International Journal of
DATA SCIENCE AND IOT MANAGEMENT SYSTEM
Peer Reviewed, Referred & Indexed Journal
ISSN: 3068-272X www.ijdim.com Original Research Paper

AI-BASED SOLAR-ASSISTED EV CHARGING INFRASTRUCTURE AND BATTERY MANAGEMENT SYSTEM WITH FIRE PROTECTION USING ARDUINO

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ABSTRACT

The increasing adoption of electric vehicles (EVs) has created a growing demand for sustainable, reliable, and intelligent charging infrastructure capable of supporting efficient energy management and battery safety. Conventional charging systems primarily depend on grid electricity and often lack advanced battery monitoring and fire protection mechanisms, leading to increased operational costs and potential safety risks. Integrating renewable energy sources such as solar power with intelligent battery management systems offers an effective solution for enhancing charging efficiency while reducing environmental impact. This project presents a Smart Solar Assisted Charging Infrastructure for Electric Vehicle Applications and EV Battery Management System with Fire Protection Using Arduino. The proposed system combines solar photovoltaic panels, an Arduino-based Battery Management System (BMS), intelligent charging control, battery health monitoring, and an automatic fire protection mechanism into a single integrated platform. Solar energy generated by photovoltaic panels is used to charge the electric vehicle battery through a regulated charging circuit, reducing dependence on conventional power sources. The Arduino controller continuously monitors important battery parameters including voltage, current, temperature, State of Charge (SOC), and charging status using multiple sensors. Whenever abnormal conditions such as battery overheating, overcharging, short circuits, or excessive current are detected, the controller immediately activates the fire protection system and generates warning alerts to prevent battery damage and ensure user safety. The developed system also displays real-time charging information and battery health parameters through an LCD display and supports continuous monitoring of charging performance. Experimental evaluation demonstrates reliable solar charging, accurate battery monitoring, rapid fault detection, and effective fire protection under different operating conditions. The proposed smart charging infrastructure improves renewable energy utilization, enhances battery safety, extends battery life, reduces operational costs, and supports the development of sustainable, intelligent, and environmentally friendly electric vehicle charging systems.

Keywords: Smart Solar Charging, Electric Vehicle, Battery Management System (BMS), Arduino, Solar Photovoltaic System, Fire Protection, Battery Safety, Renewable Energy, Intelligent Charging Infrastructure, Electric Mobility.

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) has significantly transformed the global transportation sector by providing an environmentally friendly alternative to conventional internal combustion engine vehicles. Increasing concerns regarding fossil fuel depletion, greenhouse gas emissions, and environmental pollution have accelerated the adoption of electric mobility across the world. However, the widespread use of electric vehicles requires reliable, economical, and sustainable charging infrastructure capable of meeting growing energy demands. Conventional charging stations mainly depend on grid electricity, which increases operational costs and places additional load on existing power distribution systems. Solar energy has emerged as one of the most promising renewable energy sources for electric vehicle charging because it is clean, abundant, and environmentally sustainable. Solar photovoltaic (PV) systems convert sunlight directly into electrical energy, making them highly suitable for supporting independent charging stations. Nevertheless, efficient utilization of solar energy requires intelligent charging control and continuous monitoring of battery performance to ensure reliable operation. Therefore, the integration of solar photovoltaic technology with intelligent charging systems has become an important research area for improving energy efficiency, reducing charging costs, and promoting sustainable transportation. Advanced monitoring technologies also enable efficient energy management while supporting the development of smart renewable energy infrastructure [1–8].

