

Understanding Battery Banks and Charging Systems

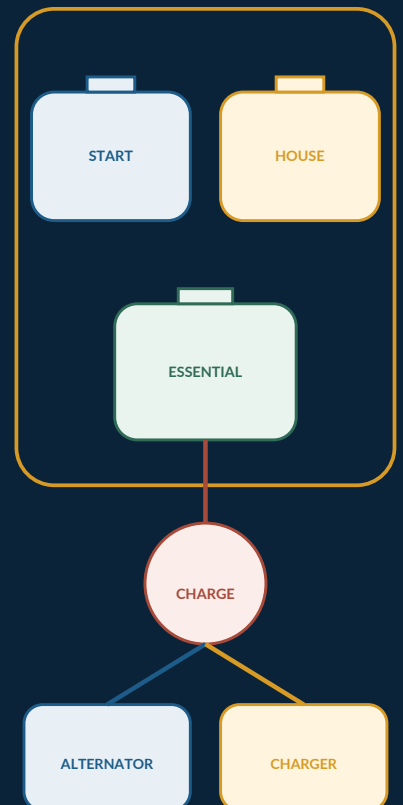
An owner's guide to battery chemistry, capacity, charging, protection and resilience

A battery bank can appear healthy until the moment real capacity is needed.

Readiness depends on usable energy, correct charging and safe isolation.

Absolute Marine

Commercial thinking for private cruising.



STORE | PROTECT | RECHARGE

GUIDE OVERVIEW

What battery banks and charging systems are designed to do

Battery banks store electrical energy for starting, essential, navigation and domestic loads. Charging sources must restore that energy without damaging the batteries, cabling or connected equipment.

SCOPE	This guide covers common 12 V, 24 V and higher-voltage low-voltage DC arrangements used on cruising yachts. It provides owner-level understanding of lead-acid and lithium iron phosphate systems, not design or repair instructions. Current manufacturer documentation remains essential.
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By the end of this guide, you should be able to:

- Identify starting, house, essential and emergency banks and understand their normal separation.
- Explain the difference between nominal capacity, usable capacity, state of charge and actual runtime.
- Recognise incorrect charging, capacity loss, imbalance, overheated connections and protection-system trips.
- Understand how alternators, chargers, inverter-chargers, DC-DC devices and solar charging interact.
- Ask better questions during purchase, survey, refit, maintenance and offshore preparation.

CORE PRINCIPLE	Voltage alone does not prove capacity, and a charger showing 'float' does not prove the bank is healthy. Readiness depends on demonstrated energy, correct settings and reliable protection.
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Safety

Battery banks can deliver very high fault current. Lead-acid batteries may release hydrogen and corrosive electrolyte; lithium systems can involve rapid heating and automatic isolation. Remove jewellery, protect terminals and do not work live unless the task and procedure are appropriate.

SYSTEM ARCHITECTURE

How stored energy, charging and protection fit together

A useful electrical drawing should show each bank, charger, alternator, isolator, fuse, busbar, emergency link, shunt, BMS, temperature sensor and the loads that remain after one component is lost.



Monitoring, temperature sensing, emergency parallel and load-shedding arrangements sit across the complete chain.

Common bank duties

- Engine starting: Delivers high current for short periods and should remain protected from domestic discharge.
- Generator starting: May be separate or shared, but the consequences of the arrangement should be understood.
- House or domestic bank: Supplies lighting, pumps, refrigeration, electronics and inverter loads.
- Essential or navigation bank: Preserves selected critical services after another bank or distribution section fails.
- Emergency bank: Supports designated emergency loads according to the vessel's design or regulatory requirements.
- Bow-thruster or windlass bank: Supplies short high-current loads and may be remotely charged.

