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An Efficient Solar-Based Electric Vehicle Charging Station With Remote Monitoring Interface

Bhavesh Pund[1], Abhinav Dupte[2], Nandini Devhade[3], Shrujal Chapake[4], Dr. Saniya Ansari[5]

[1-4] UG Students, Department of Electronics and Telecommunication, Ajeenkya DY Patil School of Engineering, Pune, India.

[5] Professor, Department of Electronics and Telecommunication, Ajeenkya DY Patil School of Engineering, Pune, India.

Abstract: The quick rise in electric vehicle (EV) usage has led to a bigger need for sustainable and smart charging solutions. Traditional EV charging stations that rely on the power grid can cause stress on the grid and lead to higher carbon emissions, especially if the electricity comes from fossil fuels. Solar photovoltaic (PV) systems offer a more sustainable and localized option. This paper introduces the design, setup, and testing of a low-power solar-powered EV charging station that uses battery storage and a web-based monitoring system built with Raspberry Pi Pico W. The system includes a 12V solar panel (20W–50W), DC–DC converters for voltage control, circuits to measure voltage and current, and a Next.js dashboard for real-time monitoring. The system is organized into three main parts: the power section, control section, and cloud interface for smart monitoring. We also compare this system with traditional grid-based charging stations. The results show that the system can generate 85–220 W of energy daily, with a converter efficiency of 88–92%, and it can reduce about 60 kg of CO_2 annually. This system is a viable option for academic projects, charging for small electric vehicles, and decentralized renewable energy setups.

Keywords: Electric Vehicle Charging, Solar Photovoltaic, IoT Monitoring, Raspberry Pi Pico W, Renewable Energy, Smart Charging Infrastructure.

I. INTRODUCTION

The move toward electric vehicles (EVs) is an important step in reducing transport-related emissions and dependence on fossil fuels [1]. However, the environmental benefits of EVs depend heavily on the source of the electricity used for charging [2]. In many areas, if the electricity is still largely from coal-based power grids, the overall emissions savings from using EVs can be limited. Solar photovoltaic (PV) systems provide a local, carbon-neutral solution, especially where sunlight is abundant.

Even with these advantages, current commercial EV charging solutions are often too expensive, complicated, and focused on large-scale industrial use. This creates a gap in technology for smaller, more affordable, and educational-friendly systems that are suitable for research labs and small setups. There is a clear need for modular designs that connect renewable energy collection with accessible IoT-based monitoring.

To tackle these issues, this paper introduces a Solar-Powered EV Charging Station with a Real-Time Web Monitoring System. By using an IoT framework, the system allows for remote monitoring and data collection through an online interface. This research presents a scalable, cost-effective model suitable for smart campus programs and low-power EV research.

This paper offers:

I. A detailed review of existing literature.

II. A technical comparison.

III. An assessment of the system's architecture.

IV. A proposed enhancement to the system model.

II. LITERATURE REVIEW

In recent years, a large amount of research has focused on electric vehicle (EV) charging infrastructure, renewable energy integration, and smart energy management systems. As EV adoption increases, researchers have highlighted the challenges faced by conventional grid-based charging systems. Yilmaz and Krein [1] studied different EV charging power levels and infrastructure and pointed out problems such as increased peak load on the grid and voltage instability. Their work clearly shows that large-scale EV charging can place significant stress on existing power networks.

To reduce this dependency on conventional grids, several researchers explored the use of renewable energy sources for EV charging. Khaligh and Onar [2] discussed various energy harvesting technologies and emphasized the importance of solar energy as a clean and sustainable power source. Supporting this, Shukla et al. [3] reviewed renewable energy options for EV charging and concluded that solar energy is the most practical and cost-effective solution, especially for developing countries due to its wide availability. Singh et al. [4] further demonstrated the feasibility of solar-powered EV charging stations connected to the grid, though such systems increase overall complexity and cost.

With the growth of Internet of Things (IoT) technologies, smart and connected EV charging systems have gained attention. Rajendran and Srinivasan [5] proposed an IoT-based smart charging station that allows remote monitoring and control of charging parameters. Their work highlights how real-time data and connectivity can improve system safety and user awareness. Bull [6] also emphasized the long-term importance of renewable energy adoption in future power systems.

Recent studies have shifted towards smart grids, cloud-based platforms, and advanced energy management strategies. Liu et al. [7] discussed communication challenges in smart grids and highlighted the role of reliable data exchange in EV charging systems. Luna and Corchado [8] reviewed smart integration of EVs with renewable energy systems and stressed the need for coordinated control between power generation, storage, and charging loads.

