



(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 6, June 2025

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www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025 |DOI: 10.15680/IJIRSET.2025.1406194| P.V Hybrid Storage System

Dipali Shripati Patil¹, Ruturaj Ramchnadra Chougle², Aditya Vijay Patil³, Omkar Sambhaji Kamble⁴,

Pratiksha Sandip Patil⁵, Sourabh Suraj Sonule⁶

U.G. Student, Department of Electrical Engineering, Sanjeevan Group of Institutes, Kolhapur, India¹⁻⁶

ABSTRACT: This paper discusses the use of hybrid energy storage systems in solar (photovoltaic or PV) applications, focusing on combining lead-acid and lithium-ion batteries. Solar power is becoming a popular clean energy option, but its output is inconsistent due to changes in sunlight during the day and seasons. To provide a steady power supply, reliable storage is essential. Lead-acid and lithium-ion batteries each have their own pros and cons when it comes to cost, energy capacity, lifespan, and efficiency. A hybrid system takes advantage of the strengths of both types. Lead-acid batteries are cheaper and well-known, making them suitable for storing large amounts of energy. Lithium-ion batteries, on the other hand, are more efficient, last longer, and are better for quick power delivery and high energy needs. This study looks into how to make the most of such hybrid systems by analyzing charge and discharge behavior, lifespan, cost-effectiveness, and overall impact on solar system performance. Simulations and real-life examples are used to show how these systems can lower costs, improve energy reliability, and promote the use of renewable energy. Overall, hybrid storage systems offer a promising solution to the storage issues faced by solar power and can help in expanding clean energy usage.

KEYWORDS: Photovoltaic, hybrid, battery technologies, lithium-ion batteries.

I. INTRODUCTION

The growing need for clean and sustainable energy has increased interest in renewable sources like solar power, which help reduce fossil fuel use and environmental damage. However, solar energy is not always available due to weather changes and day-night cycles, making it hard to use efficiently and maintain grid stability. To solve this problem, hybrid energy storage systems are being developed. Past research has studied different combinations of storage systems—especially lead-acid and lithium-ion batteries—to manage energy better and improve power reliability. Still, there are some key areas that need more attention, such as creating better control methods to fully use the benefits of hybrid systems and analyzing their technical and financial feasibility for grid-connected use. This project focuses on these issues by designing a hybrid system that combines lead-acid and lithium-ion batteries with grid support. The goal is to improve energy management and reduce costs. The system aims to boost the performance and reliability of solar power, helping promote the wider use of renewable energy.

1.1. Proposed Work

This project focuses on designing and developing a hybrid solar photovoltaic (PV) energy storage system that combines lead-acid and lithium-ion batteries to improve efficiency, reduce costs, and extend system life. The system will use solar energy to charge the batteries, while an Energy Management System (EMS) will control how the batteries are charged and discharged, based on their characteristics and the energy demand. In this setup, the lead-acid battery will be used for storing large amounts of energy because it is affordable, while the lithium-ion battery will be used for handling peak loads and quick charging/discharging due to its better performance and longer life. A control algorithm will be created to manage the energy flow effectively and protect battery health. Software tools like MATLAB/Simulink or HOMER will be used to model the system and run simulations under different conditions to test its performance. The goal is to create an efficient and cost-effective hybrid storage solution that works well for both off-grid and grid-connected solar applications.

1.2. Need for the Work

Solar PV systems depend mostly on sunlight, which varies throughout the day and changes with the weather. Because of this, it can be difficult for them to supply power consistently. A hybrid storage system, which uses solar panels along with batteries (and sometimes a grid or generator backup), helps overcome this issue by providing a more reliable and steady power supply. These systems are very helpful in remote or rural regions where access to grid electricity is





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025

|DOI: 10.15680/IJIRSET.2025.1406194|

limited or not available. They improve energy use, support the shift to clean energy, and lower the need for fossil fuels. This makes them a valuable solution for moving toward sustainable and eco-friendly development.

1.3. Aim and Objectives

Aim:

To design and implement an efficient and dependable hybrid PV storage system that ensures continuous power by combining solar energy with battery storage.