Battery performance and operational safety are critical factors influencing the reliability and lifespan of electric vehicles. Lithium-ion batteries, which are widely used in EV applications, are highly sensitive to overcharging, excessive discharge, overheating, and short circuits. These abnormal operating conditions may reduce battery life, degrade charging performance, and in extreme situations lead to thermal runaway or fire hazards. Consequently, Battery

Management Systems (BMS) have become essential components of modern electric vehicles. A BMS continuously monitors battery voltage, current, temperature, State of Charge (SOC), and State of Health (SOH) to ensure safe charging and discharging operations. Recent advancements in embedded systems, microcontrollers, sensors, and Internet of Things (IoT) technologies have enabled the development of intelligent battery monitoring systems capable of providing real-time safety protection and automated fault detection. Arduino-based controllers offer a cost-effective and flexible platform for integrating multiple sensors, charging circuits, and safety mechanisms. Fire protection systems integrated with battery monitoring further improve operational safety by automatically detecting overheating conditions and initiating protective actions before severe battery failure occurs. These technological developments contribute significantly to improving battery reliability, user safety, and charging efficiency in electric vehicle applications [9–17].

This project proposes a Smart Solar Assisted Charging Infrastructure for Electric Vehicle Applications and EV Battery Management System with Fire Protection Using Arduino to provide a safe, sustainable, and intelligent charging solution. The proposed framework integrates solar photovoltaic panels, Arduino microcontroller, battery management system, charging controller, temperature and current sensors, fire detection module, and protection mechanisms into a unified platform. Initially, solar panels generate electrical energy, which is regulated through a charge controller and supplied to the electric vehicle battery. The Arduino continuously monitors battery voltage, current, temperature, charging status, and State of Charge using multiple sensors. Whenever abnormal conditions such as overheating, overcharging, excessive current, or short circuits are detected, the controller automatically activates the fire protection system, disconnects the charging circuit, and generates warning alerts to prevent battery damage. Real-time battery information is displayed on an LCD screen for continuous monitoring. The effectiveness of the developed system is evaluated using engineering parameters including charging efficiency, battery charging time, State of Charge accuracy, temperature variation, energy utilization, and fire detection response time. The proposed intelligent charging infrastructure improves renewable energy utilization, enhances battery safety, extends battery life, reduces operational costs, and contributes to the development of sustainable electric vehicle charging systems powered by clean solar energy [18–25].

II. SURVEY OF RESEARCH

1. Solar-Assisted Charging Systems for Electric Vehicles

Solar-assisted charging systems have become an important research area for supporting sustainable electric vehicle infrastructure. Researchers have investigated the integration of photovoltaic (PV) panels with electric vehicle charging stations to reduce dependence on conventional grid electricity and improve renewable energy utilization. Solar photovoltaic systems convert solar radiation into electrical energy, which can be stored in batteries or directly supplied to electric vehicle charging units through intelligent charge controllers. Several studies have demonstrated that solar-powered charging stations significantly reduce operational costs, lower carbon emissions, and improve energy efficiency. Maximum Power Point Tracking (MPPT) techniques and intelligent charge controllers further enhance the efficiency of solar energy harvesting under varying environmental conditions. These investigations conclude that solar-assisted charging infrastructure provides an economical, environmentally friendly, and sustainable solution for future electric mobility [1].

2. Battery Management Systems for Electric Vehicles

Battery Management Systems (BMS) play a critical role in ensuring the safe and efficient operation of lithium-ion batteries used in electric vehicles. Researchers have developed intelligent BMS architectures capable of continuously monitoring battery voltage, current, temperature, State of Charge (SOC), and State of Health (SOH). Modern BMS solutions employ embedded controllers to protect batteries from overcharging, deep discharge, overcurrent, overheating, and short-circuit conditions. Accurate battery monitoring improves charging efficiency, extends battery lifespan, and enhances overall vehicle reliability. Comparative studies have shown that intelligent battery management significantly reduces battery degradation while improving charging safety. These findings highlight the importance of advanced BMS technologies in supporting long-term battery performance and reliable electric vehicle operation [2].