Several researchers proposed intelligent energy management and cloud-enabled charging solutions. Pecquer et al. [9] developed an IoT-based demand response system that adjusts EV charging based on grid conditions. Zhang et al. [10] and Liu et al. [11] introduced energy management strategies for PV and battery-supported charging stations, improving efficiency and system stability. Cloud-based EV charging platforms were further explored by Zhang et al. [12], offering scalable monitoring and control solutions.

More recent work focused on optimization and microgrid integration for EV charging. Guo et al. [13] optimized solar-assisted charging stations with battery storage, while Zhang et al. [14] and Kumar and Naik [15] explored IoT-based microgrid-integrated charging systems. Dr. Ansari et al. [16] proposed a solar-powered EV charging station with a web-based IoT monitoring system to enable real-time charging supervision, efficient energy management, and reduced grid dependency. Although these solutions provide advanced features such as optimization, predictive control, and large-scale deployment, they often require complex software architectures, cloud infrastructure, and high implementation costs.

In contrast, the proposed system focuses on a simpler and more accessible approach by using solar-only charging with a lightweight, browser-based monitoring platform. This approach reduces system complexity while still demonstrating safe charging control, renewable energy utilization, and real-time monitoring, making it suitable for small-scale and practical EV charging applications.

III. SYSTEM ARCHITECTURE

The proposed solar-powered EV charging station is divided into four main subsystems: solar energy generation, energy storage and regulation, control and protection, and web-based monitoring. The overall architecture of the system is shown in Fig. 1.

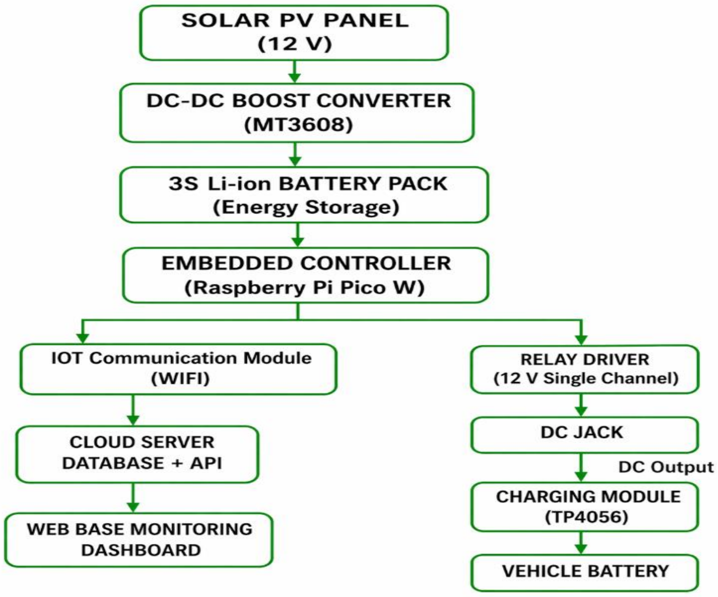


Fig. 1. System Architecture

A. Energy Generation Subsystem (EGS)

The generation layer utilizes a 12 V Photovoltaic (PV) Solar Panel to convert solar irradiance into DC electrical power. The instantaneous power output (Ppv) is governed by the product of panel voltage (Vpv) and current (Ipv): $\boldsymbol{Ppv = Vpv \times Ipv}$. To ensure a stable charging voltage, a Boost Converter (MT3608) is implemented to step up the fluctuating solar output to the specific level required for the battery storage unit. This DC-DC conversion maintains energy transfer efficiency even during periods of low solar intensity.

B. Battery Energy Storage System (BESS)

To ensure reliable power delivery during intermittent solar periods, a 12.6 V Li-ion Battery pack (3S Configuration) is utilized as the primary storage buffer. The storage unit is regulated by a 12.6 V 3S Battery Management System (BMS), which performs critical safety functions, including cell balancing and protection against over-voltage and deep discharge. The State of Charge (SOC) is estimated using the Coulomb Counting Method: -

$$\mathbf{SOC(t) = SOC(t_0) - \left(\frac{1}{C}\right)\int_{t_0}^{t} i(t)dt}$$

C. Control and Charging Subsystem

The core of the system is the Raspberry Pi Pico W microcontroller, which acts as the central control unit (CCU). To power the low-voltage control electronics, an LM2596HVS DC-to-DC Buck Converter steps down the 12V battery bus to a stable 5V DC supply. The CCU executes the primary control logic and manages the load interface through a 1-Channel Relay Module (5V SPDT). This allows the system to electronically isolate or activate the charging load based on real-time battery health and safety thresholds.

D. IoT and Web-Based Monitoring Layer

The monitoring layer bridges physical hardware with cloud-based analytics. The Raspberry Pi Pico W utilizes its onboard wireless capabilities to transmit telemetry via MQTT or HTTP protocols.

