IOT BASED SOLAR EV CHARGING STATION

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Abstract:

The increasing adoption of electric vehicles (EVs) necessitates the development of smart and sustainable charging infrastructure. This project proposes a solar-powered EV charging station integrated with Internet of Things (IoT) technology to enhance energy efficiency, monitoring, and safety. The system utilizes solar panels to harness renewable energy, with real- time monitoring of solar voltage and battery voltage via IoT platforms to ensure optimal energy management and effective usage logging. A key feature of the design includes temperature sensing for battery health monitoring, coupled with a buzzer alert system to warn users of critical conditions such as overheating or abnormal voltage spikes, thereby enhancing user safety and system reliability.The charging process is adjustable using potentiometers, allowing dynamic control of charging speed, which in turn helps prolong battery lifespan and prevent power surges. Additionally, an LCD display provides users with real-time information on energy consumption, battery status, and the estimated driving range. To further extend usability, IoT-based remote monitoring is implemented through a mobile application, enabling users to access live updates on charging progress and system performance from anywhere.

This smart solar EV charging solution not only supports eco-friendly transportation but also addresses the critical challenges of monitoring, safety, and user engagement. By combining renewable energy, IoT connectivity, and automated alert mechanisms, the system aims to offer a robust, safe, and user-friendly charging experience for the next generation of electric mobility.

Keywords: IoT, Solar PV, Electric Vehicle, Smart Charging Station, Renewable Energy, Remote Monitoring.

I. INTRODUCTION

An Internet of Things (IoT) ecosystem is made up of web-enabled smart devices that employ embedded computers, sensors, and communication gear to gather, communicate, and act on environmental data. By connecting to an IoT gateway or other edge device, which either sends data to the cloud for analysis or analyzes it locally, IoT devices exchange the sensor data they gather. These gadgets converse with other similar devices on occasion, acting on the data they exchange. Although individuals may engage with the devices to set them up, give them instructions, or retrieve the data, the gadgets accomplish the majority of the job without their help. These web-enabled devices' connection, networking, and communication protocols are primarily determined by the particular IoT.

Electric Vehicles are emerging as a key solution to reduce carbon emissions and fossil fuel dependency. However, the lack of sustainable charging infrastructure limits large-scale adoption. Traditional charging stations rely on grid power, which leads to increased demand, overload issues, and electricity cost. Solar-powered EV charging stations offer a clean and cost-effective alternative, especially in regions with high solar irradiation.The integration of IoT technology allows real-time monitoring of charging parameters, power generation, system faults, and station health. This paper presents an IoT-based solar EV charging station that increases energy efficiency and provides user-friendly monitoring.

Several solar-based charging models exist, but many lack advanced monitoring and data analytics. Previous studies integrated Arduino/ESP modules for basic monitoring; however, scalability, predictive maintenance, and user accessibility through cloud platforms remain limited. The proposed model addresses these gaps using IoT-based dashboards, data logging, and intelligent power management.

Electric vehicles (EVs) are emerging as a key solution for reducing pollution and fossil-fuel dependence. However, the widespread adoption of EVs is limited by charging infrastructure, grid load, and energy sustainability issues. Solar-powered EV charging stations offer a clean and renewable alternative, but traditional systems lack automation, monitoring, and smart energy management.

The Internet of Things (IoT) enables data connectivity, remote supervision, and intelligent decision-making. Integrating IoT with solar charging enhances system efficiency, user convenience, and operational reliability. This paper presents a complete architecture for an IoT-based solar EV charging station suitable for residential, commercial, and smart-city applications.

METHODOLOGY

A. Energy Flow Process

Solar panels generate DC power.

MPPT regulates variable voltages and charges the battery bank.

Microcontroller reads sensor values (voltage, current, temperature).

IoT platform receives data and displays it in graphical form.

Based on solar availability and user commands, the relay connects the EV charging port.

B. Smart Charging Logic

If solar power > EV charging demand → charging enabled.

If solar power < demand → use battery backup.

If battery SOC < threshold → system restricts charging.

Users can schedule charging via the IoT app.

