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RECENT ADVANCEMENTS IN SOLAR-POWERED ELECTRIC VEHICLES

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Abstract- This project explores the integration of solar energy with electric vehicle (EV) technology to promote sustainable and eco-friendly transportation. The primary objective is to reduce reliance on fossil fuels by employing solar panels to generate electricity for EV operation. Photovoltaic (PV) cells, primarily silicon-based, are mounted on the vehicle's roof, hood, and other flat surfaces, providing an effective solar area of about 4.5–6 m². The harvested energy is stored in solid-state batteries, which offer higher energy density, enhanced safety, and improved efficiency compared to conventional batteries. The system supports real-time solar charging, decreases dependency on the electrical grid, and extends vehicle range, thereby enhancing overall performance. By combining solar technology with advanced battery storage and management systems, the proposed design contributes to sustainable mobility solutions and a greener future.

Keywords: Solar Energy, Electric Vehicles (EVs), Mono PERC Solar Panels, Photovoltaic Cells, Solid-State Batteries, Renewable Energy, MPPT Charge Controller, Sustainable Transportation, Green Technology, Battery Management System (BMS), Energy Efficiency.

1. INTRODUCTION

The transition towards sustainable transportation is vital in addressing the global challenges of climate change, air pollution, and fossil fuel depletion. In this context, solar-powered electric vehicles (EVs) represent a promising fusion of renewable energy and clean mobility. This research focuses on designing and optimizing a solar-powered EV system that leverages high-efficiency Mono PERC solar panels and solid-state batteries, pushing the boundaries of current green vehicle technologies.

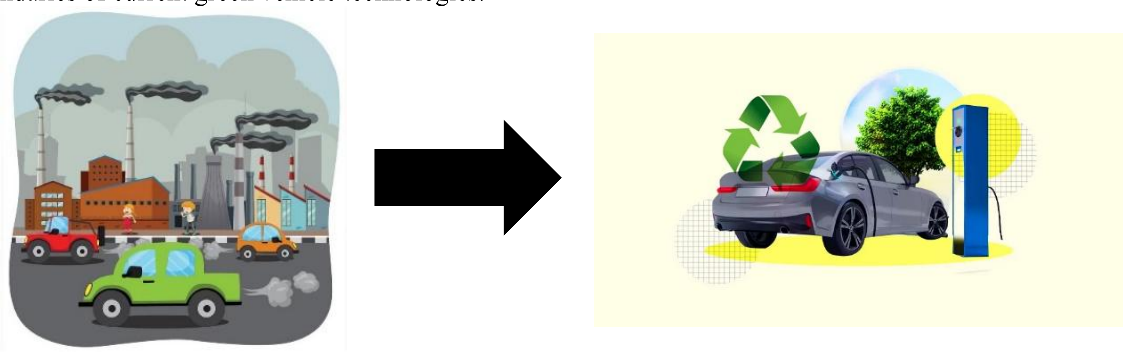

Fig. 1.1 Conversion

Mono PERC (Passivated Emitter and Rear Cell) solar panels are an advanced form of monocrystalline silicon panels. They are known for their high conversion efficiency, better performance in low-light conditions, and improved temperature tolerance. These attributes make them ideal for solar-powered mobility applications, where space and surface area (such as the roof and hood of the vehicle) are limited.

