SolarEV Solutions-Giving Second Life to EV Batteries by Connecting Them with Home Photovoltaic

[1]Prof. Pritam Ahire, [2]Chinmai R Nair, [3]Prithviraj Patil, [4]Atharva Musale

[1]Assistant Professor, [2]Student, [3] Student ,[4]Student
[1]Computer Engineering,
[1] Nutan Maharashtra Institute of Engineering and Technology, Pune, India

Abstract: As the world transitions to renewable energy, the management and storage of excess energy have become critical challenges. Second life electric vehicle (EV) batteries present a transformative opportunity for both the power and automotive sectors. By integrating these repurposed batteries into solar photovoltaic (PV) setups, it is possible to provide high-capacity, affordable, and sustainable energy storage to homes and businesses. Rather than treating these batteries as waste, professional refurbishment and deployment in stationary solar systems create a robust value loop: extending battery lifespan, reducing material extraction, and delivering reliable power even at night or during outages. This paper explores the technical, economic, and policy frameworks enabling this transition, highlights market and environmental benefits, and identifies future prospects and challenges. Results suggest that embracing second- life storage can substantially reduce the carbon footprint of renewable energy systems, make sustainable power more accessible in both urban and rural contexts, and unlock new economic opportunities.

IndexTerms **- Component,formatting,style,styling,insert.**

I. INTRODUCTION

INTRODUCTION

The explosive growth in solar photovoltaic (PV) adoption and the rapid electrification of the transport sector via electric vehicles (EVs) have created a unique intersection of opportunities and challenges within the global energy landscape. Solar energy, despite being clean, renewable, and abundant, suffers from inherent intermittency due to diurnal cycles and weather variability, thereby demanding efficient and scalable energy storage systems to ensure continuous power availability and true energy independence. Concurrently, the global EV revolution has led to an exponential rise in lithium-ion battery production, with millions of battery packs expected to reach the end of their vehicular life within the next decade. Notably, these batteries still retain approximately 70–80% of their original capacity after vehicular retirement, making them highly suitable for stationary storage applications.

Discarding such batteries prematurely results in the loss of valuable electrochemical resources, contributes to landfill waste, and exacerbates the environmental burden of raw material extraction for new batteries. Reintegrating these second-life EV batteries into residential and commercial solar systems represents a sustainable and economically viable solution that addresses both renewable intermittency and electronic waste management. By leveraging existing battery assets, these systems reduce the need for virgin material extraction, lower lifecycle carbon emissions, and provide affordable storage options for distributed solar installations.

In India, the energy transition is gaining momentum with an installed storage capacity of about 219.1 MWh as of March 2024. Government initiatives like the National Programme on Advanced Chemistry Cell (ACC) Battery Storage and the Rooftop Solar Scheme are promoting the integration of solar energy expansion with sustainable battery reuse practices. Globally, similar efforts by automotive manufacturers and energy firms are accelerating second-life battery markets through large- scale pilot projects. Research in thermal management, degradation modeling, and predictive analytics for State of Health (SOH) estimation further strengthens the technical reliability of such systems.

Need of the Study

The rapid growth of solar photovoltaic (PV) installations and the increasing adoption of electric vehicles (EVs) have created significant challenges in energy storage and electronic waste management. Solar energy, despite its abundant and renewable nature, suffers from intermittency due to daily and seasonal variations, making reliable energy storage essential for continuous power supply. On the other hand, millions of lithium-ion batteries from retired EVs still retain 70–80% of their capacity, but are often discarded prematurely, contributing to environmental pollution and loss of valuable resources. Integrating second-life EV batteries into solar PV systems addresses both these challenges, providing a sustainable, cost-effective, and environmentally friendly solution. This study is crucial for promoting circular economy practices in the energy sector, enhancing renewable energy utilization, and reducing electronic waste hazards in India and globally.

II.PROBLEM STATEMENT:

Despite the growing interest and potential, deploying second-life EV batteries in solar energy systems presents challenges. Battery health varies significantly by manufacturer, usage behavior, and environmental factors, complicating standardization and performance predictability. Safety risks such as overheating or leakage necessitate sophisticated BMS and real-time monitoring. Additionally, testing for residual life and safety is costly and not yet standardized across regions. The absence of harmonized regulatory frameworks, limited public awareness, and complex multi-brand integration further hinder large-scale adoption. This study aims to address these issues through a structured, modular system architecture and cloud-based monitoring platform.