Objectives:

- 1. To collect solar energy using photovoltaic panels.
- 2. To store extra energy in batteries for use when sunlight is low or during high power demand.
- 3. To ensure continuous electricity supply using smart load management.
- 4. To lower dependence on conventional energy sources and promote eco-friendly alternatives.
- 5. To create a cost-effective solution suitable for areas with no or poor grid connectivity.

II. LITERATURE SURVEY

A Photovoltaic (PV) Hybrid Storage System combines solar energy generation with energy storage technologies, such as batteries or supercapacitors. These systems store extra solar energy produced during the day for use when sunlight is not available. Their main purpose is to overcome the inconsistent nature of solar power, improve energy reliability, lower electricity costs, and support environmental sustainability and grid stability. This literature review provides an overview of recent developments, major research areas, system components, performance indicators, and challenges related to PV hybrid storage systems. The main objective of a PV hybrid storage system is to deliver a consistent, reliable, and affordable power supply by pairing solar panels with energy storage. These systems help in making the best use of renewable energy, decreasing dependence on the power grid, and dealing with the fluctuating output of solar energy. A typical PV hybrid system includes:

- Solar Panels Used to absorb sunlight and convert it into electrical energy.
- Energy Storage Includes components like lead-acid batteries, lithium-ion batteries, or supercapacitors that store the generated electricity for later use.
- Power Conversion Units Devices such as inverters that change DC (Direct Current) electricity from the solar panels into AC (Alternating Current), which is suitable for most appliances.
- Energy Management System (EMS) A system that manages, controls, and optimizes how energy is produced, stored, and used within the hybrid system.

In some setups, the system may also include **backup power sources**, like diesel or natural gas generators, or be integrated with other renewables like **wind turbines**, to further increase reliability.



III. BLOCK DIAGRAM AND CONSTRUCTION

Figure 1:Block diagram





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1. Solar Panel Voltage Sensor

- Measures the voltage output of the solar panel.
- Sends this data to the microcontroller for monitoring and control.

2. Battery Voltage Sensor

- Monitors the voltage level of the connected batteries.
- Helps the microcontroller determine charging needs and switching logic.

3. Microcontroller

- Acts as the central control unit.
- Receives data from voltage sensors.
- Controls charging/discharging cycles, battery selection, and load supply.
- Displays real-time data on an LCD (16x2) screen.
- Sends PWM signals to control the MOSFET driver for energy flow management.

4. PWM MOSFET Driver IR2104

- Used for driving the power MOSFETs using Pulse Width Modulation (PWM) signals.
- Regulates the charging power from the solar panel to the batteries through controlled switching.
- Works with the MPPT converter to ensure efficient power transfer.

5. MPPT Converter

- Ensures Maximum Power Point Tracking from the solar panel.
- Optimizes the power extraction from solar energy under varying sunlight conditions.
- Sends regulated energy to charge the batteries.

6. Battery 1,2 Switching Relay (Charging Side)

- Selects between Battery 1 and Battery 2 for charging based on control signals from the microcontroller.
- This allows either of the batteries (lead-acid or lithium-ion) to be charged depending on their current state.

7. Battery Bank

- Two batteries (e.g., one lead-acid, one lithium-ion) are used to store solar energy.
- Charging is done alternately or based on battery condition.

8. Battery 1,2 Switching Relay (Load Side)

- Selects the active battery to supply power to the load.
- Ensures uninterrupted power delivery by switching between batteries intelligently.
- Controlled by the microcontroller based on battery health and charge level.

9. Load

• Represents the system or device consuming the stored energy (e.g., home appliances, industrial equipment, etc.).

10. Battery Status Indicator

- Provides visual feedback (LEDs or digital readout) on battery status charging, full, low, etc.
- Controlled by the microcontroller based on voltage sensor data.

11. LCD 16x2 Display

- Displays real-time data such as solar voltage, battery voltage, load status, and battery selection.
- Useful for user monitoring and system diagnostics.