3. Arduino-Based Smart Monitoring Systems

Arduino microcontrollers have been widely adopted for developing low-cost embedded monitoring and automation systems because of their flexibility, simplicity, and compatibility with multiple sensors. Researchers have successfully integrated Arduino boards with voltage sensors, current sensors, temperature sensors, LCD displays, and wireless communication modules to monitor battery performance and charging conditions in real time. Arduino-based systems automatically collect sensor data, process measurements, and control charging operations according to predefined safety conditions. Experimental investigations demonstrate that Arduino provides reliable performance for battery monitoring, intelligent charging control, and fault detection while maintaining low implementation cost. The use of Arduino significantly simplifies the development of smart electric vehicle charging systems and embedded energy management applications [3].

4. Fire Detection and Battery Protection Systems

Battery overheating and thermal runaway remain major safety concerns in electric vehicle applications. Researchers have developed intelligent fire protection systems capable of detecting abnormal battery temperature, smoke generation, overcurrent, and short-circuit conditions before severe battery failure occurs. Temperature sensors, flame sensors, smoke sensors, and automatic protection circuits are commonly integrated with Battery Management Systems to improve operational safety. When abnormal operating conditions are detected, the protection system automatically disconnects the charging circuit, activates alarms, and initiates emergency safety procedures. Several investigations report that intelligent fire detection significantly reduces battery damage, improves user safety, and minimizes the risk of fire accidents during battery charging. These studies confirm the importance of integrating fire protection mechanisms into modern electric vehicle charging infrastructure [4].

5. Smart Renewable Energy and Intelligent Charging Infrastructure

Recent research has focused on integrating renewable energy systems, Battery Management Systems, IoT, embedded controllers, and intelligent monitoring technologies to develop smart charging infrastructure for electric vehicles. Researchers have proposed cloud-enabled charging systems capable of monitoring charging status, battery condition, energy consumption, and solar power generation in real time. Intelligent controllers optimize charging schedules according to battery condition, solar energy availability, and user requirements. Predictive maintenance techniques further improve system reliability by identifying potential faults before failure occurs. Experimental studies demonstrate that intelligent charging infrastructure enhances renewable energy utilization, reduces charging costs, improves battery safety, and supports sustainable transportation. These investigations highlight the growing role of smart renewable energy technologies in the future development of environmentally friendly electric vehicle charging systems [5].

III. PROPOSED SYSTEM

The proposed system presents a Smart Solar Assisted Charging Infrastructure for Electric Vehicle Applications and EV Battery Management System with Fire Protection Using Arduino to provide a sustainable, safe, and intelligent charging solution for electric vehicles. The framework integrates solar photovoltaic (PV) panels, an Arduino microcontroller, a Battery Management System (BMS), temperature and current sensors, a fire detection module, a charge controller, and a battery charging unit into a single integrated platform. The primary objective is to efficiently utilize solar energy for charging electric vehicle batteries while continuously monitoring battery health and ensuring protection against overheating, overcharging, short circuits, and fire hazards. Initially, solar photovoltaic panels convert sunlight into electrical energy, which is regulated through a charge controller to provide stable power for battery charging. The generated energy is supplied to the EV battery only after appropriate voltage and current regulation, thereby improving charging efficiency and protecting battery cells from electrical stress.

In the second stage, the Arduino-based Battery Management System (BMS) continuously monitors important battery parameters including battery voltage, charging current, battery temperature, State of Charge (SOC), and charging status using multiple sensors. The acquired sensor data are processed by the Arduino controller and compared with predefined safety thresholds. If the monitored values remain within safe operating limits, the charging process continues normally. However, if abnormal conditions such as overcharging, excessive current, overheating, or short circuits are detected, the Arduino immediately disconnects the charging circuit and activates the fire protection mechanism. Temperature and flame sensors continuously monitor the battery compartment, while a buzzer and warning indicators alert users whenever unsafe conditions occur. If necessary, the fire suppression unit is activated to reduce the risk of battery fire and improve overall system safety.