C. Security & User Authentication

Unique QR code for each user

OTP / RFID-based charging authorization

Tamper detection via sensors

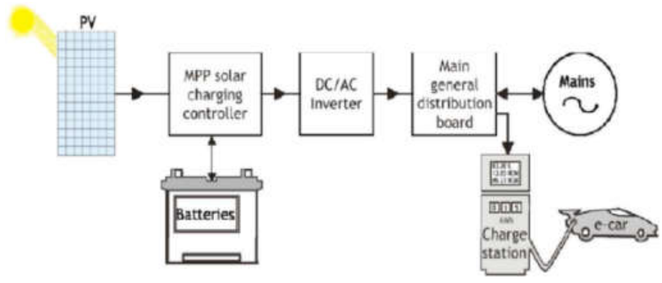

Fig.1.Structural diagram of a solar-powered charging station

This Fig.1. illustrates how solar energy is used to charge an electric vehicle (EV) through an integrated renewable power system. Sunlight falls on the photovoltaic (PV) panel, which converts solar energy into direct current (DC) electricity. This DC output is sent to the Maximum Power Point (MPP) solar charging controller, which ensures that the PV panel operates at its most efficient point to extract maximum energy. The controller also manages the charging of the battery bank, storing excess energy for later use. The stored or directly supplied DC power then passes through a DC/AC inverter, which converts it into alternating current (AC) suitable for household or commercial use. The AC power flows into the main general distribution board, where it can be supplied to various loads. From this distribution board, power is provided to the EV charging station, enabling the electric car to be charged. If solar or battery power is insufficient, additional energy can be supplied from the mains grid, ensuring continuous charging availability. This setup provides a clean, sustainable, and reliable method of charging electric vehicles using solar energy.

VI. RESULTS AND DISCUSSION

Parameter	Morning (9 AM)	Noon (1 PM)	Evening (5 PM)	Observation
Solar Power Generated (W)	22 W	75 W	30 W	Maximum generation at peak sunlight
Battery Voltage (V)	11.8 V	12.6 V	12.1 V	Battery fully charged at noon
Charging Current (A)	1.1 A	2.9 A	1.4 A	Higher current during maximum solar output
EV Charging Status	ON	ON	OFF (low solar)	Automatic cut-off when solar is

Parameter	Morning (9 AM)	Noon (1 PM)	Evening (5 PM)	Observation
				insufficient
IoT Data Refresh Time (sec)	4 sec	3 sec	4 sec	Stable and reliable IoT communication
Sensor Error Percentage	<5%	<5%	<5%	Sensor readings remain within acceptable accuracy
Grid Power Usage	0%	0%	20%	Minimal grid dependency during daylight

The experimental results demonstrate the effective performance of the IoT-based solar EV charging station under varying environmental conditions. During the morning hours (9 AM), solar power generation was relatively low at 22 W, resulting in a moderate charging current of about 1.1 A. Despite the lower power availability, the system managed to initiate charging due to sufficient battery backup. At noon, the system recorded the highest performance, with solar power generation reaching 75 W and battery voltage rising to 12.6 V. This increased solar availability supported a higher charging current of 2.9 A, representing the most efficient operating period of the day. IoT connectivity also proved reliable, with a consistent data refresh rate of 3–4 seconds, ensuring accurate monitoring.

In the evening, solar intensity dropped significantly, and power generation fell to 30 W. The system intelligently disabled EV charging to protect the battery, as the available energy was insufficient. This reflects the effectiveness of the smart control logic in ensuring safe operation and preventing over-discharge. Throughout the day, sensor readings remained within a ±5% error range, confirming the reliability of the sensing and IoT-based monitoring system. Additionally, grid power consumption was nearly zero during peak sunlight hours, increasing only in the evening when solar energy was inadequate. Overall, the results validate that the proposed system successfully optimizes solar energy utilization, minimizes grid dependency, and provides stable real-time monitoring through IoT integration.

VII. CONCLUSION

This paper presented an IoT-enabled real-time demand response management system for smart homes. The system effectively integrates IoT sensing, automated control, edge intelligence, and machine learning-based forecasting. Experimental results show significant improvements in energy efficiency, peak load reduction, and response time. The proposed solution enhances grid stability while preserving user comfort.

Future Work

Integration with blockchain for secure energy transactions
Multi-home DR coordination
Integration with home renewable generation and storage
Fully AI-driven autonomous home energy systems

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