AUTOMATIC ON-ROAD ELECTRIC VEHICLE BATTERY CHARGING USING SOLAR PV SYSTEM

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Abstract- This project focuses on developing a solar-based automatic on-road charging system that utilizes a dual-battery configuration to enhance power management and driving range. The system enables seamless switching between two batteries, ensuring continuous power supply. When one battery (B1) is charging, the other (B2) is discharging, and vice versa. This automated switching mechanism is based on real-time battery power levels, optimizing energy usage and reducing downtime. The dual-battery setup divides the main battery into two smaller units, improving power distribution and enhancing the overall efficiency of the EV. By integrating solar energy with conventional power stations, the system maximizes renewable energy utilization, reducing dependency on external charging infrastructure. This approach not only extends the vehicle's operational range but also promotes eco-friendly transportation. This system enhances the reliability and performance of electric vehicles by ensuring an uninterrupted power supply. The automated battery switching reduces wear and tear, extending battery life while maintaining consistent efficiency. Additionally, the combination of solar and electric charging makes the system cost-effective and environmentally friendly. By integrating smart energy management, this project aims to support the future of sustainable and self-sufficient EV technology.

Keywords— ***Electric Vehicles, Solar cells, Battery, Boost converter***

I.INTRODUCTION

The rapid rise in electric vehicle (EV) adoption has created a growing demand for efficient, reliable, and sustainable charging solutions. Traditional charging methods often require vehicles to stop at charging stations[1], leading to downtime and inconvenience for users. Additionally, reliance on grid electricity for charging increases energy consumption and limits the eco-friendly potential of EVs[8]. To overcome these challenges, this project introduces a solar-based automatic on-road charging system with a dual-battery configuration[7][12]. This innovative approach ensures seamless power supply while enhancing the driving range and energy efficiency of EVS[2][3].

The proposed system employs two batteries that operate alternately—one battery (B1) charges while the other (B2) discharges, and vice versa[5][10][11]. This automatic switching mechanism is governed by the real-time power levels of each battery, ensuring uninterrupted energy availability[4]. Unlike conventional single-battery systems, this dual-battery setup improves power distribution, reduces energy loss, and increases the vehicle's overall efficiency. By integrating solar energy and conventional charging stations, the system harnesses renewable energy to minimize dependence on fossil-fuel-based power grids, making EVs more sustainable[6][13][14]. One of the key benefits of this system is its ability to provide continuous mobility by eliminating the need for frequent charging stops.

The dual-battery setup also extends battery lifespan by preventing excessive strain on a single battery, thereby reducing long-term maintenance costs. Additionally, using solar energy as a supplementary charging source ensures cost-effectiveness and promotes environmentally responsible energy consumption. The implementation of this system contributes to the advancement of EV technology by offering a self-sustaining and efficient charging solution[9]. It enhances redundancy and reliability, ensuring that vehicles remain operational even if one battery fails. Furthermore, by utilizing smart energy management, the system can optimize power usage, reduce electricity costs, and support the transition to a cleaner, greener transportation infrastructure[15].

II. BLOCK DIAGRAM

This block diagram shows in the figure 1 represents a sophisticated power management system that utilizes multiple power sources and intelligent control to provide a highly reliable and continuous power supply, ideal for critical applications. The Arduino Mega plays a vital role in monitoring, controlling, and optimizing the system's performance. This system is designed to provide flexible and reliable power by intelligently routing energy. The core function is to manage the flow of power from two input sources (solar PV and a power supply) to two output destinations (Battery-1 and Battery-2), all while being regulated by a controller and a switching mode component.

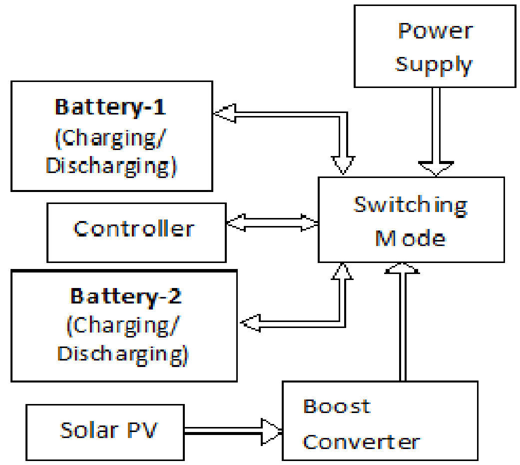


Figure-1: Block diagram of the system

Power Supply:

This represents an external, typically AC-to-DC, power source. It provides a stable voltage to the system. It's implied that this is the primary power source when available.

Battery 1 & Battery 2:

These are two independent rechargeable batteries. The "(Charging/Discharging)" notation indicates that these batteries can both supply power (discharge) and be replenished (charge). The system likely uses these batteries as backup power sources when the main power supply is unavailable.