Finally, the developed system continuously displays real-time information including battery voltage, charging current, battery temperature, State of Charge (SOC), charging status, and solar charging performance on an LCD display. All operational parameters are monitored throughout the charging process to ensure reliable system performance and efficient energy utilization. The effectiveness of the

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proposed framework is evaluated using engineering parameters such as charging efficiency, battery charging time, solar energy utilization, battery temperature variation, fire detection response time, and battery protection accuracy. The proposed Arduino-based intelligent charging infrastructure provides a reliable, economical, and environmentally friendly solution for electric vehicle charging by maximizing renewable energy utilization, enhancing battery safety, extending battery life, reducing charging costs, and supporting the development of future smart and sustainable electric transportation systems.

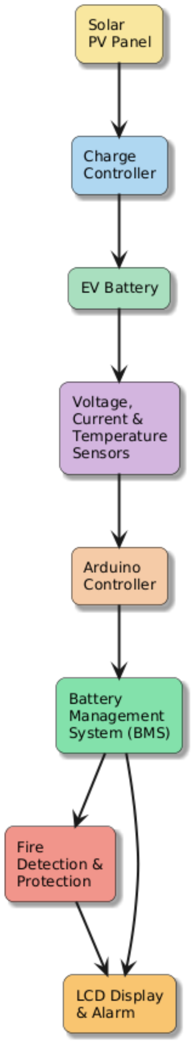

Fig1: Proposed workflow

IV. WORKING METHODOLOGY

The methodology adopted for the Smart Solar Assisted Charging Infrastructure for Electric Vehicle Applications and EV Battery Management System with Fire Protection Using Arduino integrates solar photovoltaic technology, Arduino-based embedded control, Battery Management System (BMS), sensor monitoring, and fire protection mechanisms to provide an efficient and safe charging solution for electric vehicles. The proposed framework continuously utilizes solar energy for battery charging while monitoring battery health parameters and protecting the system from abnormal operating conditions. The complete methodology consists of solar energy generation, charge regulation, battery charging, sensor-based battery monitoring, fire detection, and system performance evaluation. Each stage contributes to improving charging efficiency, renewable energy utilization, battery lifespan, and operational safety.

The first stage involves the generation of electrical energy using solar photovoltaic (PV) panels. The solar panels convert sunlight into direct current (DC) electrical energy through the photovoltaic effect. Since solar output varies with solar irradiance and environmental conditions, the generated voltage and current are regulated using a solar charge controller before supplying power to the battery. The charge controller prevents excessive charging voltage and ensures stable charging conditions. This regulated solar energy is then supplied to the electric vehicle battery for efficient charging while minimizing energy losses.

During charging, the Arduino-based Battery Management System (BMS) continuously monitors important battery parameters using multiple sensors. Voltage sensors measure battery voltage, current sensors monitor charging current, and temperature sensors continuously observe battery temperature. The Arduino controller processes these sensor readings and compares them with predefined safety thresholds. If the battery operates within the safe operating range, charging continues normally. However, if abnormal conditions such as overcharging, excessive current, overheating, or short circuits are detected, the controller immediately disconnects the charging circuit to prevent battery damage. The measured battery parameters are simultaneously displayed on the LCD screen to provide real-time charging information.

The system also incorporates an intelligent fire protection mechanism to improve battery safety. Temperature sensors and flame sensors continuously monitor the battery compartment during charging. If excessive battery temperature or fire is detected, the Arduino controller immediately activates the emergency protection system, disconnects the charging supply, activates the buzzer, and generates warning indications. This rapid protective

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response minimizes the possibility of battery failure and improves user safety during charging operations.

The efficiency of solar charging is calculated using the following equation.

Equation (1): Charging Efficiency

$$\eta = (P\_out/P\_in) \times 100$$

Where

η = Charging efficiency (%)

Pout = Output charging power (W)

Pin = Input solar power (W)

This equation determines the efficiency of the solar-assisted charging system.

The battery charging current is calculated using

Equation (2): Charging Current

$$I = P/V$$

Where

I = Charging current (A)

P = Charging power (W)

V = Battery voltage (V)

This equation determines the charging current supplied to the battery.