3.Overview:

There use of electric vehicle (EV) batteries in stationary energy systems has attracted significant academic and industrial attention. Numerous studies and pilot deployments confirm both the environmental and economic viability of second- life applications. Research by Kamath et al., Ahmadi et al., and Martinez-Laserna et al. demonstrates that repurposed EV batteries can achieve cost reductions of up to 20% compared to newly manufactured ones while substantially lowering lifecycle emissions.

3.1 Industry:

Implementation Leading automotive manufacturers such as BMW, Nissan, and Renault have already commercialized second-life initiatives, including the xStorage and grid-scale storage programs. These projects validate the feasibility of reusing EV batteries for residential, commercial, and community-level storage applications. Their success indicates strong potential for scalability and integration with renewable energy infrastructures.

3.2 Key Technical Insights:

Despite promising outcomes, challenges persist in evaluating residual battery health, managing thermal and electrical safety, and ensuring interoperability among different chemistries and manufacturers. The advancement of modern Battery Management Systems (BMS) and Energy Management Systems (EMS) has helped overcome several challenges by enhancing operational safety, boosting performance efficiency, and enabling smarter predictive contro

3.3 Policy and Research Gaps:

In India,limited regulatory clarity and the absence of standardized certification procedures continue to slow large-scale adoption. Studies emphasize the need for unified frameworks that address testing protocols, environmental compliance, and circular economy incentives. Bridging this regulatory gap through collaborative research and government industry partnerships will be essential for sustainable implementation.

3.4 Challenges and Limitation\:

Despite notable progress, challenges persist in assessing residual battery health, ensuring inter-brand compatibility, and standardizing testing procedures [8][9]. Variations in State of Health (SOH), cell chemistry, and aging mechanisms complicate reuse. Safety concerns related to thermal instability and irregular degradation patterns require monitoring and robust protection strategies.

3.5 Policy and Regulatory Developments:

In India, the absence of uniform certification and disposal guidelines remains a major bottleneck [10][11]. Current efforts by the Ministry of Heavy Industries and the Bureau of Indian Standards (BIS) aim to establish frameworks for testing, labeling, and end of-life management. Policies linking battery recycling, reuse incentives, and renewable integration are gradually emerging but require stronger enforcement.

3.6 Comparative Research and Global Strategies:

Comparative studies reveal regional variations in second life deployment strategies. While Europe emphasizes industrial-scale energy storage, Asian nations like Japan and South Korea prioritize residential reuse models [12] [13]. Multinational projects are now integrating second-life batteries into smart grids, community microgrids, and vehicle-to-home (V2H) applications, reinforcing reliability and reducing grid strain.

III. LITERATURE REVIEW

IV. METHODOLOGY

The SolarEV Solutions framework was developed through a structured approach combining system design, simulation, and digital control integration. The goal was to optimize the reuse of second-life EV batteries within solar photovoltaic (PV) systems for safe, efficient, and sustainable energy storage.

1. System Architecture:

The system follows a modular three-layer design—Power, Control, and Monitoring layers. The Power Layer includes solar panels, charge controllers, and second life EV battery modules. The Control Layer integrates the Battery The Monitoring Layer uses cloud-based dashboards for real-time data tracking and performance visualization. This architecture supports scalability, safety, and adaptability for different battery types and load conditions.3.2 Data and Sources of Data

For this study, secondary data has been collected from multiple sources. Information on solar PV systems—including capacity, location, and energy generation patterns—was obtained from MNRE reports and industry publications. Data on second-life EV batteries, such as remaining capacity and State of Health (SOH), was collected from EV manufacturers and battery recycling centers. Additionally, research studies and technical reports on battery performance, degradation, and thermal management were

used to assess feasibility. Government policies and initiatives, such as the ACC Battery Storage Program and Rooftop Solar Scheme, were also considered.
The data collection period ranges from January 2023 to December 2025, reflecting current trends in solar PV deployment and EV battery availability.

2. Data Modeling and Simulation:
MATLAB/Simulink andPython-based simulations were used to analyze solar generatio n, load patterns, and battery degradation under varying environmental conditions. The models provided insights into efficiency, cost reduction, and lifecycle performance, validating the feasibility of second-life battery reuse

3. Prototype Implementation:
A web-based prototype was built to demonstrate practical usability. It enables users to size systems, evaluate CO_2 savings, and estimate energy costs. The backend database stores performance data, while the frontend interface allows interactive visualization and customization.