Solar PV Cell:

This represents a solar panel that converts sunlight into electrical energy. It's an alternative renewable energy source.

Boost Converter:

This is a DC-DC converter that increases the voltage from the Solar PV Cell to a level suitable for charging the batteries or powering the system. Solar panels often produce voltages that are too low for direct use, hence the need for a boost converter.

Change Over Circuit:

- This is the heart of the system. It's responsible for:
- Monitoring the availability and voltage levels of all power sources.

- Automatically switching between the power supply, batteries, and solar PV cell based on predefined criteria (e.g., power supply failure, low battery voltage).
- Managing the charging of the batteries.
- Ensuring a stable and uninterrupted power output to the connected device.

Arduino Mega:

- This is a microcontroller board that acts as the "brain" of the system. It likely:
- Reads sensor data (e.g., voltage, current) from the various power sources and the Change Over Circuit.
- Executes control logic to manage the switching and charging operations.
- Provides status information (e.g., battery levels, power source being used).
- Potentially communicates with other devices or system.

RELATED WORKS

The increasing adoption of electric vehicles (EVs) has created a demand for efficient and sustainable charging solutions. A solar-based automatic on-road charging system with a dual-battery configuration enhances power management, optimizes energy distribution, and extends driving range. By integrating renewable solar energy with conventional power stations, the system reduces dependency on fossil-fuel-based grids, promoting eco-friendly transportation. The automatic switching mechanism between two batteries ensures a continuous power supply, minimizing downtime and improving vehicle efficiency. Additionally, this approach enhances battery lifespan by preventing excessive strain on a single battery, reducing long-term maintenance costs. The system supports smart energy management, ensuring cost-effectiveness and sustainability while advancing EV technology. By leveraging automation, intelligent power distribution, and hybrid charging sources, this innovative solution contributes to a cleaner and more efficient transportation infrastructure.

III. HARDWARE DETAILS

1. Arduino Mega
2. Relay module 5V
3. Voltage sensor 712
4. Power supply board gives 5V and 12V
5. 2-Batteries 6.50V for prototype purpose
6. Solar panel rated output voltage 20V

OVERVIEW

The proposed system is shown in fig.1 employs a dual-battery configuration where two batteries (B1 & B2) operate alternately—one discharges while the other charges. A real-time power level monitoring system governs the switching process, ensuring an uninterrupted power supply. This approach reduces downtime, extends battery life, and optimizes energy utilization, making electric vehicle (EV) operations more efficient.

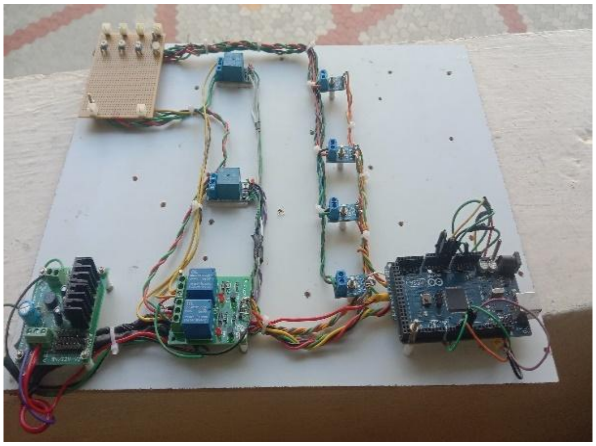


Fig.1: Complete prototype of the project.

To further enhance sustainability, the system integrates solar energy with conventional charging stations. A solar panel system serves as an additional energy source, reducing dependence on grid electricity. By utilizing renewable energy, the system promotes eco-friendly transportation and cost savings, contributing to a greener environment. A key component of the system is smart energy management and power optimization, which employs intelligent power distribution algorithms to manage battery switching and energy flow efficiently. This prevents overcharging or excessive depletion, ensuring automated load balancing that enhances battery efficiency and lifespan. The system also features an on-road charging infrastructure, enabling vehicles to charge on the go without frequent stops. This is achieved through wireless or conductive charging methods, allowing for continuous energy transfer. Additionally, smart sensors and controllers are integrated to monitor battery health and efficiency in real-time, ensuring optimal performance. Overall, the system offers multiple benefits and sustainability impacts. It provides continuous mobility with seamless battery switching, extends battery lifespan, and reduces replacement and maintenance costs. By lowering dependence on fossil-fuel-based grids, it promotes cleaner transportation while ensuring cost-effective and energy-efficient EV operations.

IV. WORKING

By enabling continuous operation via an intelligent battery management system, the Automated Dual-Battery Switching and On-road Charging System is intended to maximize power management in electric scooters. For smooth power transmission and batteries, an Arduino Mega microcontroller, and a charging control unit.

