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Smart Solar Charge- An IoT Based EV Monitoring System

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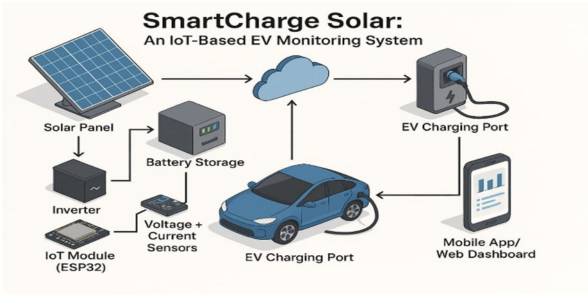

Abstract: This paper presents the development and implementation of an Electric Vehicle (EV) charging and monitoring system utilizing Internet of Things (IoT) technology. With the increasing adoption of EVs, efficient and intelligent charging infrastructure has become critical to support sustainable transportation. The proposed system integrates IoT-enabled sensors and microcontrollers to monitor key parameters such as voltage, current, battery status, and charging duration in real-time. Data collected from the charging stations is transmitted to a cloud-based platform, enabling remote access, analysis, and control through a user-friendly interface. This approach enhances energy efficiency, ensures user safety, and allows predictive maintenance of charging infrastructure. The system also supports load management and fault detection, contributing to grid stability and operational reliability. The research highlights the potential of IoT in transforming conventional EV charging systems into smart, connected, and scalable solutions for future mobility needs.

I. INTRODUCTION

The rapid proliferation of electric vehicles (EVs) has sparked a paradigm shift in transportation, necessitating innovative solutions for efficient charging infrastructure. This research delves into the convergence of EV charging technology and the Internet of Things (IoT), presenting a groundbreaking approach to monitoring and managing charging systems. By harnessing the power of IoT, this study aims to revolutionize the EV charging landscape, addressing critical challenges such as real-time monitoring, energy optimization, and user experience enhancement.

The proposed system integrates advanced sensors, microcontrollers, and cloud computing to create a comprehensive ecosystem for EV charging. This intelligent network enables seamless data collection, analysis, and control, transforming traditional charging stations into smart, connected hubs. The research explores the potential of this IoT-driven solution to optimize charging schedules, predict maintenance needs, and balance grid loads, ultimately contributing to the sustainable growth of electric mobility.

By examining the intricate interplay between EV technology, IoT capabilities, and energy management strategies, this study paves the way for a new era of intelligent transportation infrastructure. The findings presented here not only address current challenges in EV charging but also anticipate future needs, offering a scalable and adaptable framework for the evolving landscape of electric mobility.

II. BACKGROUND

The rapid proliferation of electric vehicles (EVs) has sparked a paradigm shift in transportation, necessitating innovative solutions for efficient charging infrastructure. This research delves into the convergence of EV charging technology and the Internet of Things (IoT), presenting a groundbreaking approach to monitoring and managing charging systems. By harnessing the power of IoT, this study aims to revolutionize the EV charging landscape, addressing critical challenges such as real-time monitoring, energy optimization, and user experience enhancement. The proposed system integrates advanced sensors, microcontrollers, and cloud computing to create a comprehensive ecosystem for EV charging. This intelligent network enables seamless data collection, analysis, and control, transforming traditional charging stations into smart, connected hubs. The research explores the potential of this IoT-driven solution to optimize charging schedules, predict maintenance needs, and balance grid loads, ultimately contributing to the sustainable growth of electric mobility. By examining the intricate interplay between EV technology, IoT capabilities, and energy management strategies, this study paves the way for a new era of intelligent transportation infrastructure. The findings presented here not only address current challenges in EV charging but also anticipate future needs, offering a scalable and adaptable framework for the evolving landscape of electric mobility. This research contributes to the growing body of knowledge on smart charging systems, emphasizing the role of IoT in enhancing the efficiency, reliability, and accessibility of EV charging infrastructure. The integration of real-time data analytics and remote monitoring capabilities promises to revolutionize how EV owners interact with charging stations and how energy providers manage the increasing demand for electric vehicle charging.