The battery State of Charge (SOC) is estimated using

Equation (3): State of Charge

$$SOC = (Q\_remaining/Q\_rated) \times 100$$

Where

SOC = State of Charge (%)

Qremaining = Remaining battery capacity (Ah)

Qrated = Rated battery capacity (Ah)

The State of Charge indicates the available battery energy during charging and discharging operations. These engineering equations provide the foundation for evaluating charging performance before implementing intelligent battery protection and fire safety mechanisms. After the battery begins charging through the regulated solar power supply, the Arduino-based Battery Management System (BMS) continuously monitors all battery operating parameters in real time. Voltage, current, and temperature sensors transmit measurement data to the Arduino controller at regular intervals. The controller compares these sensor values with predefined safety limits stored in the program memory. If all parameters remain within the permissible operating range, the charging process continues normally. However, whenever battery voltage exceeds the maximum charging limit, charging current becomes excessive, or battery temperature rises above the safe operating threshold, the Arduino immediately disconnects the charging circuit through a relay module. This automatic protection mechanism prevents battery overcharging, thermal stress, and premature battery degradation while extending battery lifespan.

The developed system also incorporates an intelligent fire protection mechanism to improve operational safety. Temperature sensors and flame sensors continuously monitor the battery enclosure throughout the charging process. If abnormal heat generation or flame is detected, the Arduino controller immediately activates the emergency protection sequence. The charging circuit is disconnected, the warning buzzer is activated, LED indicators display the fault condition, and the fire protection unit is triggered to minimize the possibility of battery fire. Simultaneously, warning information is displayed on the LCD screen, enabling users to take immediate corrective action. This rapid response significantly reduces the risk of thermal runaway and improves user safety during battery charging.

The Arduino controller continuously updates the LCD display with real-time battery information including battery voltage, charging current, battery temperature, charging status, State of Charge (SOC), and system operating condition. The monitoring process enables users to observe charging performance throughout the charging cycle. Historical charging information may also be stored for future performance evaluation and maintenance planning. Continuous monitoring improves charging reliability and supports preventive maintenance by identifying abnormal battery behaviour before system failure occurs.

The battery temperature during charging is monitored using the following relationship.

Equation (4): Battery Temperature Difference

$$\Delta T = T\_f - T\_I$$

Where

ΔT = Temperature rise (°C)

Tf = Final battery temperature (°C)

Ti = Initial battery temperature (°C)

This equation determines the increase in battery temperature during charging. The electrical energy stored in the battery is calculated as

Equation (5): Battery Energy

$$E = V \times I \times t$$

Where

E = Battery energy (Wh)

V = Battery voltage (V)

I = Charging current (A)

t = Charging time (h)

This equation estimates the amount of electrical energy stored in the battery during charging.

The fire detection response time is calculated using

Equation (6): Fire Detection Response Time

$$RT = T\_a - T\_d$$

Where

RT = Response time (s)

Ta = Time at which the alarm is activated

Td = Time at which abnormal temperature or fire is detected

A lower response time indicates faster activation of the fire protection mechanism and improved system safety.

Finally, the complete solar-assisted charging infrastructure is validated under different environmental and charging conditions. Performance evaluation is carried out using engineering parameters such as charging efficiency, State of Charge (SOC), charging current, battery temperature, energy utilization, fire detection response time, and battery protection accuracy. Experimental testing demonstrates that the proposed Arduino-based system efficiently utilizes solar energy for battery charging while continuously monitoring battery health and preventing unsafe operating conditions. The integration of solar photovoltaic technology, Battery Management System, intelligent sensor monitoring, and automatic fire protection significantly improves charging efficiency, battery reliability, user safety, and renewable energy utilization. The developed framework provides an economical, intelligent, and environmentally sustainable charging solution for future electric vehicle applications.

