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Solar PV Charging Station for Electric Vehicles

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ABSTRACT

The project presents a solar-based electric vehicle (E-Vehicle) charging station that integrates intelligent control using infrared (IR) sensors and a nano controller for efficient and automated energy management. The system consists of two primary sections: the transmitter (TX) unit and the receiver (RX) unit. In the TX block diagram, a solar panel generates renewable energy, which is then routed through a booster circuit to step up the voltage. The boosted voltage is stabilized using a voltage regulator and supplied to a nano controller, which acts as the central processing unit. The system includes two IR sensors (IR Sensor 1 and IR Sensor 2) that detect the presence of vehicles at their respective charging ports. Upon detection, the nano controller activates Relay 1 or Relay 2 corresponding to Charging Port 1 or Charging Port 2, respectively. This enables a smart switching mechanism, ensuring power is only delivered when a vehicle is present, thereby improving efficiency and safety. Additionally, a voltage sensor continuously monitors the output voltage from the solar system and relays this information to the controller, which is then displayed on an LCD/Display unit for real-time monitoring. The RX block diagram, on the other hand, illustrates the receiver side where a regulated power supply energizes a nano controller. This controller processes input from its connected voltage sensor and displays the relevant data on an LCD display. This RX module can serve as a monitoring or feedback system to track the charging status or voltage levels remotely. Overall, this solar-powered EV charging station provides a sustainable and intelligent solution for modern transportation needs by leveraging renewable energy and automation, reducing dependency on traditional power grids and minimizing energy wastage.

Keywords: *LCD Interface, Firebase Integration, Power Supply (Solar), Motor Control Logic Tank Level Monitoring, Voltage Sensing Safety Measures (Buzzer Alerts,) IOT Dashboard and App Interface, Real-Time Feedback System*

I. INTRODUCTION

The electric vehicles (EVs) have created a significant demand for efficient, eco-friendly, and accessible charging infrastructure. Traditional EV charging stations often rely on grid electricity, which may be generated from non-renewable sources, defeating the purpose of promoting green transportation. In this context, the integration of renewable energy systems such as solar power into EV charging stations presents a sustainable and forward-thinking solution. This project introduces a solar-based electric vehicle charging station that harnesses the power of the sun to charge electric vehicles while implementing intelligent control features for optimized operation and energy management. The system is divided into two major sections: the Transmitter (TX) unit and the Receiver (RX) unit. The TX unit is the primary functional module that manages energy generation, distribution, and user interaction. A solar panel acts as the renewable energy source, capturing sunlight and converting it into electrical energy. Since the raw solar output may not meet the required voltage levels for efficient operation, a booster circuit is incorporated to step up the voltage. This is followed by a voltage regulator that ensures a constant and safe voltage level is maintained before supplying it to the nano controller, the brain of the system. The nano controller manages inputs from multiple sensors and components. Two infrared (IR) sensors are deployed near the charging ports to detect the presence of a vehicle. When IR Sensor 1 detects a vehicle, the controller activates Relay 1, which powers up Charging Port 1. Similarly, IR Sensor 2 controls Relay 2 and Charging Port. This ensures that the charging mechanism is responsive to actual demand, turning on the respective charging port only when a vehicle is present. This not only conserves energy but also enhances safety by eliminating the risk of exposed live terminals.

II. RESEARCH METHOD

The existing system for electric vehicle (EV) charging primarily relies on conventional grid electricity, which contributes to increased load on the utility grid and higher carbon emissions. Traditional EV charging stations often lack intelligent energy management, leading to inefficient power usage, continuous power supply regardless of vehicle presence, and minimal integration of renewable energy sources.

In such systems, the absence of automation or smart control mechanisms results in energy wastage and poses safety risks due to continuous live charging ports. Monitoring of charging status or energy utilization is typically manual or requires expensive infrastructure, making these systems less viable for decentralized or rural applications. Furthermore, these conventional setups do not incorporate vehicle detection features or power delivery optimization, and there's often no real-time feedback or display of system voltage, which limits their adaptability and user convenience. Maintenance and energy consumption tracking also remain manual or limited in scope, reducing the operational intelligence of the system.

The need for physical supervision increases labor and operational costs, while the lack of dynamic response to power availability further contributes to inefficiency. With limited or no use of solar energy, such systems depend heavily on non-renewable energy sources, undermining sustainability goals.