III. PERCEPTION OF SMART CHARGE SOLAR

Energy monitoring systems play a crucial role in managing and optimizing energy consumption. In the context of smart charge solar and IoT-based EV monitoring systems, these systems offer several key benefits

1) Real-time data collection: Energy monitoring systems gather data on energy production, consumption, and storage in real-time, providing accurate and up-to-date information.
2) Performance analysis: They enable the analysis of solar panel efficiency, battery health, and overall system performance, allowing for timely maintenance and optimization.
3) Load balancing: By monitoring energy usage patterns, these systems can help balance the load between solar power, grid electricity, and EV charging needs.
4) Predictive maintenance: Advanced monitoring systems can predict potential issues or failures, allowing for proactive maintenance and minimizing downtime.
5) Energy efficiency optimization: By identifying energy consumption patterns, these systems can suggest ways to optimize energy usage and reduce waste.
6) Integration with smart grids: Energy monitoring systems can facilitate seamless integration with smart grids, enabling better management of energy distribution and consumption.
7) User awareness: These systems provide users with detailed insights into their energy consumption habits, promoting more conscious and efficient energy use.
8) Remote monitoring and control: IoT-based systems allow for remote monitoring and control of energy systems, enhancing convenience and responsiveness.
9) Data-driven decision making: The collected data can inform policy decisions, infrastructure planning, and future energy management strategies.
10) Cost savings: By optimizing energy usage and identifying inefficiencies, these systems can lead to significant cost savings for both individuals and organizations.

IV. THE DESING OF SMARTCHARGE SOLAR

The Smart Charge Solar system integrates solar energy, IoT technology, and electric vehicle (EV) monitoring. The design incorporates solar panels for energy generation, connected to a smart inverter and battery storage system. IoT sensors monitor solar production, battery status, and EV charging parameters. A central control unit processes this data, optimizing charging schedules based on solar availability and grid demand. The system includes a user interface, typically a mobile app, providing real-time information on charging status, energy production, and consumption. For EVs, smart charging stations are equipped with IoT-enabled meters to track charging rates and times. The entire system is connected to a cloud platform for data storage, analysis, and remote management. This design enables efficient use of solar energy for EV charging, reduces grid dependence, and provides users with detailed insights into their energy usage and vehicle charging patterns.

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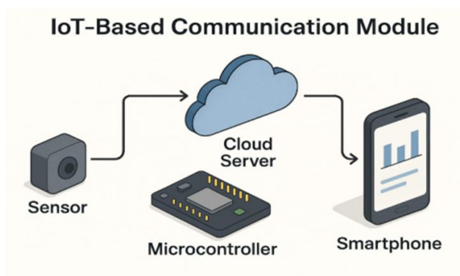
V. ENERGY OPTIMIZING SYSTEM

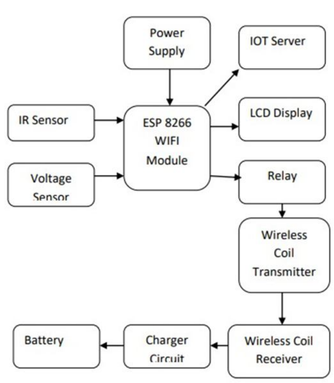
Energy monitoring systems play a crucial role in managing and optimizing energy consumption. In the context of smart charge solar and IoT-based EV monitoring systems, these systems offer several key benefits. Real-time data collection enables gathering of information on energy production, consumption, and storage, providing accurate and up-to-date insights. Performance analysis allows for evaluation of solar panel efficiency, battery health, and overall system performance, facilitating timely maintenance and optimization. Load balancing capabilities monitor energy usage patterns to balance the load between solar power, grid electricity, and EV charging, maximizing efficiency and minimizing costs. Predictive maintenance features can anticipate potential issues or failures enabling proactive maintenance and reducing downtime. These systems also promote user awareness by providing detailed insights into energy consumption patterns, fostering energy-conscious behavior. Additionally, they facilitate better integration of renewable energy sources with the existing power grid, supporting smart grid initiatives. Remote management capabilities allow users to access and control their energy systems from anywhere, while cost optimization features help identify areas for potential savings. Furthermore, these systems can track and report on the reduction of carbon emissions, helping users understand their environmental impact. Lastly, they assist in ensuring compliance with energy-related regulations and standards. Collectively, these features contribute to an optimized energy management system that enhances efficiency, reduces costs, and promotes sustainability.