4. Control and Optimization:
The integrated BMS ensures cell balancing, temperature regulation, and overcharge protection, while the EMS optimizes power flow between the PV system, battery, and connected loads. This dual layer control minimizes losses, extends battery life, and improves system reliability. 5. Evaluation Parameters System performance was assessed using indicators such as energy efficiency, degradation rate, cost per kWh stored, and CO_2 reduction potential. Results showed that repurposed batteries can achieve high reliability at significantly lower costs than new lithium-ion units.

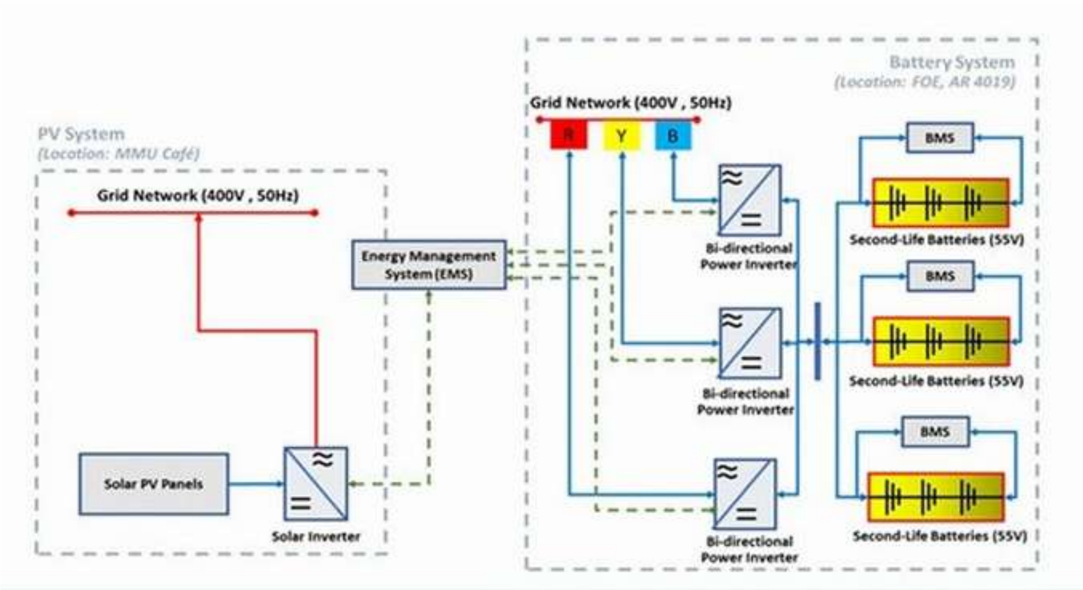

Fig 2.0. System Architecture

V. RESULT AND DISCUSSION

Fig1. Interface

Fig2. Solutions

Fig3. Marketplace

Fig4. Installation

VI. APPLICATIONS:

• Residential Storage: Homeowners can store excess solar energy efficiently using second-life batteries.
• Commercial and Industrial Backup: Offers reliable power during outages.
• Community Microgrids: Enables shared renewable energy storage and peer-to-peer energy trading.
• Educational and Research Use: Serves as a demonstrator for renewable and circular economy education.

VII. FUTURE SCOPE:

Future work will explore AI-based predictive BMS for health estimation, blockchain-based traceability for transparency, and modular architectures for compatibility across battery chemistries. Standardized testing and automation in installation will improve scalability. Policy incentives for reuse and recycling are expected to further accelerate adoption. Collaboration between academia, industry, and government will be essential for maximizing the environmental and economic impact of second-life systems.

IX. CONCLUSION:

The research highlights that combining second-life EV batteries with solar PV systems offers a sustainable and economical solution for expanding renewable energy use. By repurposing batteries that retain about 70–80% of their initial capacity, this method reduces waste, lessens reliance on raw materials, and improves grid reliability and energy access. Moreover, advanced control systems such as Battery Management Systems (BMS) and Energy Management Systems (EMS) further enhance performance, safety, and system longevity. Collaboration between policymakers and industry stakeholders is vital to create unified standards and certification processes for large-scale deployment. Overall, second-life battery applications contribute to energy resilience, promote circular economy principles, and support the global transition to a clean, low-carbon future.

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