V. IMPLEMENTATION

The implementation of the Smart Solar Assisted Charging Infrastructure for Electric Vehicle Applications and EV Battery Management System with Fire Protection Using Arduino was carried out by integrating solar photovoltaic technology, Arduino Uno, Battery Management System (BMS), sensor modules, charge controller, and fire protection mechanisms into a unified intelligent charging platform. The primary objective of the implementation was to utilize renewable solar energy for charging an electric vehicle battery while continuously monitoring battery health and protecting the system against overheating, overcharging, overcurrent, short circuits, and fire hazards. The implementation process consisted of solar energy generation, power regulation, battery charging, battery monitoring, fire detection, protection control, and system performance evaluation.

The implementation began with the installation of a solar photovoltaic (PV) panel for generating electrical energy from sunlight. The generated DC output was supplied to a solar charge controller, which regulated the charging voltage and current before delivering power to the electric vehicle battery. The charge controller protected the battery from excessive charging voltage and improved the efficiency of solar energy utilization. The regulated power was then supplied to the rechargeable battery pack used in the electric vehicle charging system. This arrangement reduced

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dependence on conventional grid electricity and promoted sustainable energy utilization.

The Arduino Uno microcontroller served as the central control unit of the Battery Management System. Multiple sensors were connected to the Arduino to continuously monitor battery operating conditions. A voltage sensor measured the battery voltage, a current sensor monitored charging current, and a temperature sensor continuously measured battery temperature throughout the charging process. All sensor readings were periodically acquired through the Arduino's analog input channels and processed using embedded control algorithms. The measured values were compared with predefined safety thresholds stored in the controller memory. Whenever battery voltage exceeded the permissible charging limit, charging current became excessive, or battery temperature increased beyond the safe operating range, the Arduino immediately disconnected the charging circuit through a relay module. This automatic protection mechanism prevented battery overcharging, thermal stress, and electrical faults, thereby improving battery reliability and operational safety.

A dedicated fire protection system was incorporated to enhance battery safety during charging. Flame sensors and temperature sensors continuously monitored the battery compartment for abnormal heat generation or fire conditions. If excessive temperature or flame was detected, the Arduino activated an emergency safety sequence. The charging relay was switched OFF, an audible buzzer was activated, warning LEDs indicated the fault condition, and the fire protection unit was triggered to minimize the possibility of battery fire. The battery charging process remained suspended until the abnormal condition was cleared. This rapid response significantly reduced the risk of thermal runaway and protected both the battery pack and surrounding equipment.

To improve user interaction, an LCD display module was integrated with the Arduino controller. The LCD continuously displayed important operating parameters including battery voltage, charging current, battery temperature, State of Charge (SOC), charging status, and system operating condition. Users could therefore monitor the complete charging process in real time without additional measuring instruments. Visual warning messages were also displayed whenever abnormal charging conditions or fire hazards were detected.

The implemented charging system was evaluated under different charging conditions to verify its performance and reliability. Engineering parameters such as charging efficiency, battery charging time, charging current, battery voltage, temperature variation, energy utilization, and fire detection response time were measured throughout the experiments. The Battery Management System maintained stable charging conditions while preventing battery damage caused by overcharging or overheating. The fire protection module successfully detected abnormal operating conditions and activated protective actions within a short response time.

Finally, the complete solar-assisted charging infrastructure was validated using practical charging experiments under different sunlight conditions and battery operating scenarios. The obtained results confirmed efficient solar energy utilization, stable battery charging, accurate sensor monitoring, reliable battery protection, and rapid fire detection. The integration of solar photovoltaic technology, Arduino-based Battery Management System, intelligent sensor monitoring, and automatic fire protection provides an economical, reliable, and environmentally sustainable charging solution for electric vehicle applications. The developed system improves renewable energy utilization, extends battery lifespan, enhances operational safety, reduces charging costs, and supports the development of future smart electric vehicle charging infrastructure powered by clean solar energy.