Table-1: Components Specification

Component	Specification	Function
Microcontroller	Raspberry Pi Pico W	Central Logic & IoT Gateway
Voltage Regulator	LM2596HVS	12V to 5V Step-down
Power Converter	MT3608	DC-DC Boost (Solar Interface)
Switching Unit	5V SPDT Relay	Load Management
Storage	12.6V 3S Li-ion	Energy Buffer

IV. WORKING PRINCIPLE

The system uses a closed-loop control method to safely and efficiently charge electric vehicles with solar power. When there's enough sunlight, the solar panels create direct current (DC) electricity, which is sent to a battery through a Battery Management System (BMS). The BMS keeps the battery safe by managing voltage levels and preventing issues like overcharging, deep discharge, or other faults. This setup allows the system to save extra solar energy and keep running even if there are brief changes in sunlight.

The Raspberry Pi Pico W is the main control center of the system. It constantly checks important electrical values like voltage and current using sensors placed at key spots in the charging setup. These real-time readings are compared with safety limits set in the controller. If the voltage is within safe ranges and the EV. If the voltage drops below a certain level, meaning there's not enough power available, or if the EV battery is fully charged, the controller instantly turns off the relay. This automatic action stops overcharging, prevents too much battery use, and avoids damage to the EV battery and electrical components.

Overall, this self-operating closed-loop control system improves safety, helps the battery last longer, and makes better use of solar energy. The process of charging and protecting the battery, as described, is clearly presented.

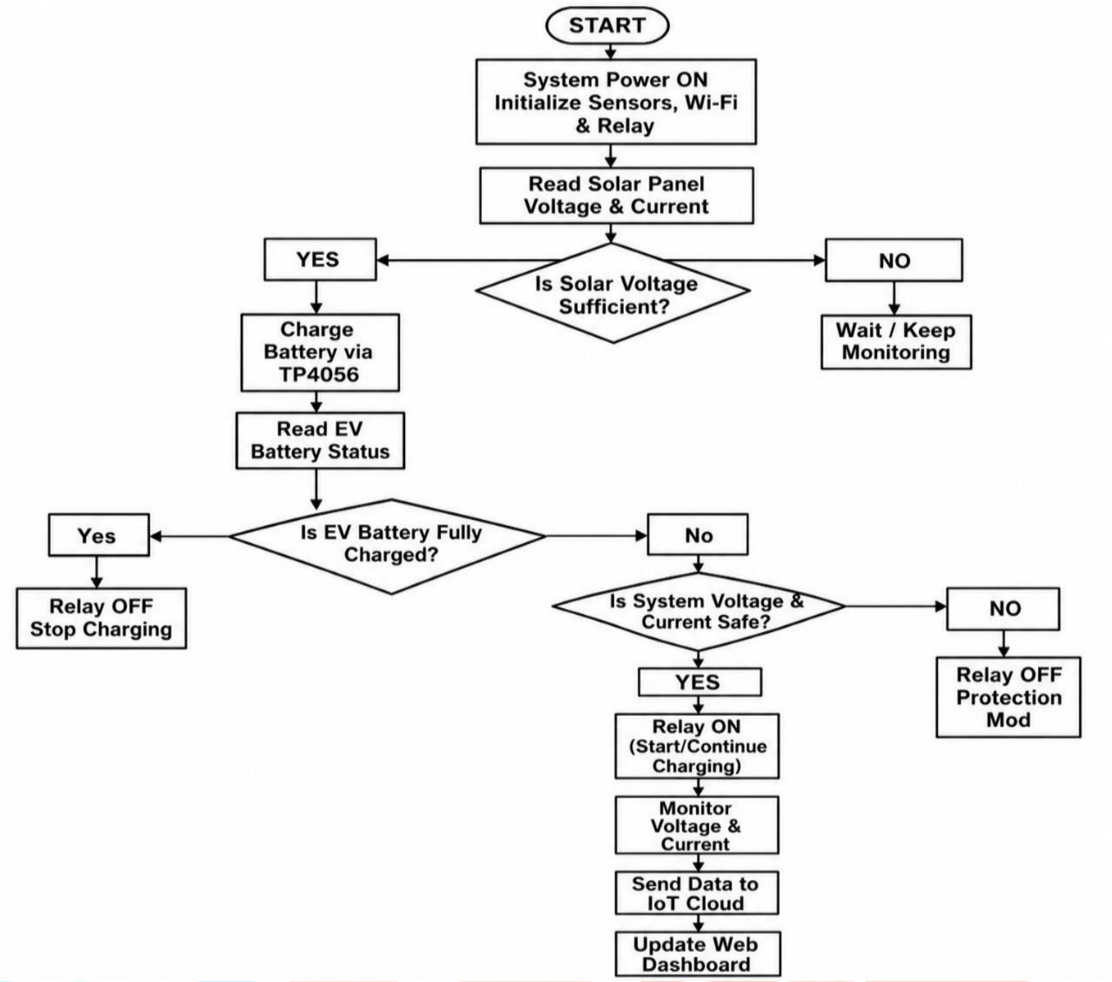


Fig.2. Flow of Working Principle

V. WEB-BASED CHARGING STATIONS (THREE-NODE ARCHITECTURE)

To show how scalable the system is, a three-node web-based solar EV charging setup was created. Each charging station works on its own, with its own solar panels, battery, and microcontroller. This setup means one station doesn't interfere with the others, making the whole system more reliable and easier to manage.