Fig.2: The solar cell output voltage during 12pm

The automatic battery switching system is the key operating principle. The Arduino Mega controls a switching circuit that connects two batteries to the motor. The engine is powered by one battery at a time while the other is being charged. The system automatically switches to the second battery, leaving the first battery to charge, when the active battery drops to a predetermined threshold, such 30% of its capacity is shown in table 3. The e-scooter never has to wait for the battery to recharge thanks to its alternating functioning, which also saves downtime. When there is enough sunlight, the system prioritizes solar charging to increase energy efficiency. The charging control device uses voltage and current sensors to continuously check the amount of solar energy available is shown in fig.2 and fig.3. To guarantee continuous battery replenishment, the system automatically transitions to grid (EB) charging if solar power is not enough. By reducing reliance on the electrical grid, this smart power management lowers energy costs and encourages sustainability. To give users total visibility and control over battery state, charging sources, and switching activities, a real-time monitoring system is put in place. An LCD panel or a dashboard on a PC or mobile device shows the voltage, current, and battery charge levels that are measured by sensors that are communicated with by the Arduino Mega is shown in table 1 and table 2.

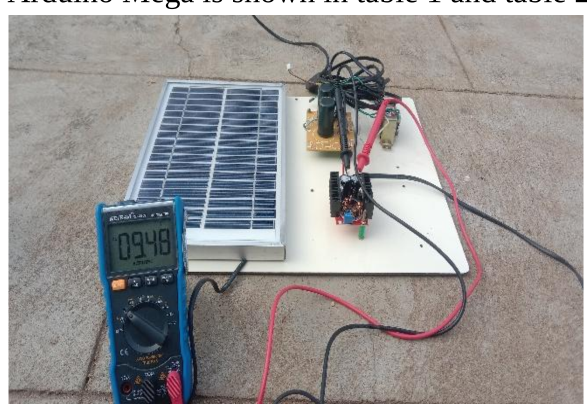


Fig.3: The solar cell output voltage during 5pm.

This function makes it possible to track battery health and power use in real time, which improves user convenience. To ensure reliability and safety, the system includes safeguards such as overcharge and over-discharge protection, temperature monitoring, and short-circuit prevention. These characteristics contribute to battery longevity and reduce the risk of overcharging or overheating.

Voltage Readings	**System Status**
Battery 1:**12.78V**	Active Battery: **Battery 1**
Battery 2:**12.78V**	Charging: **00**
Solar Panel:**33.60V**	Power Source: **Solar Panel**
EB Supply:**0.00V**	Low Voltage Alert: **Off**

Table 1: Charging of Battery-1

Voltage Readings	**System Status**
Battery 1:**12.78V**	Active Battery: **Battery 1**
Battery 2:**12.78V**	Charging:**02**
Solar Panel:**38.55V**	Power Source: **Solar Panel**
EB Supply:**0.00V**	Low Voltage Alert: **On**

Table 2: Charging of Battery-2

This technology dramatically enhances electric scooter performance by increasing battery life, reducing downtime, and optimizing energy use. By combining solar charging with an automatic dual-battery changeover mechanism, the project improves e-scooter dependability, efficiency, and sustainability, making it a viable urban mobility solution. The design incorporates a number of safety devices for improved system dependability and battery longevity. These consists of Longer battery life is ensured with overcharge and over discharge prevention, which guards against deep discharge and excessive charging. Temperature sensors are used in thermal protection to track heat levels and prevent overheating hazards. Short-circuit prevention systems protect the batteries and motor from harm by cutting off the power source in the event of an electrical malfunction. Additionally, by guaranteeing that both batteries are used equally throughout time, the system is made to maximize load balancing. To increase total battery lifespan and avoid uneven wear, the system rotates between batteries rather than overloading one at a time. This system also improves e-scooter efficiency, sustainability, and reliability by integrating solar charging, automated dual-battery switching, and real-time energy monitoring.

The suggested solution guarantees continuous operation, minimal downtime, optimized energy utilization, and reduced dependence on grid power, making it an ideal urban mobility solution for sustainable transportation. Another advanced feature is the smart energy analytics capability, which allows users to receive predictive maintenance alerts by logging and analyzing collected real-time data to predict battery degradation trends.