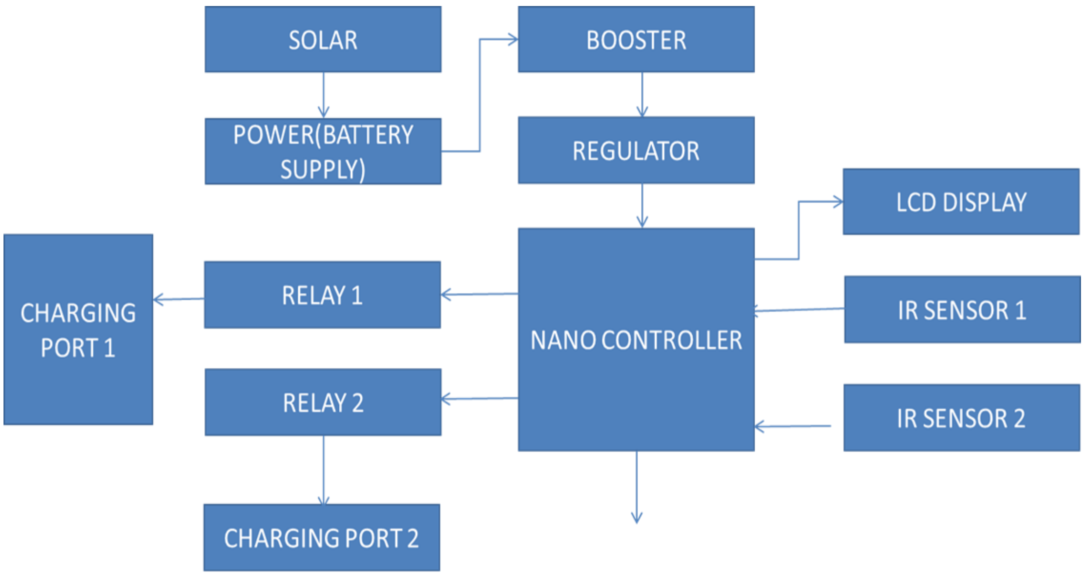
These limitations emphasize the growing need for an upgraded, eco-friendly, and smart EV charging infrastructure that can automatically manage energy flow, optimize power delivery, and provide real-time monitoring while utilizing renewable energy sources such as solar power.

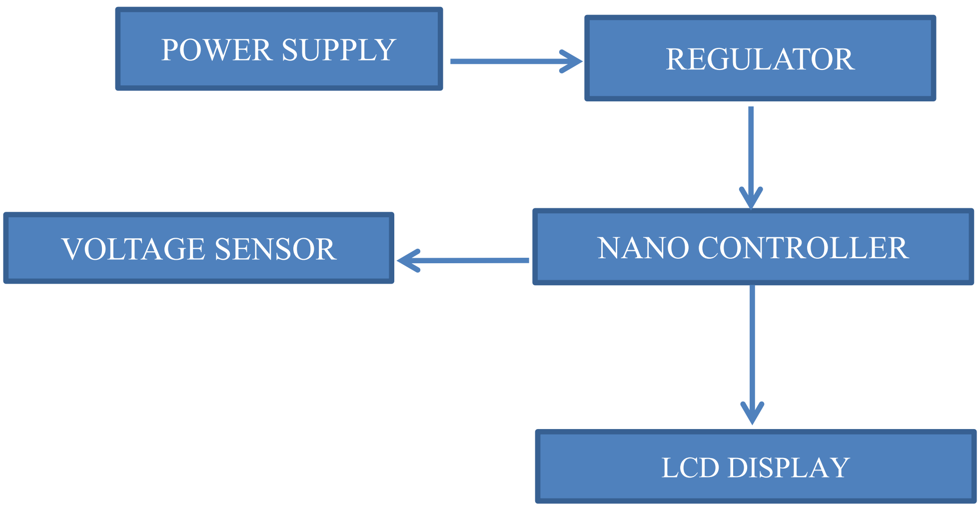
The current lack of integration between energy sensing, vehicle detection, and automated switching remains a critical gap that needs to be addressed to improve efficiency, reduce power losses, and support a greener transportation ecosystem