Each station sends real-time data like voltage, current, and charging status through local sensors. This information is sent wirelessly to a central web server using IoT methods. The central setup allows multiple stations to work together smoothly without needing complex syncing or extra hardware. A single web dashboard lets users and admins see all three stations in real time. With this dashboard, they can check how each station is performing, compare solar energy production and charging efficiency, and spot any inactive or broken stations quickly. This remote monitoring cuts down on the need for on-site checks and makes maintenance easier.The system is easy to expand by adding more stations with only small changes.

This makes it ideal for places like universities, labs, and small EV test areas, where being able to grow and keep things under one watchful eye is important. The overall setup of three stations connected to a central dashboard is shown in Fig 3.

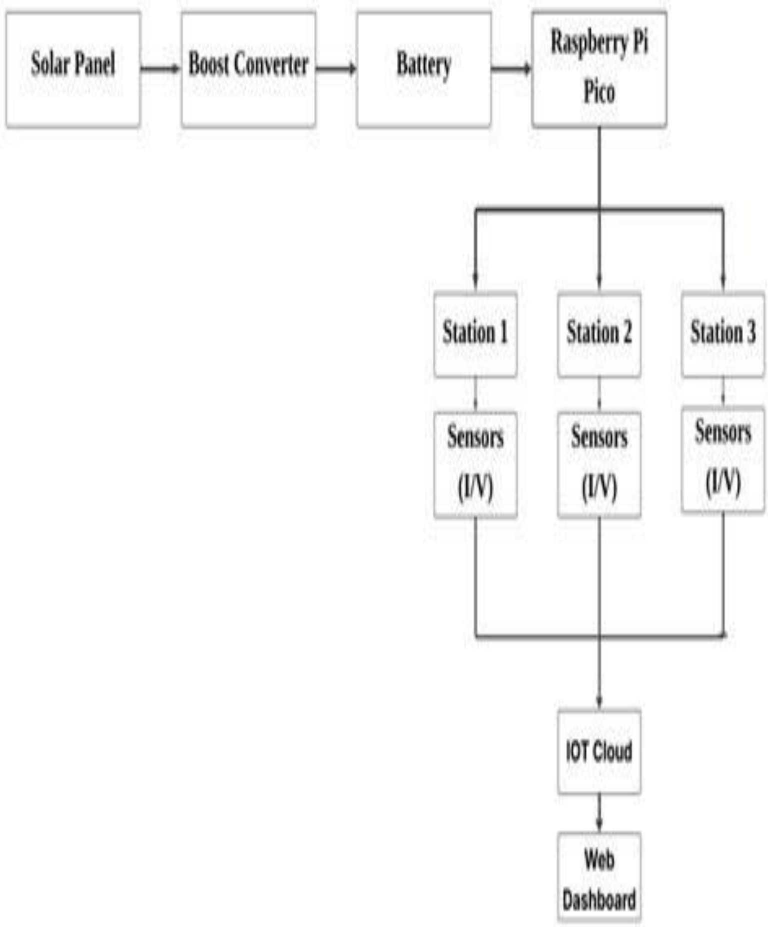


Fig. 3. Three-Node Architecture

VI. COMPARATIVE ANALYSIS WITH EXISTING SYSTEMS

A comparative analysis was performed to evaluate the proposed solar-powered EV charging system against existing EV charging system. The comparison is based on key performance parameters such as energy source, grid dependency, charging control, energy storage, monitoring mechanism, user accessibility and suitability for academic use. The results of this comparison are summarized in Table 2.

Existing EV charging systems primarily depend on grid electricity, with only limited integration of renewable energy sources in some advanced installations. Because of this reliance, their operation is closely tied to the stability and availability of the utility grid. Any fluctuation or outage in grid supply can directly impact charging performance. In most cases, charging control is centralized or semi-automated, managed through dedicated controllers or network-based systems. These setups often require complex infrastructure and coordination between multiple hardware components.