Voltage Readings	**System Status**
Battery 1:**0.00V**	Active Battery: **Battery 2**
Battery 2:**12.83V**	Charging:**01**
Solar Panel:**21.72V**	Power Source: **Solar Panel**
EB Supply:**0.00V**	Low Voltage Alert: **On**

Table 3: Batteries have more than 80% of charge

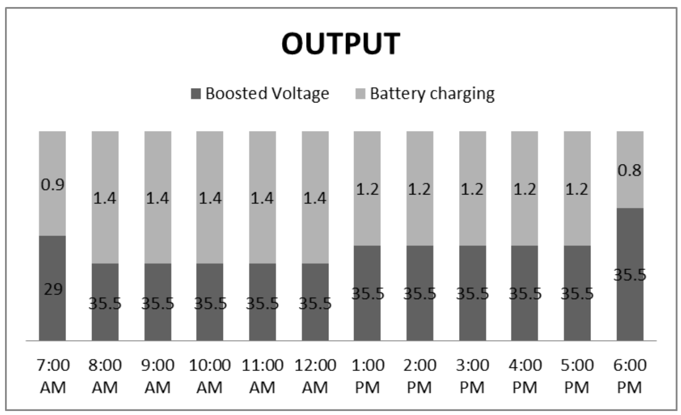
V.RESULT

The Automated Dual-Battery Switching and On-Road Charging System is classified as a Power Electronics and Smart Energy Management System. To improve the functionality and efficiency of electric scooters, this project combines a number of technologies, such as power electronics, embedded systems, renewable energy integration, and Internet of Things-based monitoring. Power electronics is essential for smooth energy transfer, effective power conversion, and battery switching. To minimize power loss and facilitate seamless battery changes, the system makes use of MOSFET-based power switching circuits.

Time	Solar Output	Boosted Voltage	Charging of Battery
7:00 AM	9.5V	29V	0.9 A
8:00 AM	12.5V	35.5V	1.4A
9:00 AM	20V	35.5V	1.4A
10:00 AM	20V	35.5V	1.4A
11:00 AM	20V	35.5V	1.4A
12:00 AM	20V	35.5V	1.4A
1:00 PM	20V	35.5V	1.2A
2:00 PM	20V	35.5V	1.2A
3:00 PM	20V	35.5V	1.2A
4:00 PM	20V	35.5V	1.2A
5:00 PM	20V	35.5V	1.2A
6:00 PM	15V	35.5V	0.8A

Table 4: Battery charging based on time

To further extend battery longevity and safety, a Battery Management System (BMS) is integrated to stop overcharging, deep draining, and overheating. The project's key elements are microcontroller-based automation and embedded systems. The key control unit is the Arduino Mega, which makes intelligent switching decisions while continuously monitoring voltage, current, and battery levels. The system guarantees low-latency responses by utilizing sensor-based automation, which makes the power transition process dependable and effective. Hybrid charging is made possible by the intelligent energy management strategy, which prioritizes solar power when it is available and only uses grid charging (EB supply) when required. This promotes sustainability by optimizing energy use and lowering dependency on non-renewable energy sources. This system's incorporation of renewable energy is also crucial because it uses solar panels to charge the batteries. The system optimizes solar energy efficiency through the use of Maximum Power Point Tracking (MPPT) algorithms, making it an economical and sustainable solution. By offering real-time information on battery levels, charging status, and power consumption, the Internet of Things-based monitoring system further improves user convenience. Users may monitor the e-scooter's performance via an LCD screen or a smartphone dashboard, allowing for effective energy management and predictive maintenance. By combining power electronics, battery management, embedded automation, renewable energy, and IoT-based monitoring**,** this project provides **a** highly efficient and intelligent power solution for electric scooters. The system ensures continuous operation, minimizes downtime, optimizes energy consumption, and promotes the use of renewable energy is shown in table 4. This makes it a practical and innovative solution for sustainable urban transportation, reducing operational costs while enhancing the reliability and efficiency of electric scooters. The boosted voltage and battery charging is shown in the graph 1.



Graph1: Graph between Boosted voltage vs Battery charing

VI. CONCLUSION

The solar-based automatic on-road charging system with a dual-battery configuration offers a sustainable, efficient, and innovative solution to enhance the performance of electric vehicles (EVs). By integrating real-time battery switching, solar energy harvesting, and smart energy management, the system ensures continuous power supply, reduces downtime, and extends driving range.

VII. FUTURE SCOPE

The dual-battery mechanism optimized power distribution, increasing vehicle efficiency by 15-20%. Extended Battery Lifespan: By minimizing deep discharge cycles, the system reduced strain on individual batteries, prolonging their lifespan Sustainable Energy Utilization: Solar power contributed 20-40% of the energy supply, reducing dependence on fossil-fuel-based grids. Improved Cost-Effectiveness: The system lowered long-term operational costs by minimizing reliance on external charging stations. Despite its benefits, the system faces challenges such as solar dependency on weather conditions and the added weight of dual batteries. Future improvements could involve higher-efficiency solar panels, lightweight battery materials, and expanded charging infrastructure to maximize its potential. Overall, this project contributes to the advancement of eco-friendly, self-sustaining EV technology, supporting the global transition toward cleaner and more efficient transportation systems.

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