BESS & MICROGRIDS · 45–60 MIN

BESS and Microgrids: A Practical Guide to Power, Energy and Control

A rigorous, plain-language study of how storage behaves as a controlled power system, from power and energy fundamentals to safety, degradation, dispatch, resilience, economics and acceptance evidence.

ORIGINAL METRO POWER PAPER

Second edition · 30 August 2026 · Review before project use

PUBLICATION CONTROL

A traceable educational edition.

This record separates publication authority from project approval. It identifies what was researched, what remains limited and when the source base must be reviewed again.

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NEXT SOURCE REVIEW

30 August 2027 or earlier if a controlling issuance changes

Earlier if a controlling issuance changes

ABSTRACT

What this paper examines.

This paper treats battery storage as a controlled power system. It separates power from energy, traces BMS, PCS and EMS authority, explains usable capacity and degradation, examines dispatch conflicts, safety layers, microgrid transitions, economics and acceptance evidence, and identifies the Philippine questions that must be resolved before commercial commitment.

IN SCOPE

- Stationary electrochemical BESS and microgrid planning
- Power, energy, controls, safety, resilience and economics
- Project evidence gates from discovery through handover

LIMITATIONS

- Does not provide final sizing, protection, fire, structural or interconnection design
- Chemistry, product configuration, location and operating mode materially change the hazard and approval path
- Draft regulatory material is identified as draft and must not be treated as final

PHILIPPINE APPLICABILITY AND SOURCE AUTHORITY

Guidance, drafts and controlling authorities are not interchangeable.

AUTHORITY · Energy Regulatory Commission

INSTRUMENT ·

ERC Case No. 2024-006 RM, draft ESS rules and interconnection standards

STATUS · **Draft rulemaking · verify whether superseded or finalized**

USE ·

Philippine ESS regulatory and interconnection pathway

AUTHORITY · Energy Regulatory Commission

INSTRUMENT ·

Resolution No. 11, Series of 2026 and MGSP ATO advisory

STATUS · **Current microgrid authority material**

USE ·

Microgrid-service-provider operating authority and ESS records

AUTHORITY · US Department of Energy

INSTRUMENT ·

Energy Storage Safety Strategic Plan

STATUS · **International safety research and lifecycle guidance**

USE ·

Validation, commissioning, operations and safety research priorities

AUTHORITY · Sandia National Laboratories

INSTRUMENT ·

DOE Energy Storage Handbook

STATUS · **International engineering guidance**

USE ·

Technology, applications, engineered systems and project planning

ACRONYMS AND WORKING TERMS

Use the same language at every decision gate.

BESS	Battery Energy Storage System
BMS	Battery Management System
EMS	Energy Management System
PCS	Power Conversion System
POI	Point of Interconnection
SOC	State of Charge
SOH	State of Health
STS	Static Transfer Switch

REVISION HISTORY

What changed and when.

1.0	28 August 2026	Initial public web edition
2.0	30 August 2026	Research, technical-writing and editorial-control upgrade

SUGGESTED CITATION

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What you should be able to explain after reading.

01 Distinguish kW, kWh, state of charge and usable energy

02 Trace the battery, BMS, PCS, EMS, protection and site interfaces

03 Match operating use cases to data, dispatch and acceptance criteria

04 Identify the engineering, safety and commercial evidence required before sizing

SYSTEM ARCHITECTURE

Follow the complete operating chain.

01 →

02 →

03 →

04 →

05 →

06

BESS AND MICROGRIDS · LONG-FORM TECHNICAL EDITION

At 3:00 p.m., site demand begins to climb. Should the battery discharge now?

A battery can respond in milliseconds, but a responsible decision begins much earlier with the use case, load profile, reserve policy, electrical design and operating authority.

Imagine a facility with a 600 kW demand target, rooftop solar, a critical operations building and a Battery Energy Storage System. At 3:00 p.m., load rises toward the target while solar output begins to fall. The EMS can discharge the battery to reduce imported power. Three hours later, the grid fails.