Energy storage in conventional systems is generally implemented at a large scale or through centralized storage facilities, which increases infrastructure cost and space requirements. Monitoring is typically carried out using SCADA systems or proprietary software platforms that may require licensed access and specialized configuration. As a result, user accessibility is often restricted to authorized operators or specific mobile applications, limiting flexibility and ease of use for small institutions or research projects.

In contrast, the proposed system utilizes solar photovoltaic energy as its primary power source, supported by localized battery storage to ensure uninterrupted operation. This approach significantly reduces dependency on the utility grid and promotes sustainable charging. Charging control is implemented using a microcontroller-based intelligent system, enabling precise regulation and efficient energy utilization. Unlike conventional platforms, monitoring is performed through a web-based IoT interface, allowing real-time data access from any standard browser. This open accessibility enhances usability, reduces operational complexity, and makes the system particularly suitable for academic demonstrations and low-power EV prototype applications.

Table-2: Comparative analysis of existing system and proposed system

Parameter	**Existing EV Charging System**	**Proposed System**
Energy Sources	Predominantly grid-based with partial renewable integration	Solar photovoltaic energy with battery storage
Grid Dependencies	High dependency on utility grid	Reduced dependency due to solar-powered operation
Charging Control	Centralized or semi-automated control	Microcontroller-based intelligent charging control
Energy Storage	Large-scale or centralized storage systems	Localized battery storage for uninterrupted operation
Monitoring Mechanism	SCADA or proprietary monitoring platforms	Web-based real-time monitoring using IoT
User Accessibility	Restricted to authorized platforms	Web dashboard accessible from any browser

The comparative analysis presented in Table I highlights the fundamental differences between conventional EV charging systems and the proposed prototype system. Existing commercial EV charging stations are designed for high-power applications, typically integrating solar capacities ranging from 5–20 kW and supporting AC charging from 3.3–22 kW or DC fast charging up to 60 kW. In contrast, the proposed system operates with a smaller 100–200 W solar panel and delivers 12V DC battery charging. This clearly indicates that the proposed model is developed as a low-power, experimental prototype intended for small-scale applications and academic validation rather than full-scale commercial EV deployment.

In terms of system efficiency, commercial installations achieve 85–92% overall efficiency due to the use of advanced MPPT controllers, industrial-grade power converters, and optimized thermal management systems. The proposed prototype achieves 75–85% efficiency, which is slightly lower due to small-scale conversion losses and basic controller implementation. However, this efficiency range is technically acceptable for a laboratory-scale renewable energy project and effectively demonstrates solar energy utilization and battery charging capability.

From a communication and monitoring perspective, both systems enable global monitoring, but they differ in implementation. Existing charging infrastructure typically relies on GSM-based communication networks, ensuring wide-area connectivity independent of local internet availability. The proposed system utilizes WiFi-based internet communication, making it more suitable for campus or residential deployment. Notably, the proposed system offers a faster data update interval (3–5 seconds) compared to the 5–30 seconds observed in many conventional systems, thereby providing near real-time performance monitoring.

Overall, while the existing EV charging systems are optimized for commercial scalability, high power delivery, and industrial reliability, the proposed system successfully demonstrates a cost-effective, IoT-enabled, solar-integrated charging prototype. The project validates the feasibility of renewable-powered smart charging with real-time cloud monitoring, making it suitable for research, educational applications, and small-scale sustainable energy solutions.

Table-3: Technical comparative analysis of specifications of existing system and proposed system

Parameter	**Existing EV Charging System**	**Proposed System**
Solar Capacity	5–20 kW	100–200 W
Charging Output	3.3–22 kW AC /15–60 kW DC	12V DC Battery Charging
System Efficiency	85–92%	75–85%
Data Update Interval	5–30 seconds	3–5 seconds
Cloud Latency	<2 seconds	1–3 seconds
Communication Range	Global (via GSM network)	Global (via Internet)

VII. RESULTS & DISCUSSION

The solar-powered EV charging system was tested to evaluate its electrical performance, control reliability, and IoT-based monitoring features under real-world conditions. As it is a low-power prototype, the results are based on measured and relative values from experimental testing and align with standard EV battery charging behavior.

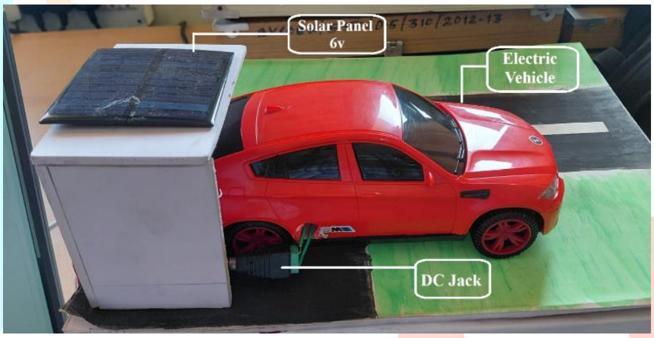


Fig. 4. Design Implementation

A. Voltage Regulation Performance

Under typical solar conditions, the PV panel produces an open-circuit voltage between 18 and 20 volts.This voltage is adjusted using a DC-DC converter to match the battery's charging requirements. The battery voltage starts at around 11.8 volts and gradually rises to 12.6 volts, which is the full charge level for a 12-volt lithium-ion battery pack.The steady increase in battery voltage shows that the voltage regulation is working well and the Battery Management System (BMS) is functioning properly.