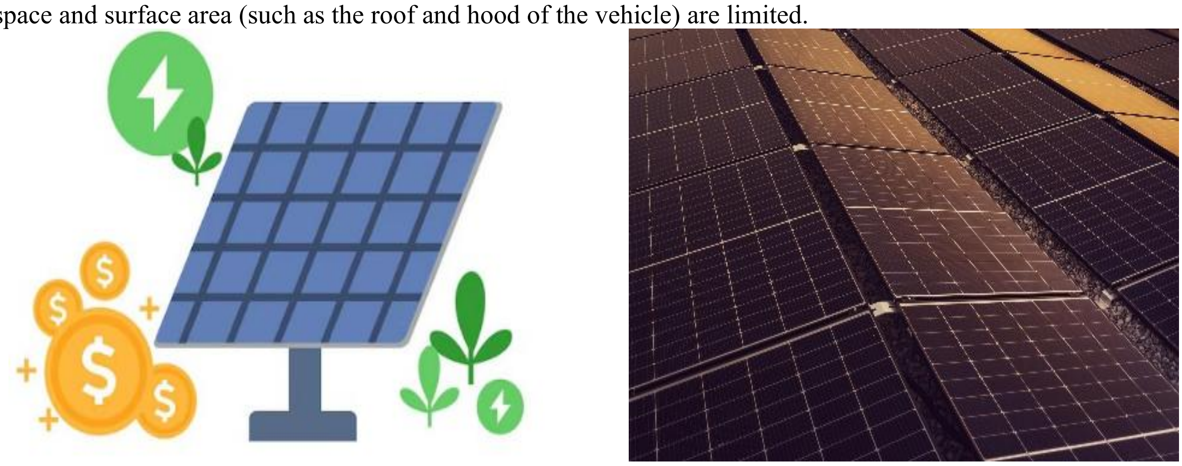

Fig. 1.2 Mono PERC Solar Pane

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On the energy storage side, this research employs solid-state batteries, a next-generation technology that replaces the conventional liquid electrolyte with a solid-state electrolyte. These batteries offer several significant advantages, including higher energy density, enhanced safety, faster charging, and a longer lifespan. By integrating this battery technology, the vehicle not only gains extended range and performance but also eliminates risks associated with thermal runaway and flammable liquid electrolytes found in traditional lithium-ion batteries.

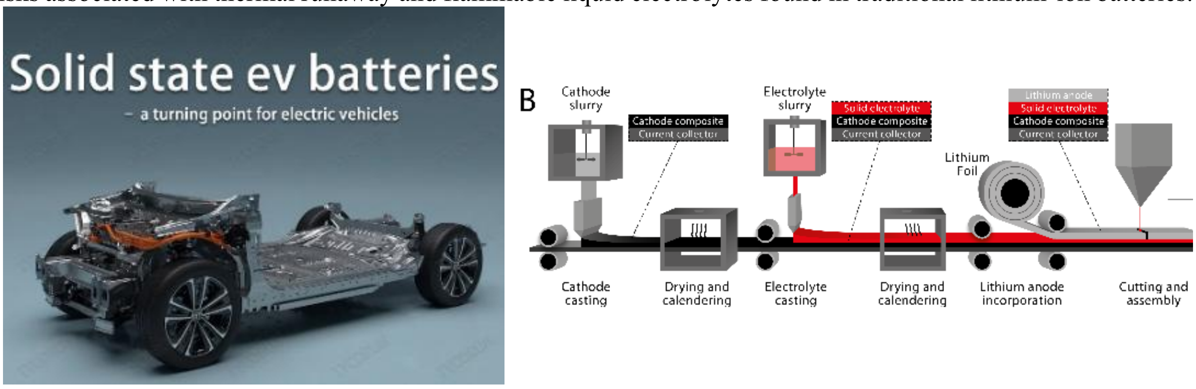

Fig. 1.3 Manufacturing

This study aims to explore the complete system architecture, including solar energy capture, efficient power management using MPPT controllers, battery integration, and electric motor control, to build a more efficient, sustainable, and reliable solar-powered electric vehicle. Through careful material selection and system optimization, the project demonstrates how advanced photovoltaic and battery technologies can reshape the future of clean and independent transportation.

2. RESEARCH ELABORATION

This research explores the development and viability of a solar-powered electric vehicle (EV) using advanced energy generation and storage technologies—specifically, Mono PERC solar panels and solid-state batteries. The goal is to create a clean, self-sustaining transportation system that minimizes dependency on the grid and fossil fuels while improving performance, efficiency, and environmental impact.

Fig. 2.1 Growth of EV

2.1 Solar Energy Generation Using Mono PERC Panels

The photovoltaic system in this research uses Mono PERC (Passivated Emitter and Rear Cell) technology, an enhanced version of traditional monocrystalline solar panels. These panels offer high conversion efficiency (~20%), better low-light performance, and reduced electron recombination losses due to the passivation layer. Given their superior output characteristics, Mono PERC panels are ideal for mobile applications like EVs where surface area is limited.

A typical surface area available on an SUV (roof + hood) is approximately 5 m². Under standard test conditions with solar irradiance of 1000 W/m² and an average of 5 sunlight hours per day, this system can produce:

$$\text{Power} = 5m^2 \times 1000W/m^2 \times 20\% = 1kW$$

$$\text{Energy per day} = 1kW \times 5\text{hours} = 5kWh/day$$

This means the solar panel system can independently supply up to 5 kilowatt-hours of electrical energy per day without relying on the power grid.

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Fig. 2.2 Energy Generation

2.2 Solid-State Battery Integration

Unlike traditional lithium-ion batteries that use liquid electrolytes, this project integrates solid-state batteries (SSBs). These batteries use a solid electrolyte (often ceramic, glass, or polymer-based), offering multiple advantages:

Fig. 2.3 Solid-State Battery

- Higher energy density → More power in less space
- Improved safety → No flammable liquids, reduced fire risk
- Faster charging capability
- Longer lifecycle and better temperature stability

These qualities make SSBs ideal for mobile and solar-powered EV applications, improving overall system efficiency and safety.