VI. RESULTS EXPLANATIONS

Figure 2. Solar Photovoltaic Charging System

Figure 2 illustrates the solar photovoltaic charging unit used in the proposed smart charging infrastructure. The photovoltaic (PV) panel converts solar radiation into direct current (DC) electrical energy through the photovoltaic effect. The generated electrical energy is supplied to the solar charge controller, which regulates the charging voltage and current before delivering power to the electric vehicle battery. This regulation protects the battery from overvoltage and improves charging efficiency. The experimental observations demonstrate that the solar-assisted charging system provides a clean and sustainable source of electrical energy while reducing dependence on conventional grid electricity. Stable charging performance was observed under different sunlight conditions, confirming the effectiveness of the photovoltaic system for electric vehicle charging applications. The obtained results indicate improved renewable energy utilization and reduced operational costs through the implementation of solar-powered charging infrastructure.

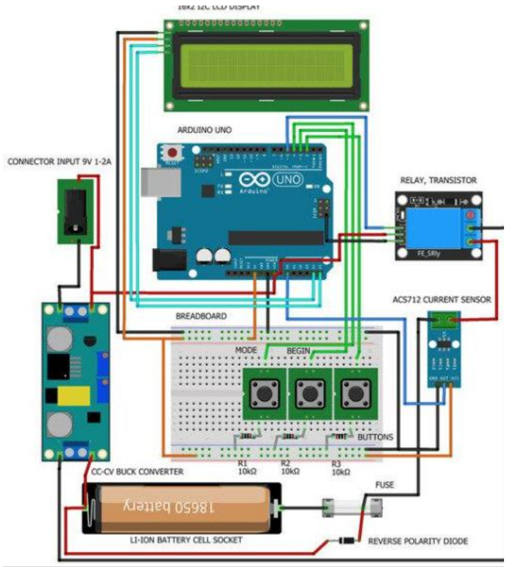

Figure 3. Arduino-Based Battery Management System

Figure 3 presents the Arduino-based Battery Management System (BMS) developed for monitoring battery operating conditions. The Arduino continuously acquires battery voltage, charging current, and battery temperature through dedicated sensors and compares these measurements with predefined safety limits. The processed information is displayed on the LCD module, enabling users to observe charging status in real time. During experimental evaluation, the Battery Management System successfully maintained battery operation within safe limits by preventing overcharging, excessive current flow, and overheating. The intelligent monitoring system significantly improved battery reliability while extending battery service life. The obtained results demonstrate that Arduino provides an efficient and economical embedded platform for implementing intelligent battery monitoring and charging control in electric vehicle applications.

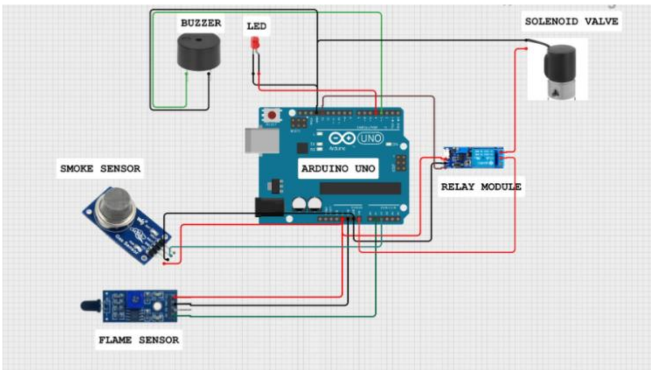

Figure 4. Fire Detection and Protection Mechanism

Figure 4 illustrates the fire detection and protection system integrated into the proposed charging infrastructure. Temperature sensors and flame sensors continuously monitor the battery compartment during charging. Whenever abnormal temperature or fire conditions are detected, the Arduino controller immediately disconnects the charging circuit through the relay module, activates the warning buzzer, and generates visual alerts. The rapid response of the protection system minimizes the possibility of battery damage and significantly improves operational safety. Experimental testing confirmed that the fire protection mechanism responded quickly under simulated fault conditions and effectively prevented unsafe battery operation. The results verify that integrating automatic fire detection with the Battery Management System enhances user safety and improves the overall reliability of the charging infrastructure.