If the battery used too much energy for peak shaving, the resilience reserve may be insufficient. If the PCS cannot establish voltage and frequency, the battery cannot form an island. If protection, grounding and switching were not designed for that mode, opening the grid breaker does not create a safe microgrid. The same battery capacity can therefore produce very different outcomes depending on control priorities and system architecture.

THE PROMISE OF THIS PAPER

By the end, you should be able to separate power from energy, trace the battery through BMS, PCS and EMS controls, evaluate usable capacity, explain why safety and interconnection are lifecycle responsibilities, and challenge a storage proposal that begins with container size instead of operating evidence.

FLAGSHIP TECHNICAL EDITION

BESS and microgrids as controlled power systems

This edition separates power from energy, connects the battery to PCS and EMS behavior, and examines safety, degradation, interconnection, resilience, economics and acceptance evidence.

8 chapters | 12 original figures | 2 worked cases | 45–60 minute study

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01

USE-CASE DEFINITION

The required service determines the battery system

A BESS is not sized responsibly from a monthly bill or a desired container count. First define the service: demand reduction, energy shifting, renewable firming, backup, frequency response, capacity support, power-quality assistance or microgrid operation. Each service has a different response time, power, energy, reserve, availability and dispatch requirement. The US DOE Energy Storage Handbook organizes storage around technologies, engineered systems and applications for exactly this reason [1] .

Start by writing the operating statement in plain language. “Hold grid import below 600 kW during the utility demand interval” is testable. “Provide two hours of critical-load support after loss of grid” is testable once the critical-load profile and transition requirement are defined. “Install a 1 MWh battery” is not a use case. It is an equipment quantity without an operating promise.

A project may pursue several value streams, but they can compete. Energy reserved for an outage cannot simultaneously be committed to daily arbitrage. High cycling for one service can accelerate degradation and reduce future energy available to another. Dispatch priority and commercial priority must therefore be written together.

FIGURE 1

BESS operating architecture

1
Grid or generation →

2
Transformer and protection →

3
PCS / inverter →

4
Battery racks and BMS →

5
EMS / microgrid controller →

6
Loads and dispatch

How to read this figure. The battery stores DC energy, the PCS exchanges controlled AC power, and the EMS decides when operation is permitted. Protection and the grid interface remain system-level responsibilities.

FIGURE 2

Use-case requirements are not interchangeable

Use case	Response	Energy
Peak shaving	Medium response	High daily energy
Frequency support	Very fast response	Short-duration energy
Backup	Transfer dependent	Reserved duration
Renewable firming	Variable response	Forecast-dependent energy
Microgrid	Grid-forming may apply	Critical-load duration

How to read this figure. Relative profiles are conceptual. Final ratings require interval data, network studies, operating rules and vendor performance evidence.

02

SIZING FUNDAMENTALS

Power, energy, duration and usable state of charge answer different questions

Power, expressed in kW or MW, describes the instantaneous rate of charge or discharge. Energy, expressed in kWh or MWh, describes how much can be delivered over time. A 1 MW / 2 MWh system has a nominal two-hour duration at rated power before accounting for usable SOC window, auxiliary consumption, conversion loss, temperature, degradation and operating reserve.

Nameplate energy is not the same as energy delivered at the point of interconnection. The model should distinguish DC battery capacity, usable DC window, PCS efficiency, transformer and cable loss, HVAC and controls, minimum reserve and end-of-life guarantee. NREL notes that power and energy together define BESS size and that oversizing can strand capital [2] .