VI. IoT-BASED COMMUNICATION MODULE



The IoT-based communication model for a smart charge solar EV monitoring system involves several interconnected components. At the core are sensors and devices that collect data from various points in the system, including solar panels, charging stations, and electric vehicles. These sensors continuously monitor parameters such as energy production, consumption, battery levels, and charging status. The collected data is then transmitted through a network of IoT devices using protocols like MQTT or CoAP, which are designed for efficient machine-to-machine communication. This data is sent to a central gateway or edge computing device that acts as an intermediary between the local network and the cloud. The gateway preprocesses the data, filtering out unnecessary information and ensuring data integrity. From here, the processed data is securely transmitted to a cloud-based platform using protocols like HTTPS or WebSocket. The cloud platform stores, analyses , and visualizes the data, employing advanced algorithms for predictive analytics and optimization. Users can access this information through web or mobile applications, allowing them to monitor and control their smart charge solar system remotely. The communication model also includes feedback loops, enabling the system to automatically adjust based on real-time data and user preferences, optimizing energy usage and charging schedules.

VII. BLOCK DIAGRAM



The block diagram shown in Figure [X] illustrates the overall system architecture of the proposed IoT-Based Wireless EV Charging and Monitoring System. The design is centered around the ESP8266 Wi-Fi module, which acts as the core controller responsible for data processing, communication, and system control.

A. Power Supply

The system is powered using a regulated DC power supply. It provides the necessary operating voltage to the ESP8266 module and all connected sensors and output components.

B. ESP8266 Wi-Fi Module

This is the heart of the system. It collects real-time data from the IR and voltage sensors, processes it, and communicates the results to the IoT server for remote monitoring. It also controls the output devices such as the LCD display, relay module, and wireless charging transmitter based on sensor feedback and programmed logic.

C. Sensors

IR Sensor: Used to detect the presence of the electric vehicle. When the EV is properly aligned with the charging setup, the sensor sends a signal to the ESP8266 to initiate charging.

Voltage Sensor: Continuously monitors the voltage level of the charging system or EV battery. This ensures safety and provides data for monitoring and analysis.

D. IoT Server

The ESP8266 transmits the collected data to a cloud-based IoT server (such as Blynk or Thing Speak). This allows users to access real-time charging information remotely through a web dashboard or mobile application.

E. LCD Display

A local LCD display is used to show real-time system information such as voltage, connection status, or charging state. This provides a quick view of system performance without requiring access to the cloud.

F. Relay

The relay module acts as a switch that controls the power supply to the wireless coil transmitter. It is activated or deactivated by the ESP8266 based on vehicle detection and voltage level.

G. Wireless Coil System

Wireless Coil Transmitter: Connected to the power circuit via the relay, this coil generates an alternating magnetic field for contactless power transfer.

Wireless Coil Receiver: Mounted on the EV, this coil captures the magnetic energy from the transmitter and converts it back to electrical energy.

H. Charger Circuit and Battery

The received power is regulated using a charger circuit to safely charge the EV's battery. The charger ensures the correct voltage and current levels are delivered to the battery for efficient and safe energy storage.