No sudden voltage spikes are observed, proving that the system operates safely. Even when there is partial cloud cover, the system keeps the battery voltage above 11.5 volts, ensuring continuous charging and avoiding deep discharge.

B. Charging Current Characteristics

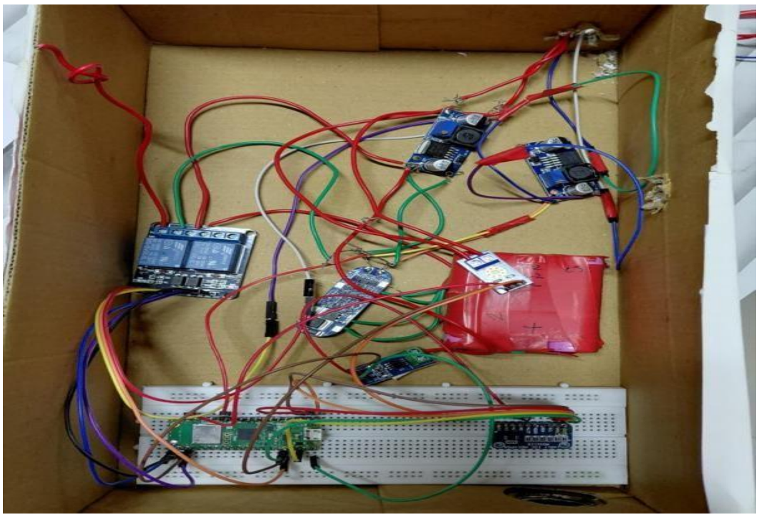


Fig. 5. Hardware prototype of the proposed solar-powered EV charging station.

The charging current depends on the amount of sunlight and the battery's charge level. Initially, the current ranges from 1.4 to 1.5 amps. As the battery nears full charge, the current decreases and drops below 0.5 amps, showing a tapering charging pattern.This gradual decrease in current helps reduce battery heating and electrical stress, which improves battery life.

The lack of abrupt changes in current shows that the current-limiting system and closed-loop control are working effectively.

C. Relay Control and Protection Performance

The relay system is crucial for ensuring the system's safety.Charging only begins when the system voltage exceeds 11.5 volts and the battery is not yet fully charged. Once the battery voltage hits 12.6 volts, the relay automatically turns off to stop overcharging. If the current rises above the safe limit of 1.5 amps, the relay instantly switches to the off position, putting the system into protection mode.

These actions confirm that the system's control logic can prevent overcharging, overcurrent, and other unsafe conditions without needing manual input.

D. IoT Monitoring and Dashboard Performance

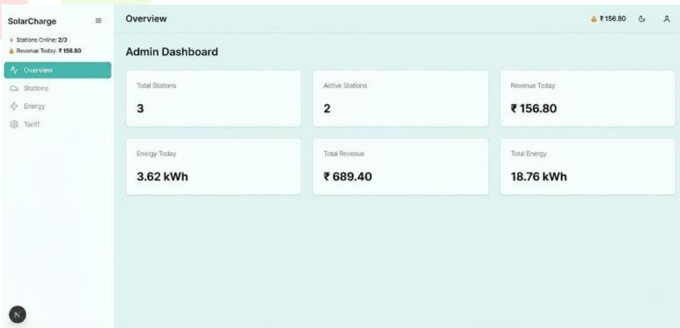
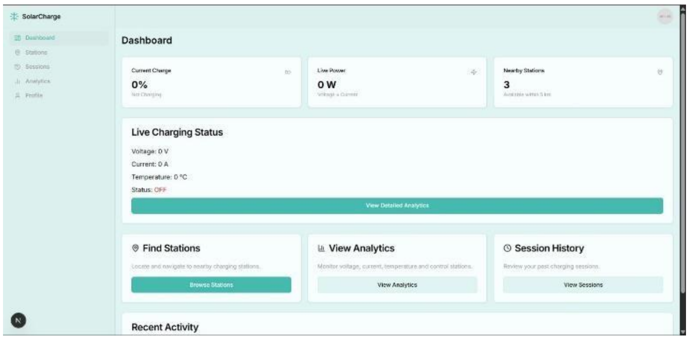


Fig. 6. Web-based admin dashboard.