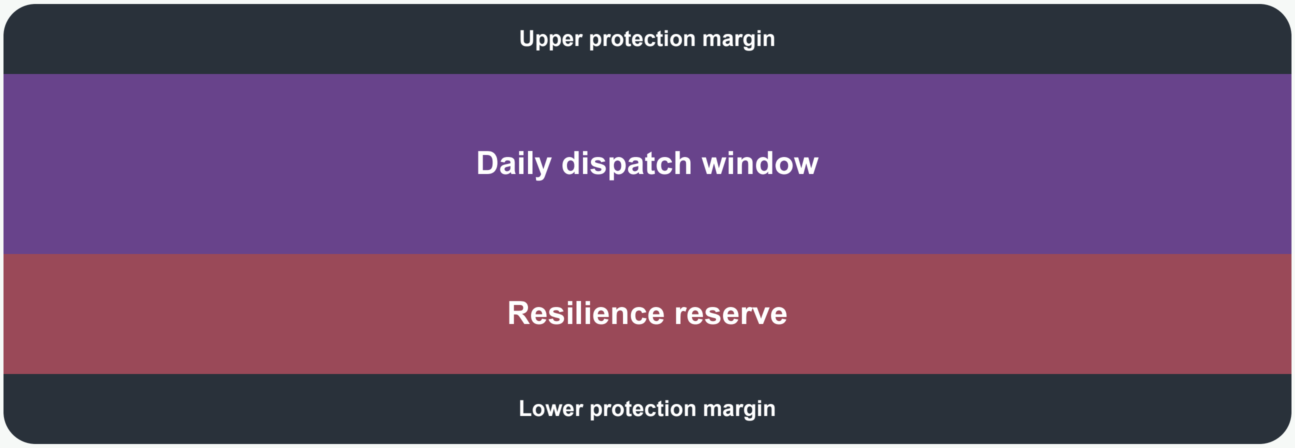
State of charge is an estimate inside an operating window

State of charge, or SOC, expresses the estimated remaining charge relative to a defined usable reference. It is not a direct fuel-gauge measurement. The BMS estimates SOC from electrical and temperature behavior using its supported methods. Accuracy can vary with operating history, calibration and cell condition.

Operators also distinguish state of health, which describes how present capability compares with an agreed beginning-of-life reference. A system at 90 percent SOC late in life does not necessarily contain the same usable energy it held at 90 percent when new. Warranty and dispatch models should therefore state whether limits and guarantees apply at cell, rack, DC bus, PCS output or point of interconnection.

FIGURE 3A

SOC, reserve and degradation define different boundaries



How to read this figure. Illustrative bands. The operating controller should know which energy is available for daily dispatch, which is reserved and how end-of-life capacity changes the absolute energy behind the percentages.

FIGURE 3

From nameplate energy to useful delivered energy

How to read this figure. Illustrative waterfall. Each project must use the exact warranted SOC window, efficiency method, auxiliary profile and degradation condition.

CONCEPT SIZING RELATIONSHIP

Required nominal energy

delivered load energy ÷ (usable SOC fraction × discharge-path efficiency × end-of-life capacity fraction)

This frames the calculation only. A qualified design must include load sequence, power limits, reserve, auxiliaries, temperature and warranty rules.

WORKED CASE 1

Why 500 kW for two hours is not simply a 1,000 kWh purchase

A facility wants 500 kW delivered for two hours. Assume, only for illustration, an 80 percent usable SOC window, 92 percent discharge-path efficiency and 80 percent end-of-life capacity.

Required delivered energy: 500 kW × 2 h = **1,000 kWh**.

Combined usable factor: 0.80 × 0.92 × 0.80 = **0.5888**.

Indicative beginning-of-life nameplate: 1,000 ÷ 0.5888 = **1,698 kWh**.

Add verified auxiliary and reserve requirements, then check whether 500 kW remains available across SOC, temperature and warranty limits.

Decision lesson

Duration is an operating requirement. Nameplate capacity is only one input to meeting it.

Battery cells do not operate the AC system by themselves

Cells form modules, modules form racks and racks form DC subsystems monitored by a battery-management system. The BMS supervises voltage, current, temperature, SOC estimates and protective limits. The PCS converts between DC and AC and controls active and reactive power within its capability. The EMS or microgrid controller translates site objectives into permitted setpoints while coordinating forecasts, meters, generators and operating constraints.

These controls operate at different speeds and authority levels. Cell voltage or temperature protection cannot wait for an economic optimizer. The BMS should constrain permitted charge and discharge. The PCS should respect those limits while controlling AC behavior. The EMS may choose the desired dispatch only inside the permitted envelope. Independent protection should isolate faults under the approved design even if a supervisory communication link is unavailable.