This system not only enables wireless EV charging, but also incorporates IoT-based monitoring, allowing users to track the charging process remotely. The use of sensors and automated control enhances safety, while the wireless design ensures user convenience and system flexibility.

VIII. HARDWARE AND SOFTWARE COMPONENTS

A. Hardware Components

The proposed IoT-based wireless EV charging and monitoring system, named Smart Charge Solar, comprises the following key hardware elements:

1) ESP8266 Wi-Fi Module: The ESP8266 is a low-cost microcontroller with built-in Wi-Fi capabilities. It serves as the central controller, managing sensor data, activating modules, and communicating with the IoT platform for real-time monitoring and control.

2) IR Sensor: The IR (Infrared) sensor is used to detect the presence of the electric vehicle. It ensures that charging is initiated only when the vehicle is properly aligned with the system.
3) Voltage Sensor: This sensor measures the voltage level of the battery or charging circuit and sends the data to the ESP8266. It helps in monitoring battery health and system safety.
4) Relay Module: The relay acts as an electronic switch, controlled by the ESP8266, to enable or disable the wireless charging transmitter. It ensures safe and automated charging operations.
5) Wireless Coil Transmitter and Receiver: The transmitter coil generates an alternating magnetic field to transfer energy wirelessly. The receiver coil, installed on the EV side, captures this energy and converts it into electrical energy for charging the battery.
6) Charger Circuit: The charger circuit regulates and converts the power received via wireless transmission into a suitable form for safe battery charging.
7) Battery: The battery stores the electrical energy received through wireless transmission and represents the energy storage of the EV in the prototype setup.
8) LCD Display: A liquid crystal display is used to show real-time parameters like battery voltage, system status, and connection confirmation.
9) Power Supply Unit: A regulated power supply is used to provide the required DC voltage to the ESP8266 module and other connected components.

B. *Software Components*

1) Arduino IDE: The Arduino Integrated Development Environment (IDE) is used to write, compile, and upload code to the ESP8266 module. The software is written in C/C++ and utilizes various libraries for sensor input, Wi-Fi connectivity, and display control.
2) IoT Platform (e.g., Blynk / Thing Speak / Firebase): A cloud-based IoT platform is used to receive data from the ESP8266 and present it in a user-friendly format. Users can remotely monitor voltage levels, battery charging status, and other system parameters via the platform's mobile or web dashboard.
3) Embedded C/C++ Code: Custom logic is implemented using C/C++ to handle sensor inputs, control the relay and display, and send data to the cloud. The code also includes safety features such as voltage threshold checks.
4) Mobile/Web Dashboard: The dashboard allows users to view the system’s performance in real-time. It provides an interface for remote monitoring and optionally, for controlling the system through manual inputs.

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Referenced Study: (Kumar et al., 2022)

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Referenced Study: (Sharma & Verma, 2021)

Referenced Study: (Patel et al., 2020)

IX. CONCLUSION

The proposed system, Smart Charge Solar, successfully integrates solar energy and IoT technology to create an efficient, eco-friendly, and smart EV charging and monitoring solution. By using real-time data collection and cloud-based monitoring, users can track energy consumption, charging performance, and solar contribution remotely. This reduces dependency on grid electricity and promotes the use of renewable energy.

The system is cost-effective, scalable, and user-friendly, making it suitable for both personal and small-scale commercial EV charging setups. Overall, it contributes to the development of sustainable and intelligent transportation infrastructure.

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Declarations
Consent to Publish declaration: Not applicable.
Consent to Participate declaration: Not applicable.
Ethics declaration: Not applicable.

Author Contributions:
Pradnya Pramod Narwade developed the system architecture, conducted the research, and drafted the manuscript. Prof. V. V. Kulkarni supervised the project, provided technical guidance, and reviewed the manuscript. All authors have read and approved the final version of the manuscript.
Competing Interests: The authors declare that they have no competing interests.