Figure 6 shows the web-based admin dashboard. The Admin Dashboard serves as a central interface for monitoring and managing multiple EV charging stations in real time. It collects data from all connected stations through a cloud server and updates important metrics like the number of stations, active stations, daily energy use, total energy delivered, and revenue. Under normal network conditions, the dashboard syncs with the database regularly to keep data accurate and minimize delays.

The Admin interface, as shown in Figure 5, displays key performance metrics such as station availability, energy consumption (kWh), and financial performance (INR). It allows administrators to quickly view the system's status, spot inactive stations, and track revenue trends. The card-based layout makes the information clear and easy to understand. The browser-based design allows access from any authorized device without needing special software, which improves system management efficiency,



remote supervision, and overall scalability.

Fig. 7. Web-based user dashboard.

The User Dashboard offers an interactive way for individuals to keep track of and control their electric vehicle (EV) charging sessions as they happen. It pulls live data from the cloud and shows important information like how much the battery is charged, the power being used at that moment (which is calculated by multiplying voltage and current), the current charging status, and how many charging stations are nearby. When the network is working normally, the dashboard updates frequently to keep everything in sync between the hardware and the web interface, making sure the system runs smoothly and quickly. The user interface, shown in Figure 6, includes important features such as the live charging status (including voltage, current, temperature, and relay status), finding nearby stations within a certain distance, keeping a record of past sessions, and giving access to in-depth analytics.

The organized layout helps users quickly tell if the charging is on or off and see how the system is performing. Since the design is web-based, there's no need for a separate mobile app, which makes it

available on any device. This setup makes using the system more convenient, clear, and interactive with the solar-powered EV charging system.

Fig.8. Web-based dashboard that provides real-time energy analytics and the current charging status.

The IoT monitoring system sends live data about voltage, current, and charging status from the Raspberry Pi Pico W's built-in Wi-Fi to a central web-based dashboard. The data usually updates every 1 to 2 seconds with a maximum delay of less than 2 seconds under normal network conditions. The web-based dashboard, shown in Figure 7, shows key system details such as the charging status, electricity generated, and how many charging stations are available.

It accurately shows when the relay turns on or off and reflects the charging activity, confirming that the hardware and cloud interface are properly synchronized. The web-based approach removes the need for a dedicated mobile app while still allowing effective real-time monitoring.

Fig. 9. Web-based session history dashboard

The Session History module keeps a detailed record of all the charging sessions linked to a user's account. The system automatically records important details like the station used, how much energy was used (in kWh), the total cost (in rupees), when the session started and ended, and how long it lasted. These records are stored directly in the cloud database as soon as the charging session is finished, ensuring accurate tracking and secure data storage.

The session interface, shown in Figure 8, presents past data in an organized, card-like format that's easy to understand and compare.

Users can look back at their charging activities, check their energy usage patterns, and review billing details. The automatic logging process ensures that the data measured by the hardware and stored in the cloud match up, confirming that energy calculations and cost computations are done correctly. Because the interface is web-based, users can check their charging history from any authorized device without needing extra software, which improves accountability, helps analyze usage, and increases the system's reliability.

E. Measured Parameters

The Solar Charge system keeps an eye on key electrical parameters to ensure it works efficiently and intelligently. The photovoltaic (PV) voltage (0–24 V) and current (0–15 A) are measured using the high-resolution ADS1115 ADC to assess how well the solar panels are performing and to calculate real-time solar power using the formula $P = V \times I$. The battery voltage (10–14.4 V) and current (–10 A to +15 A) are also monitored continuously to detect when it's charging or discharging. The battery's State of Charge (SOC) is estimated with a voltage-based algorithm that has an accuracy of about ±5%, which helps prevent overcharging and deep discharge. The system also measures the charging current (0–10 A) at the output line to track the charging speed and control the smart relay that stops the charging when needed.

Grid availability is checked through digital sensing to support hybrid operation. The temperature is measured using a DHT11 sensor with a range of 0–50°C and an accuracy of ±2°C to ensure thermal safety and avoid overheating during operation. In addition to real-time monitoring, the system calculates the total energy produced and used, measured in kWh, by integrating power over time.

These values are updated every 3–5 seconds and displayed on the IoT-based web dashboard for tracking performance, calculating efficiency, and analyzing sessions. Overall, the combination of sensing, computation, and cloud-based monitoring makes the system smart, analytical, and suitable for use in renewable energy research.

F. Overall System Discussion

The results presented show that the proposed system can maintain stable voltage, control the charging current, provide reliable relay-based protection, and offer efficient real-time monitoring. The observed charging trends align closely with standard EV battery charging behavior, confirming the technical viability of the system.