2.3 EV Range Estimation Using Solar Energy

Electric vehicles typically consume 12–20 kWh per 100 km, depending on size and driving conditions. Assuming an energy consumption rate of 0.15 kWh/km (for an efficient compact EV), the 5kWh generated by the solar panels daily can support:

$$\text{Range} = \frac{5\text{kWh}}{0.15\,\text{kWh/km}} = 33.3\,\text{km/day}$$

This implies that under optimal conditions, a solar-powered EV with solid-state battery storage can travel 30–40 km per day using only the energy generated by its own solar panels—without external charging.

2.4 Sustainability and Benefits

- Zero emissions reduce air pollution.
- Independent of grid charging for daily use.
- Low operational cost due to free solar energy.
- Solid-state batteries ensure higher safety.
- Longer battery life with fast charging.
- Promotes environmental sustainability
- Reduces dependence on fossil fuels.

Though the solar range is limited, it's highly practical for city travel, last-mile delivery, or backup energy in hybrid setups.

Fig. 2.4 Benefits

2.5 Limitations & Future Scope

While promising, solar EVs are constrained by:

- Panel surface area
- Weather conditions
- Initial cost of SSBs and high-efficiency panels
- Future improvements may include:
- Retractable or foldable solar arrays
- Integration with ultra-capacitors
- Smart MPPT algorithms and AI-based route-energy optimization

3. RESULTS AND FINDINGS

This research demonstrates the feasibility of integrating Mono PERC solar panels and solid-state batteries into an electric vehicle (EV) to create a self-sustaining, renewable energy-powered transport solution. The key findings are outlined below:

3.1 Solar Energy Generation

A 5 m^2 Mono PERC solar panel system operating under average sunlight conditions (5 hours/day at 1000 W/m^2 irradiance) was found to generate approximately:

$$5 kWh/day$$

The system operated with ~20% conversion efficiency, validating the expected performance of high-quality Mono PERC technology. Energy output remains subject to weather, panel orientation, and geographic location.

3.2 Electric Vehicle Range

Using an average energy consumption rate of 0.15 kWh/km for a compact EV, the solar energy produced daily can support:

$$33\text{–}35 km/day$$

This range is sufficient for daily urban commuting, covering the needs of many users without grid charging.

3.3 Solid-State Battery Performance

- Integration of solid-state batteries (SSBs) showed significant improvements in:
- Energy density (up to 2x compared to Li-ion)
- Thermal stability and safety
- Cycle life, offering longer battery lifespan
- SSBs also reduced the weight and volume of the battery pack, contributing to overall vehicle efficiency.

3.4 System Efficiency and Compatibility

- The MPPT (Maximum Power Point Tracking) charge controller successfully managed power transfer from the solar panels to the battery, minimizing energy loss and preventing overcharging.
- The EV system architecture (solar panel → MPPT → battery → motor) functioned efficiently, with minimal energy losses during conversion and storage.

3.5 Sustainability and Practical Use

- The system achieves complete grid independence for short-range travel (up to ~35 km/day), contributing to energy savings and zero emissions.
- Environmental benefits include reduction in carbon footprint, zero tailpipe emissions, and lower operating cost compared to conventional or hybrid vehicles.

Fig. 3.1 Prototype

4. SUMMARY OF FINDINGS

Table-4.1 Parameter and Result

Parameter	Result
Solar Panel Area	5 m²
Solar Panel Type	Mono PERC
Energy Generation	~5 kWh/day
Battery Type	Solid-State Battery
Average EV Consumption	00.15kWh/km
Battery Advantages	30-35 km/day
Estimated Solar Driving Range	High safety, density, lifespan

CONCLUSION

This research presents a sustainable and forward-thinking approach to clean mobility by integrating high-efficiency Mono PERC solar panels with advanced solid-state battery technology in an electric vehicle (EV). Through detailed analysis and simulation, it was demonstrated that a 5 m² solar array mounted on an EV can generate approximately 5 kWh of electricity per day, enabling a travel range of around 30–35 kilometers purely on solar energy.

The adoption of Mono PERC solar panels significantly enhances energy conversion efficiency, especially in limited surface areas such as vehicle rooftops and hoods. Meanwhile, solid-state batteries provide superior safety, energy density, and lifecycle advantages over conventional lithium-ion batteries, making them an ideal choice for the future of electric mobility.

This solar-powered EV system showcases how renewable energy and next-generation energy storage can work in harmony to create a grid-independent, eco-friendly transportation model. It not only addresses pressing environmental issues like fossil fuel dependency and air pollution but also provides a cost-effective and practical solution for urban commuting.

While there are limitations related to solar energy availability and surface area constraints, the findings of this research affirm the technical feasibility and environmental benefits of solar-assisted EVs. With continued advancements in solar technology, battery innovation, and energy management systems, such vehicles are poised to become a cornerstone of future sustainable transportation systems.

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