Literature Survey

S.No	TITLE	AUTHOR	CONTENT	YEAR
1	System design for a solar powered electric vehicle charging station	G.R. Chandra Mouli, P. Bauer, M. Zeman	The efficient utilization of solar energy using SLC. The presented SLC is closed loop controlled using FPGA Spartan 6 processor. The suggested SLC influences the quality of DC link voltage and transfer gain. The attained DC link voltage is three times greater than that of the voltage from the PV array. Also, the ripple content inthe DC link voltage is less than 1%.	2021
2	Types of Solar Cells and Application	Bagher1, Mirzaei Mahmoud Abadi Vahid2, Mirhabibi Mohsen1	The proposed charging station microgrid model for off-grid EV charging station with the integration of renewable energies such as solar photovoltaic, wind, Fuel Cell with provision for storage with mainly battery and optional storage with ultra-capacitors has been presented.	2022
3	Design of a New Type of Charging Station for Solar Electric Vehicle	Huaizhong Chen	It indicated a benefit to the campus for such a structure and also room for improvement on other existing charging stations. Other stations the team found were quite expensive to build. Additionally, solar designs and innovations are rapidly advancing which could contribute to a more efficient charging station.	2020

Block Diagram





III. Proposed Topology

The proposed system presents a solar-powered electric vehicle (EV) charging station integrated with intelligent control mechanisms to ensure efficient, safe, and sustainable energy management. Designed with two primary sections the transmitter (TX) and receiver (RX) units this system leverages renewable solar energy as its core power source. The TX unit is equipped with a solar panel that captures sunlight and generates DC electricity. To enhance utility, this energy is passed through a booster circuit that steps up the voltage to a usable level. Following this, a voltage regulator ensures the output remains stable and consistent to protect downstream electronics. Central to this design is a Nano microcontroller that serves as the control hub. Connected to the controller are two IR sensors IR Sensor 1 and IR Sensor 2 strategically placed at Charging Port 1 and Charging Port 2, respectively. These sensors detect the presence of a vehicle at the charging ports. Once a vehicle is detected at either port, the Nano controller intelligently activates Relay 1 or Relay 2, thereby powering the respective charging port only when necessary. This smart switching mechanism optimizes energy use, prevents wastage, and enhances operational safety by ensuring that electricity flows only in the presence of a vehicle. A voltage sensor is included to monitor the real-time output from the solar system, feeding continuous data to the controller. The collected voltage data is then displayed on an LCD unit, allowing users and operators to visually monitor charging conditions and system status. The RX unit, meanwhile, functions as a remote feedback and monitoring system. Powered by a regulated supply, this unit hosts another Nano microcontroller interfaced with a voltage sensor and LCD display. It receives input from the voltage sensor and presents live voltage readings, which can be useful for diagnostics, monitoring, or display at a control station. By dividing control and monitoring into transmitter and receiver sections, the system facilitates modular design and potential scalability.

Advantages

- The proposed solar-based electric vehicle (EV) charging station offers a wide range of advantages that contribute to environmental sustainability, energy efficiency, and user convenience.
- One of the most significant benefits is the utilization of solar energy, a renewable and clean power source, which reduces dependence on non-renewable fossil fuels and helps lower greenhouse gas emissions.
- This contributes to a cleaner environment and aligns with global efforts toward sustainable development. The system's intelligent control mechanism, enabled by a Nano microcontroller, ensures optimal energy usage by delivering power only when an EV is detected at the charging port.
- This smart switching mechanism minimizes energy wastage and prevents idle power consumption, enhancing overall efficiency.
- The integration of IR sensors for vehicle detection adds an automated layer of safety, ensuring that power is supplied only when necessary, reducing the risks associated with unattended electrical flow.
- The dual-port design allows for simultaneous charging of two vehicles, increasing station utility and reducing wait times for users.
- The inclusion of a booster circuit and voltage regulator ensures that the energy generated from the solar panel is stepped up and stabilized before reaching critical components, protecting the electronics from voltage fluctuations and extending the system's lifespan.
- Real-time monitoring through voltage sensors and LCD displays at both the transmitter and receiver units offers transparency, allowing users and operators to keep track of power generation and consumption instantly.

Disadvantages

- The current electric vehicle (EV) charging infrastructure suffers from multiple disadvantages that hinder its efficiency, scalability, and sustainability. One of the primary drawbacks is its reliance on conventional grid electricity, which increases dependency on fossil fuels and contributes to higher carbon emissions.

- This undermines the environmental benefits of using electric vehicles. Additionally, most existing systems operate without any smart control mechanisms, meaning power is constantly supplied to charging ports regardless of whether a vehicle is connected.
- This leads to significant energy wastage and potential safety hazards, such as short circuits or overheating. The absence of vehicle detection systems means there's no automated control to enable or disable power flow based on real-time need.
- Monitoring is often manual or limited, making it difficult to track energy consumption or detect faults in a timely manner. This lack of real-time data reduces the system's responsiveness and operational intelligence. Furthermore, there is minimal or no integration of renewable energy sources like solar power, resulting in high operational costs and poor sustainability.
- These systems often lack modularity and are not easily adaptable for use in remote or rural areas where grid access is limited. They require continuous human supervision, which increases maintenance costs and reduces convenience. In addition, the inability to dynamically regulate voltage based on load conditions can lead to inefficient charging and reduced battery life for EVs.
- Conventional systems typically do not include user-friendly interfaces or displays, leaving users without immediate feedback on charging status or voltage levels. This lack of transparency can result in user dissatisfaction and improper usage.