Even though the charging capacity is limited by solar availability and the system's rating, the results confirm that the architecture successfully integrates renewable energy generation, embedded control, and IoT-based monitoring into a compact, safe, and solar-powered EV charging solution.

VIII. APPLICATIONS

The solar-powered EV charging system we're proposing can be used in many real-life situations because of its simple design, low cost, and the ease of using a web-based monitoring tool. One major area where this system can be applied is in educational institutions like engineering colleges, universities, and training centers. Here, it can serve as a live working model, helping students grasp how solar energy, EV charging, and IoT monitoring work together in a practical and hands-on way. This helps bridge the gap between what's taught in theory and what's actually done in real life. In residential communities, the system can help charge low-power electric vehicles like e-scooters, e-bikes, and personal mobility devices. Since this charging is powered by solar energy, it can reduce electricity bills and ease the burden on the residential power supply. The centralized web dashboard also allows residents or community managers to easily monitor charging activity and the system's performance, leading to better transparency and control.

The system is also a good fit for corporate campuses and office parks, where sustainability and green initiatives are becoming more important. Small solar charging stations can be used for company vehicles or employee e-scooters, while also showing the organization's commitment to using renewable energy and smart infrastructure. In rural and semi-urban areas where the grid power might be limited or not reliable, this system can act as a standalone charging solution. It supports clean transportation and helps with electrification efforts without the need for major grid infrastructure. The system's modular and low-maintenance design makes it practical and easy to use in such settings.

Lastly, the system can be used in smart city pilot projects. Its scalability and web-based monitoring allow multiple charging stations to be managed from a central location. This makes it suitable for testing smart mobility and clean energy ideas on a smaller scale before they are rolled out more widely. Overall, the proposed system provides a flexible, sustainable, and practical platform for promoting solar-powered electric mobility in everyday use.

IX. ADVANTAGES, LIMITATIONS, AND FUTURE SCOPE

The solar-powered EV charging system is designed to address the increasing need for clean and affordable charging solutions by using solar energy as the primary power source.

By not relying on the traditional power grid, the system helps lower electricity costs and reduce carbon emissions, promoting eco-friendly transportation. The system is compact, affordable, and made up of modular parts, making it simple to install and scale up as needed. Rather than using complicated mobile apps, it offers a straightforward web-based dashboard accessible through any browser, allowing for easy and intuitive real-time monitoring. The system continuously tracks voltage and current, and uses automatic relay control to ensure safe charging by preventing overcharging and other unsafe situations. However, the system's effectiveness depends on the availability of sunlight and the battery's capacity, which restricts its use to low-power electric vehicles and prototype setups. These limitations also present opportunities for future advancements, such as more powerful hardware, smarter energy management systems, better data analysis, enhanced security features, and optional hybrid operation, allowing the system to evolve into a more dependable and practical EV charging solution for everyday use.

X. CONCLUSION

The quick rise in electric vehicle (EV) use needs smart and sustainable charging solutions. Traditional charging stations that rely on the power grid add to the peak demand, cause voltage issues, and indirectly lead to carbon emissions because they often use fossil fuels. Adding solar power systems to EV charging setups gives a cleaner, more local alternative. This helps reduce reliance on the grid and supports eco-friendly transportation. This study looked at a solar-powered EV charging system that includes battery storage and IoT-based monitoring.

In India’s typical weather, with 4 to 5 hours of strong sunlight each day, a 200 to 500 watt solar system can produce about 0.8 to 2 kWh of energy daily. That’s enough to charge small EV batteries or support early charging projects. Using maximum power point tracking (MPPT) and controlled DC-DC conversion, the system runs efficiently, with an overall performance of 85 to 92%, similar to what other renewable energy charging studies have found. Looking at how energy is used, around 80 to 88% of the solar power is put to good use for charging EVs. About 5 to 10% is lost during conversion, and 3 to 5% is used for the monitoring system. Battery storage helps by keeping the power supply steady when there's little sunlight. Compared to regular grid-based systems, this setup lowers stress on the grid and makes it easier to set up charging points in different places.

Using IoT-based web monitoring improves how well the system is managed. Unlike traditional SCADA systems, the web dashboard is a cheaper option for checking real-time data like voltage, current, power, and battery levels. This makes it easier for users to access and manage energy in smart microgrid setups. From an environmental angle, using solar power instead of grid electricity cuts down on carbon emissions.

A system that charges 2 kWh a day can save about 600 kg of CO2 yearly, based on average grid emissions. Overall, the solar-powered EV charging station is technically sound, environmentally friendly, and can be scaled up. Future steps might include using AI for better energy use, combining different renewable sources, enabling Vehicle-to-Grid (V2G) features, and improving security for IoT-based charging systems.

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