Protection, switchgear, transformer, grounding, metering, communications, HVAC, fire detection, enclosure and auxiliary power are not accessories. They determine whether the system can connect, survive faults, maintain temperature, stop safely and be operated after handover.

FIGURE 4

Control hierarchy and decision ownership

1	**Business objective**	Tariff, resilience and service commitment
2	**EMS or controller**	Dispatch, reserve and coordination
3	**PCS control**	AC power, voltage and frequency behavior
4	**BMS**	Cell limits, temperature and protective state
5	**Protection**	Independent trip and isolation functions
6	**Physical system**	Cells, racks, cables, transformer and grid

How to read this figure. Fast protective action remains close to the equipment. Economic optimization must never bypass BMS, PCS, protection or interconnection limits.

FIGURE 5

Key interfaces to control

Interface	Information or power exchanged	Failure question	Acceptance evidence
BMS to PCS	Permitted current and status	What happens when data is stale?	Limit and trip tests
EMS to PCS	Power and mode setpoints	What happens on comms loss?	Fallback-mode test
PCS to grid	AC current and voltage behavior	Will protection coordinate?	Study and witnessed tests
BESS to site	Power, auxiliaries and alarms	Can the site sustain safe shutdown?	Integrated commissioning

How to read this figure. Many failures occur between packages. The responsibility matrix should name who designs, supplies, configures, tests and accepts each boundary.

04

DISPATCH AND EMS

A schedule is only valid inside operating constraints

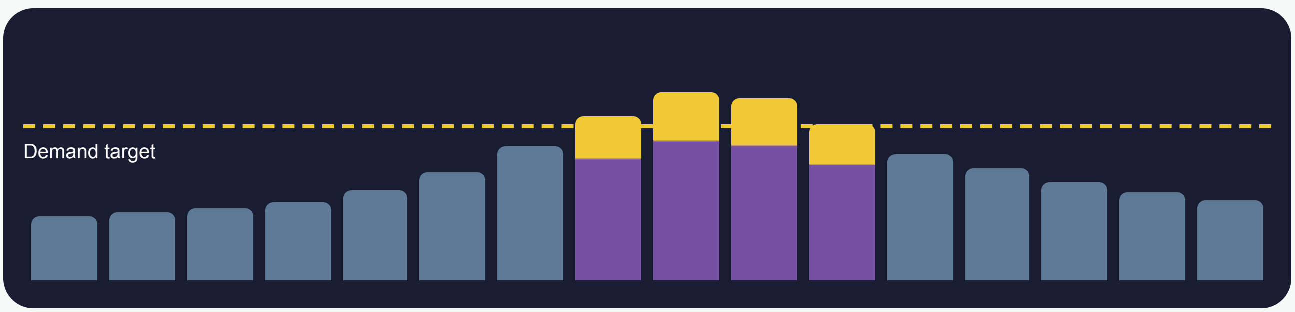
Peak shaving requires a demand forecast and enough power and energy to hold the site below a target through the peak interval. Arbitrage requires tariff spread large enough to cover efficiency loss, degradation, operating cost and financing. Renewable firming needs a forecast, ramp objective and curtailment logic. Resilience needs an explicit reserve policy and critical-load model.

The shape of the peak matters. A 1 MW spike lasting five minutes can require high power but relatively little energy. A 400 kW exceedance lasting three hours needs less instantaneous power but much more energy. Monthly bills normally reveal the peak charge and total energy, not the interval shape needed to distinguish these cases.

The EMS should define priority when services conflict, recovery after communication failure, SOC targets, generator coordination, import and export limits, maintenance states and manual authority. Cybersecurity matters because the controller can influence substantial real power.