Hardware view

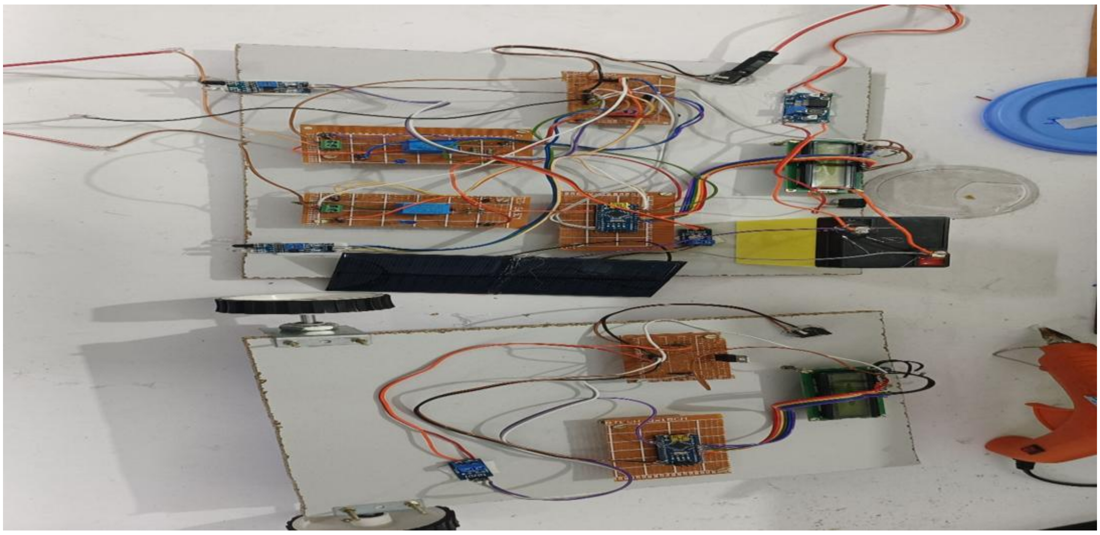


Fig:3. Hardware view

IV. RESULTS AND DISCUSSION

The implementation of the proposed solar-based electric vehicle (EV) charging station demonstrated successful integration of renewable energy with intelligent automation for efficient energy management. The system effectively generated and utilized solar power to charge EVs through two independent charging ports, activated only upon vehicle detection using IR sensors. The Nano microcontroller accurately processed sensor inputs and controlled relays to ensure that power was delivered only when required, thereby optimizing energy usage and improving operational safety. The voltage booster and regulator maintained a stable output, ensuring consistent performance and protection of electronic components. Real-time voltage monitoring was successfully displayed on the LCD screens at both the transmitter and receiver units, providing clear and instant feedback on system performance. The RX unit operated effectively as a remote monitoring module, accurately reflecting voltage conditions and supporting system transparency. Overall, the project achieved its objective of creating a self-sustained, automated, and eco-friendly EV charging solution, demonstrating strong potential for deployment in residential, commercial, and off-grid applications.

V. CONCLUSION

In conclusion, the developed solar-based electric vehicle (EV) charging station successfully combines renewable energy with intelligent automation to deliver a sustainable and efficient charging solution. By utilizing solar power as the primary energy source, the system significantly reduces reliance on traditional power grids and minimizes environmental impact. The integration of a Nano microcontroller with IR sensors and relays enables smart energy management by ensuring that power is supplied only when an EV is present, thereby reducing energy wastage and enhancing operational safety. The inclusion of voltage sensors and LCD displays provides real-time monitoring, improving system transparency and user awareness. The modular design featuring transmitter and receiver units supports scalability and remote monitoring, making it suitable for various applications, including urban, rural, and off-grid environments. This project not only promotes the adoption of green technology but also serves as a practical model for future smart energy systems. Ultimately, the system offers a reliable, eco-friendly, and cost-effective solution to meet the growing demand for sustainable EV infrastructure

Declaration by Authors

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Conflict of Interest: No conflicts of interest declared.

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