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Table 1: List of Component

Sr. No	Component	Specification
1	Solar Panel	20W, 18V, 1.2 Amp
2	LCD 16*2	24V DC
3	MOSFAT Drive	IR2104
4	MPPT Buck Converter	DC-DC Buck Converter
5	Inductor	33mH (5Amp)
6	Capacitor	220 uf
7	Lithium- Ion Battery	12V,9Ah
8	Battery Switching Relay	12 V DC
9	Lead acid Battery	12V, 9Ah
10	BLDC Motor Driver	24V DC
11	BLDC Motor Controller	24V DC
12	BLDC Motor	24V DC

IV. CALCULATIONS

1. Solar Panel Load Calculation

Panel Specifications:

The solar panel used in this system has the following key specifications: Rated **Power (Pmax) -** 10 W Open Circuit Voltage -21.5VVoltage at max Power (Vmp) -17.07 V Current at max power (Imp) -0.56 A

Maximum System Voltage: 600 V (This is relevant for system design safety, especially in larger arrays, but not for this small-scale calculation.)

For load calculations, the most relevant values are **Vmp** and **Imp**, as they represent real operating conditions under full sunlight.

Step 1: Current Calculation at Maximum Power

To verify the current output at maximum power, we use the power formula:

$$P = V \times I$$

Rearranging the formula to solve for current:

$$I=\frac{P}{V}=\frac{10W}{17.07V}\approx 0.586A$$

This confirms that the panel delivers approximately **0.586** A under ideal conditions, which is slightly higher than the rated **Imp** value of 0.56 A—indicating the data aligns well.

2. Lithium Iron Phosphate (LiFePO₄) Battery Backup Calculation

Battery Specifications:

A 12V, 9Ah LiFePO₄ battery is chosen for energy storage due to its high efficiency, lightweight design, and longer cycle life compared to traditional batteries.





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Battery Voltage: 12 V Battery Capacity: 9 Ah Battery Type: Lithium Iron Phosphate (LiFePO₄) Load Power: 12W and 24W are considered for comparison.

Step 1: Converting Battery Capacity to Watt-hours (Wh) Battery energy is typically expressed in watt-hours for easier power calculations:

Battery Capacity = $12V \times 9Ah = 108Wh$

This means the battery can supply 108 watt-hours of energy under ideal conditions.

Step 2: Run Time Calculations for Different Loads a) For a 12W Load:

$$\operatorname{Run Time} = \frac{108Wh}{12W} = 9 \operatorname{hours}$$

Assuming 95% system efficiency (due to inverter loss, cable losses, etc.):

Effective Run Time = $9 \times 0.95 = 8.55$ hours

So, this battery can power a 12W device for approximately 8.55 hours.

b) For a 24W Load:

Run Time = $\frac{108Wh}{24W}$ = 4.5 hours

Effective Run Time = $4.5 \times 0.95 = 4.28$ hours

In this case, the same battery will run a 24W load for around 4.28 hours.

3. Lead-Acid Battery Load Calculation

Battery Specifications:

The system also considers a 12V, 9Ah lead-acid battery, a widely available and cost-effective energy storage option.

Voltage – 12V and Capacity – 9Ah Load Power: Example load of 12W is used.

Step 1: Energy Capacity in Watt-hours

As with the LiFePO₄ battery, we convert amp-hours to watt-hours:

Battery Capacity=12V×9Ah=108Wh

However, lead-acid batteries are typically used only up to 50-70% of their rated capacity to avoid shortening their lifespan.

Assuming 70% usable capacity:

Usable Energy=108Wh×0.70=75.6Wh

Step 2: Run Time for a 12W Load

 $\operatorname{Run Time} = \frac{75.6Wh}{12W} = 6.3 \operatorname{hours}$





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Therefore, under safe usage limits, a 12V, 9Ah lead-acid battery can power a 12W load for approximately 6.3 hours.