FIGURE 6

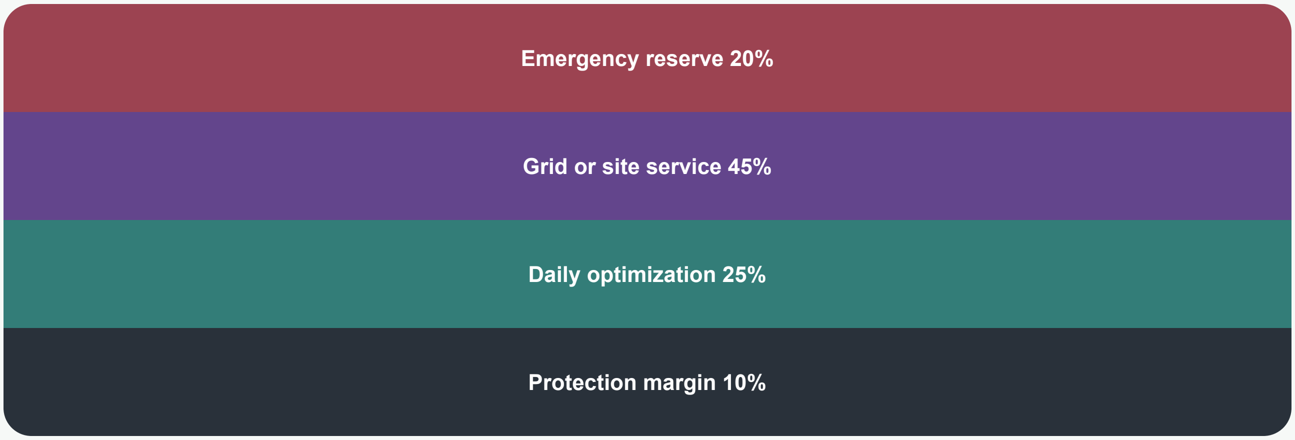
Illustrative peak-shaving dispatch



How to read this figure. The BESS discharges only where the original site load exceeds the target. Required energy equals the area between load and target, adjusted for system losses and reserve.

FIGURE 7

Competing value streams need dispatch priority



How to read this figure. The same SOC cannot be promised twice. Reservation rules preserve energy for the highest-priority obligation.

05

SAFETY AND LIFECYCLE

Safety is an engineered lifecycle, not a certificate list

Electrochemical hazards depend on chemistry, cell condition, enclosure, propagation behavior, ventilation, detection, suppression strategy, separation, emergency access and operating response. The US DOE Energy Storage Handbook addresses performance testing, electrochemical safety, physical security, cybersecurity, procurement and commissioning as distinct engineering topics [1] .

A thermal event can progress through abnormal cell behavior, heating, venting and propagation depending on chemistry, design and failure conditions. Detection must be connected to an approved response. An alarm that reaches an unattended dashboard has not created emergency readiness. Site personnel and responders need clear isolation boundaries, hazards, access information and authority.

The project must identify applicable current codes and authority requirements, then translate them into site design, product evidence, hazard analysis, emergency procedures, training, inspection and maintenance. A foreign listing or report can be relevant evidence but does not, by itself, establish Philippine approval.

FIGURE 8

Layered safety model

1 **Prevent** Cell quality, limits and thermal management	2 **Detect** Gas, smoke, heat and electrical monitoring
3 **Contain** Propagation and enclosure strategy	4 **Isolate** Protection, shutdown and electrical separation
5 **Respond** Emergency plan, access and trained personnel	

How to read this figure. Prevention, detection, containment, isolation and response work together. No single layer should carry the entire risk treatment.

06

MICROGRIDS AND RESILIENCE

Backup capability requires a supported electrical operating mode

A grid-connected BESS does not automatically form an island. Microgrid operation requires a defined boundary, isolation method, grid-forming source or compatible control strategy, protection changes, grounding treatment, load shedding, generator and renewable coordination, black-start sequence where required, resynchronization and utility approval.

Grid-following operation generally synchronizes to an existing voltage and frequency reference. **Grid-forming** operation can establish or regulate that reference within a supported design. These phrases do not prove black-start capability, seamless transfer or compatibility with every generator and inverter. The exact PCS mode, controller sequence, protection and tested configuration determine what can be claimed.

Critical-load resilience must use an interval or scenario profile, not merely the building peak. Motor starting, step load, inrush, harmonics, minimum generator loading and communications availability can determine whether the island remains stable.