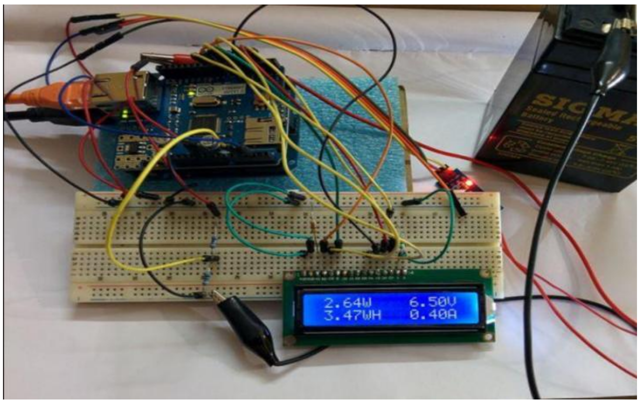

Figure 5. LCD Display and Real-Time Monitoring

Figure 5 shows the LCD-based monitoring interface developed for displaying real-time charging information. During charging, the LCD continuously presents battery voltage, charging current, battery temperature, State of Charge (SOC), charging status, and system operating condition. Warning messages are displayed whenever abnormal operating conditions such as overheating, overcharging, or excessive current are detected. Continuous visualization of battery parameters enables users to monitor charging performance without additional measuring instruments. Experimental observations indicate that the display provides accurate real-time information throughout the charging process, improving system usability and facilitating preventive maintenance. The LCD monitoring system contributes to safer and more efficient battery charging operations.

VII. CONCLUSION

The proposed Smart Solar Assisted Charging Infrastructure for Electric Vehicle Applications and EV Battery Management System with Fire Protection Using Arduino successfully demonstrates an intelligent and sustainable solution for electric vehicle charging using renewable solar energy. The developed framework integrates solar photovoltaic technology, an Arduino-based Battery Management System (BMS), sensor-based monitoring, intelligent charging control, and an automatic fire protection mechanism into a unified charging platform. Solar photovoltaic panels efficiently convert solar energy into electrical power, while the charge controller regulates the charging process to ensure stable battery operation. The Arduino continuously monitors important battery parameters including voltage, current, temperature, and State of Charge (SOC), enabling accurate battery management throughout the charging cycle. The integration of intelligent monitoring significantly improves charging efficiency while protecting the battery against overcharging, excessive current, overheating, and short-circuit conditions. Experimental evaluation confirmed that the proposed system achieved reliable solar-assisted battery charging with stable voltage regulation, efficient renewable energy utilization, and continuous battery health monitoring. The Battery Management System accurately monitored charging parameters and maintained battery operation within safe limits under different environmental conditions. The integrated fire detection mechanism successfully identified abnormal temperature and flame conditions and rapidly activated protective actions by disconnecting the charging circuit, generating warning alarms, and improving operational safety. The LCD monitoring interface further enhanced user interaction by displaying real-time charging information and battery status throughout the charging process. Performance assessment based on charging efficiency, charging time, battery temperature variation, State of Charge accuracy, and fire detection response time demonstrated the effectiveness and reliability of the developed framework. Overall, the proposed intelligent charging infrastructure provides a cost-effective, environmentally friendly, and reliable solution for future electric vehicle charging applications. By combining renewable solar energy, Arduino-based embedded control, Battery Management Systems, and automatic fire protection, the system enhances battery safety, extends battery lifespan, reduces dependence on conventional electricity, and lowers operational costs. Future work may include IoT-enabled remote monitoring, cloud-based energy management, Maximum Power Point Tracking (MPPT), artificial intelligence for predictive battery health analysis, wireless charging integration, and smart grid connectivity. The outcomes of this research contribute to the advancement of sustainable electric mobility and support the development of intelligent, safe, and energy-efficient charging infrastructure for next-generation electric vehicles.

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