Table 2: Summary of calculations

Parameter	Value
Solar Panel Output Current (at Vmp)	0.586 A
LiFePO ₄ Battery Capacity	108 Wh
Lead-Acid Battery Usable Capacity	~75.6 Wh (70% DOD)
LiFePO ₄ Runtime (12W Load)	~8.55 hours
LiFePO ₄ Runtime (24W Load)	~4.28 hours
Lead-Acid Runtime (12W Load)	~6.3 hours

V. MATLAB SIMULATION

5.1. Schematic diagram:



Figure 2: Schematic diagram for Matlab Simulation

5.2. MATLAB Simulation results:

1. MATLAB simulation of MPPT buck converter



Figure 3: MATLAB simulation of MPPT buck converter





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2. Solar Panel Output



Figure 4: Solar Panel Output

3. Solar Panel Output Power



Figure 5: Solar Panel Output power

4. Output Voltage of MPPT Buck Converter



Figure 6: Output Voltage of MPPT Buck Converter

5. MOSFET Firing



Figure 7: MOSFET Firing





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6. Output Parameter of Li-Ion Battery



Figure 8: Output Parameter of Li-Ion Battery

7. Output Parameters of Lead Acid Battery



Figure 9: Output Parameters of Lead Acid Battery

8. Change Over of Charging Relay Form Li-Ion to Lead Acid Battery When Li-Ion Charges Over 90%



Figure 10: Change Over of Charging Relay Form Li-Ion to Lead Acid Battery When Li-Ion Charges Over 90%

VI. RESULTS

A PV Hybrid Storage System typically consists of solar panels (photovoltaic or PV), batteries for energy storage, and sometimes a grid connection to supply electricity to a load. This system improves the dependability of renewable energy, reduces electricity expenses, and ensures continuous power even during grid outages or times of low solar generation.

To evaluate the performance of a PV Hybrid Storage System, the following main components should be considered:

1. **Solar Panel Output** – This is the amount of electricity produced by the solar panels under standard sunlight conditions.





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- 2. Battery Capacity Refers to the amount of energy the battery can store, usually measured in ampere-hours (Ah) or watt-hours (Wh).
- 3. Load Requirements The power needed by the devices or appliances connected to the system, generally measured in watts (W).
- 4. Efficiency of System Components Accounts for energy losses in different parts of the system, such as during solar energy conversion, battery charging/discharging, and inverter operation.
- 5. Sunlight Hours The average number of full sunlight hours the system receives daily, which varies depending on location and weather conditions.
- 6. **Hybrid System Characteristics** Describes whether the system is **off-grid**, **on-grid**, or **grid-connected with battery backup**, and explains how it interacts with the grid for energy supply and backup.

VII. CONCLUSION

A PV hybrid storage system is an intelligent and environment-friendly energy setup that combines solar photovoltaic (PV) panels with battery storage to deliver consistent and efficient electricity. The system collects solar energy during daylight and stores any extra power in batteries. This stored energy can then be used at night or when there is little sunlight, such as on cloudy days.

This system offers many useful benefits. It reduces the need for conventional electricity by producing power from sunlight, which helps save on electricity bills. With battery storage, power remains available even when solar panels are not generating electricity. This is especially helpful during power outages or in rural areas where grid power is limited or unavailable.

PV hybrid systems can work partly or completely without grid support, providing flexibility and improved energy security. They also help in reducing carbon emissions, supporting a cleaner and healthier environment.

The system functions through several steps. Solar panels absorb sunlight and generate direct current (DC) electricity. An inverter then converts the DC electricity into alternating current (AC), which is suitable for running appliances. Any extra power that isn't used right away is stored in batteries, which can later supply electricity when needed. This ensures the load (appliances or equipment) always has a steady power supply—either from the sun or from stored energy.

There are different types of hybrid systems, depending on how they work with the grid:

- Grid-tied hybrid systems stay connected to the grid and can transfer extra solar power back to the utility.
- **Off-grid hybrid systems** work completely independently from the grid, making them ideal for isolated or rural areas.
- **Grid-interactive hybrid systems** can operate both with or without the grid, providing backup power and flexibility depending on energy needs.

In conclusion, PV hybrid storage systems are a dependable, cost-saving, and eco-friendly way to meet energy demands. They reduce the need for fossil fuels, lower energy expenses, and offer continuous power supply, making them a valuable solution for a sustainable energy future.

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www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

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|DOI: 10.15680/IJIRSET.2025.1406194|

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