se parathion distance

D. Metal Detection Analysis

The variation in voltage in the presence of metallic objects was also studied. The measured values are presented in Table 5, while Fig. 9 illustrates their graphical variation.

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Table 5: Voltage variation with distance during metal detection

Distance (mm)	Voltage (V)
0	7.50
2	7.60
4	7.70
6	7.80
6.5	7.85
8	8.20
10	8.50

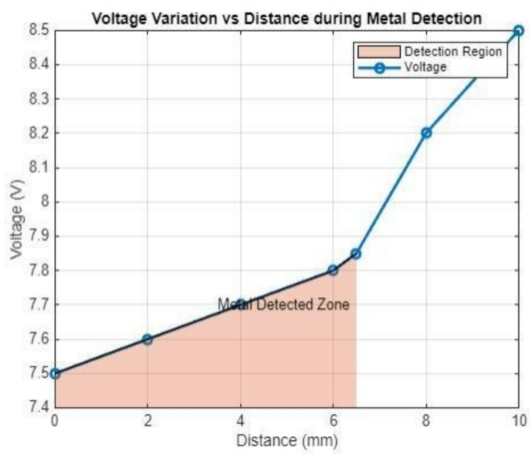

Fig. 9: Voltage variation vs distance during metal detection

As shown in Fig. 9 and supported by Table 5, the voltage changes gradually in the presence of a metallic object. Within the range of 0 to 6 mm, the variation is relatively slow, indicating the effective detection region. Beyond this range, the voltage increases more rapidly, showing a stronger response. This behavior suggests that closer proximity of metal leads to more noticeable voltage changes, enabling effective detection and distance estimation.

In summary, the MATLAB analysis establishes that the system provides efficient wireless energy transfer with steady charging and the system integrates solar energy with battery storage, and because of the system's solar powered and storage ability it provides continuous operation.

IX. Conclusion

This study focused on the design and implementation of a practical and efficient wireless EV charging system, which combines a renewable energy source with intelligent controls. The system incorporates solar energy and battery backup with a relay switching system. The system shows

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adequate power transfer through inductive coupling between coils, and reduces mechanical damage caused by contact. The system provides improved control and user participation by incorporating charging applications, with real-time monitoring using Arduino and LCD display, which increases system control and user awareness.

Safety has been improved by adding a metal detection mechanism that stops power transfer whenever a foreign metallic object is detected between the coils. USB charging support is also included, which makes the setup more useful for charging small electronic devices. By combining solar energy with wireless charging, the system reduces dependency on conventional charging methods and provides a cleaner approach for EV charging applications. The developed model also shows that wireless charging, renewable energy, and control circuits can work together in a single setup for modern EV infrastructure.

Further improvement can be made by modifying the coil design, improving coil alignment, and using compensation networks to obtain better power transfer. In future, dynamic wireless charging can also be explored, where charging takes place while the vehicle is moving, reducing the need for stationary charging systems.

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