FIGURE 9

Grid-connected to islanded operating sequence

1 Detect grid event

2 Confirm trip criteria

3 Open point of common coupling

4 Establish voltage and frequency

5 Connect prioritized loads

6 Balance sources and SOC

7 Resynchronize and return

How to read this figure. Each transition requires approved controls and witnessed tests. Opening a breaker is not a complete microgrid design.

07

ECONOMICS AND DEGRADATION

Model each value stream once and carry performance through time

Economics should separate demand reduction, energy shifting, avoided outage cost, renewable utilization and other services. A benefit must have a baseline, dispatch rule, tariff or valuation basis, adoption timing and responsible owner. Avoid double counting energy that serves two commitments in the same interval.

Round-trip efficiency is also conditional. It depends on power level, temperature, auxiliaries, SOC range and where energy is measured. A headline PCS efficiency does not equal site-level round-trip efficiency. The economic model should use the warranted or tested boundary relevant to billing and include HVAC, controls and standby energy.

FIGURE 9A

One stored megawatt-hour does not return one delivered megawatt-hour

1,000 kWh AC energy imported	→	**940 kWh** After charge conversion	→	**910 kWh** After storage and standby	→	**855 kWh** Delivered after discharge path

How to read this figure. Illustrative energy path. Project economics should use the agreed measurement boundary and realistic auxiliary load rather than a component peak-efficiency claim.

Capacity and efficiency change with age, cycles, calendar time, temperature and operating window. The model should state beginning and end-of-life performance, augmentation, replacements, availability, downtime, auxiliary energy, warranty throughput and residual value.

WORKED CASE 2

Testing whether a demand-saving claim is technically available

A project assumes 600 kW of monthly demand reduction. Interval data shows the relevant peak lasts 2.6 hours, while another resilience commitment reserves 30 percent SOC.

Calculate energy needed above the demand target from interval data, not 600 kW × the billing period.

Apply PCS limit, SOC reserve, efficiency, auxiliary load and end-of-life capacity.

Verify recharge opportunity before the next potential peak.

Model missed forecasts and downtime instead of assuming perfect dispatch.

Value only demand reduction that the operating strategy can reliably deliver.

08

PHILIPPINE PATHWAY AND PROCUREMENT

Freeze the use case, evidence and approval path before commitment

The Philippine DOE issued an ESS policy framework under DC2019-08-0012, and current project treatment depends on application, ownership, connection and applicable market or utility requirements [3] . Confirm the current DOE, ERC, NGCP or distribution-utility pathway, system-impact requirements, environmental and local permits, fire and electrical approvals, and the authority having jurisdiction for the exact project.

Procurement should define the guaranteed power and energy at an agreed condition and measurement point, usable SOC window, efficiency method, auxiliary treatment, availability, degradation curve, throughput or cycle conditions, augmentation, warranty exclusions and acceptance tests. A warranty stating only years and cycles may not explain how operating temperature, depth of discharge, C-rate and annual throughput affect coverage.

Before sizing

Obtain interval load, tariff, outage, critical-load, renewable and site data.

Before selection

Confirm use case, ratings, duration, chemistry, warranty and operating envelope.

Before production

Freeze SLD, protection, controls, interfaces, safety design and tests.

Before energization

Complete studies, permits, commissioning, emergency plan and training.

Before acceptance

Before final handover

Demonstrate capacity, power, efficiency, controls, protection and use case.

Deliver as-builts, settings, credentials, spares, warranty and lifecycle plan.

FIGURE 10

Project evidence gates

GATE 1 **Use case and data**	GATE 2 **Concept and studies**
GATE 3 **Approved design**	GATE 4 **Factory evidence**
GATE 5 **Site commissioning**	GATE 6 **Performance acceptance**

How to read this figure. Proceed only when the current stage has controlled evidence and an authorized decision.

NUMBERED REFERENCES

Primary sources engaged in this edition

US DOE Energy Storage Handbook

Sandia National Laboratories. Technologies, engineered systems, safety, commissioning and applications.

Preparing Distribution Utilities for Utility-Scale Storage and Electric Vehicles

NREL. BESS power, energy, sizing and peak-shaving context.

