## 1. Introduction

Battery backup systems (also called UPS energy storage systems or standby power systems) provide electrical energy to critical loads during grid outages or unstable power conditions. They are used in residential solar systems, data centers, telecom towers, industrial processes, and emergency power installations.

A well-designed battery backup system must:

Deliver sufficient power (kW) for the connected loads.

Provide sufficient stored energy (kWh) for the required autonomy (backup duration).

Operate safely with proper protection, charging, and environmental controls.

Meet lifecycle and reliability expectations.

## 2. Components of a Battery Backup System

### 2.1 Core Components

Component Purpose

Battery Bank Stores energy (chemical → electrical).

Inverter/Charger Converts AC↔DC, manages charging & discharging.

Battery Management System (BMS) Safety, voltage/cell monitoring, balancing.

Automatic Transfer Switch (ATS) Switches load between grid and battery.

DC Disconnects & Protection Breakers/fuses for safety.

telemetry.

3. Battery Technologies for Backup Applications

3.1 Lead-Acid Variants

Flooded Lead-Acid (FLA) - low cost, high maintenance.

AGM (Absorbent Glass Mat) - sealed, good for UPS.

Gel - improved deep-cycle capability.

Pros: Affordable, reliable.
Cons: Heavy, shorter cycle life, lower usable depth-of-discharge (DoD).

3.2 Lithium-Ion (Li-ion)

NMC (Nickel-Manganese-Cobalt)

LFP (Lithium Iron Phosphate)

Pros: High cycle life (3000-6000 cycles), high energy density, fast charging, 80-95% usable DoD.
Cons: Higher cost, requires sophisticated BMS.

3.3 Others (less common)

Flow batteries

Sodium-ion (emerging)

Ni-Cd for extreme conditions

## 4.1 Key Design Parameters

Load Power (W or kW)

Backup Duration (hours)

Battery Chemistry

Voltage System Architecture (12V / 24V / 48V / 72V)

Depth of Discharge (DoD)

Efficiency losses (inverter, wiring)

Temperature effects

Safety margins (typically 10–25%)

# 5. Battery Sizing Methodology

Battery sizing is based on energy and power.

## 5.1 Step 1: Determine connected load

Step 3: Calculate Required Battery Ah Capacity This calculation accounts for system inefficiencies and the permissible Depth of Discharge (DoD).

Required Battery Ah = (Total Energy (Wh) / System Voltage (V)) / (Battery DoD / 100) / Inverter Efficiency / Battery Efficiency

System Voltage (V): 48V

Assumed Li-ion (LFP) parameters:

DoD: 80% (0.80)

Inverter Efficiency: 90% (0.90)

Battery Round-Trip Efficiency: 95% (0.95)

Required Battery Ah = (2120 Wh / 48 V) / 0.80 / 0.90 / 0.95
Required Battery Ah = 44.17 Ah / 0.80 / 0.90 / 0.95
Required Battery Ah ≈ 64.57 Ah

Thus, a battery bank providing at least 65 Ah at 48V is needed.

Step 4: Determine Battery Bank Configuration If using 12V 100Ah LiFePO4 batteries:

Number of batteries in series: 48V / 12V = 4 batteries.

This forms one string of 48V 100Ah. Since 100Ah > 65Ah, one string of 4 x 12V 100Ah batteries is sufficient.

3.2. Inverter Sizing
Objective: Determine the continuous power rating (in Watts or VA) for the inverter.

Step 1: Calculate Total Peak (Surge) Load

Identify the maximum instantaneous power demand by including the higher starting (surge) currents of inductive loads (e.g., refrigerators, motors). These surge currents can be 3–7 times the normal running current for a brief period.

Example (from previous loads):

Refrigerator (100W running, 500W surge)

Lights (50W), Router (15W), Laptop (50W), TV (60W)

Worst-case Peak Load = (Refrigerator Surge) + Lights + Router + Laptop + TV

Peak Load = 500W + 50W + 15W + 50W + 60W = 675W

Component Parameter Calculated Value / Selection Notes
Battery Bank Total Energy Demand 2120 Wh For 12-hour essential load backup
System Voltage 48 V DC
Required Ah Capacity 65 Ah @ 48V Using Li-ion (80% DoD), Inverter (90%), Battery (95%) Efficiencies
Selected Batteries 4 x 12V 100Ah LiFePO4 Connected in series for 48V 100Ah total capacity
Inverter Peak Load (W) 675 W Refrigerator surge + running loads
Required Rating (W/VA) 844 W / 1000 VA With 1.25x safety factor on peak load
Selected Inverter 1000W / 1000VA Pure Sine Wave Ensures compatibility with sensitive electronics

Other Important Factors:

devices (fuses, circuit breakers, disconnects) and ensure proper grounding. Battery installations require proper ventilation and protection from environmental extremes.

Battery Management System (BMS): Crucial for Li-ion batteries to monitor cell health, balance charge, and protect against hazardous conditions.

Maintenance: While Li-ion is low-maintenance, lead-acid batteries require regular checks.

5. Conclusion

Designing an effective battery backup system is a systematic process that begins with a thorough analysis of the critical loads and desired backup duration. By carefully calculating the required battery capacity and inverter power, while accounting for system efficiencies and safety factors, a resilient and reliable power solution can be engineered.