Philippine DOE Energy Sector Accomplishment Report

Official context for DC2019-08-0012 and ESS applications.

BESS Procurement Checklist

US DOE FEMP. Procurement planning reference.

All diagrams and illustrative calculations are original Metro Power educational material. Concept examples are not final engineering or a performance guarantee.

SECOND-EDITION TECHNICAL REVIEW

Second-edition evidence review: usable energy, hazard boundaries and operating authority

A storage decision is complete only when the energy model, electrical behavior, safety case, interconnection path and commercial obligation use the same configuration and operating assumptions.

01

DC cell energy, DC rack energy, PCS AC output and point-of-interconnection delivery are not interchangeable. Efficiency, auxiliaries and guarantees must use an identified boundary.

02

Daily peak shaving, arbitrage, resilience and grid services can compete for the same state of charge. EMS priority and commercial commitment must reconcile.

03

Product reports, site design, installation, commissioning, emergency planning, training, maintenance and change control form one lifecycle safety case.

A BESS evidence schedule should control every package boundary.

Boundary

Battery to BMS

Design question

What cell limits, sensors and protective states apply?

Acceptance evidence

Exact model data, alarms, limits and witnessed protective behavior

Do not infer

A chemistry label proves system safety

Boundary

BMS to PCS

Design question

How are permitted power and stale data handled?

Acceptance evidence

Interface specification and loss-of-communications test

Do not infer

Compatible connectors prove coordinated control

Boundary

PCS to grid

Design question

What active, reactive, fault and transition behavior is supported?

Acceptance evidence

Study models, settings and witnessed tests

Do not infer

Rated kW proves interconnection compliance

Boundary

EMS to site

Design question

Which service has priority and what reserve is protected?

Acceptance evidence

Approved dispatch logic, scenarios and audit records

Do not infer

Optimization will always preserve backup

Boundary

Enclosure to responders

Design question

How are abnormal conditions detected, isolated and communicated?

Acceptance evidence

Site hazard analysis, emergency plan, access and drills

Do not infer

A factory certificate completes site readiness

WORKED EVIDENCE CASE

Sizing a resilience obligation through the delivered-energy boundary

A critical load needs 420 kW for 2.5 hours. Illustrative assumptions are 85 percent usable SOC, 91 percent discharge-path efficiency, 82 percent end-of-life capacity and 35 kW of continuing BESS auxiliaries.

Load energy is 420 kW × 2.5 h = 1,050 kWh.

Auxiliary energy is 35 kW × 2.5 h = 87.5 kWh.

Total delivered requirement is 1,137.5 kWh before additional reserve.

Combined usable factor is 0.85 × 0.91 × 0.82 = approximately 0.634.

Illustrative beginning-of-life nameplate is 1,137.5 ÷ 0.634 = approximately 1,794 kWh, before project-specific reserve and power checks.

Verify that PCS power, starting current, temperature, SOC limits and island controls support the full load sequence.

DECISION LESSON

The calculation frames a requirement. It is not a final design because power limits, load sequence, protection, temperature, warranties and approved reserve policy still control.

FAILURE-MODE REVIEW

What to challenge before commitment.

Peak shape and required dispatch energy remain unknown

Evidence: Validated interval load profile

Backup mode cannot establish a stable electrical reference

Evidence: Exact mode declaration and integrated transition test

Delivered duration is overstated

Evidence: Measured or warranted auxiliary profile

Commercial commitment follows an unverified approval path

Evidence: Current ERC, DOE, NGCP, DU and local-authority confirmations

VERIFIED CONTEXT

- ERC has published draft ESS rules and interconnection standards under ERC Case No. 2024-006 RM
- ERC issued 2026 microgrid-service-provider operating-authority materials

VERIFY FOR THE PROJECT

- Whether the draft ESS rules have been finalized or superseded
- Project classification and applicable COC, ATO, interconnection, market and local requirements
- Fire, building, electrical, environmental and emergency-response acceptance for the exact site

PROJECT GATE

Hold final price, performance and approval commitments until the project classification, interval data, single-line, site constraints, exact configuration and responsible authorities are confirmed.