REDUNDANCY DEPENDS ON SEPARATION	Two labelled banks are not independent if they share one charger, fuse, negative connection, BMS, isolation contactor or control supply that can remove both.
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BATTERY CHEMISTRY

Lead-acid, AGM, gel and lithium iron phosphate

Different chemistries have different charging voltages, temperature limits, ventilation needs, usable-depth assumptions and failure behaviour. Settings should match the exact battery, not a broad label.

FLOODED LEAD-ACID

Serviceable electrolyte, venting and spill control

AGM / GEL

Sealed lead-acid with chemistry-specific charging

LITHIUM IRON PHOSPHATE

High usable capacity with BMS and system integration

OTHER CHEMISTRIES

Require exact manufacturer limits and installation design

Chemistries must not be treated as interchangeable: charging, protection, ventilation and emergency behaviour differ.

Chemistry	Typical characteristics	Owner focus
Flooded lead-acid	Serviceable electrolyte, gas during charging, proven starting capability and gradual ageing.	Ventilation, electrolyte level where applicable, corrosion, spill containment and correct charge profile.
AGM lead-acid	Sealed construction, low routine maintenance and good high-current performance.	Avoid overcharge and chronic undercharge; temperature compensation and correct absorption time matter.
Gel lead-acid	Sealed gelled electrolyte with lower tolerance for excessive charge voltage.	Use chemistry-specific settings and avoid assuming AGM and gel are interchangeable.
Lithium iron phosphate	High usable capacity, low voltage sag and strong charge acceptance with electronic protection.	BMS integration, low/high-temperature limits, contactors, alternator control and emergency isolation strategy.
Mixed chemistry installation	Different banks may require different voltage and current profiles.	Use isolated or controlled charging paths; do not parallel incompatible banks casually.
Unknown or modified bank	Labels, charger settings and documentation may not agree with installed cells/modules.	Identify exact model, age, configuration and protection before changing settings or combining banks.

DO NOT COPY SETTINGS FROM ANOTHER YACHT

Charge voltage, absorption time, float use, temperature limits and maximum current vary by battery model and installation. Use current manufacturer data.

BANK CONFIGURATION AND CAPACITY

Series, parallel, nominal ratings and usable energy

Battery banks are assembled to provide the required voltage, current and endurance. Capacity ratings depend on test conditions, temperature, discharge rate, age and the permitted state-of-charge window.

SERIES
Raises voltage while amp-hour capacity remains

PARALLEL
Raises amp-hour capacity at the same voltage

SERIES-PARALLEL
Combines voltage and capacity groups

BANK SEPARATION
Keeps starting, house and essential duties independent

Term or arrangement	What it means	Owner focus
Amp-hours (Ah)	Charge capacity stated at a defined voltage, discharge rate and temperature.	Do not compare Ah across different bank voltages without converting to energy.
Watt-hours (Wh)	Approximate electrical energy: nominal voltage multiplied by amp-hours.	Useful for comparing banks and loads, but actual usable energy remains lower.
Series connection	Voltages add while the string's Ah remains that of one battery.	One weak unit can limit the complete string; cable and fuse ratings follow full bank voltage/current.
Parallel connection	Ah and current capability add at the same voltage.	Balanced cabling, matched batteries and individual string protection where required.
Usable capacity	Energy available inside the permitted depth-of-discharge and voltage limits.	Chemistry, age, temperature, discharge rate, inverter cut-off and reserve strategy.
Capacity test	Controlled discharge measures actual runtime or delivered Ah/Wh.	Use an appropriate procedure and protect critical services; specialist testing may be preferable.

ONE WEAK UNIT CAN LIMIT THE BANK

Replacing a single battery in an aged series or parallel bank may create imbalance. Assess the complete bank, installation history and manufacturer guidance.

INSTALLATION AND PROTECTION

Restraint, ventilation, fusing, cabling and isolation

High-current DC faults can develop very quickly. Battery boxes, cables, fuses, isolators and busbars should limit movement, contact, overheating and the spread of a single fault.

RESTRAINT

Secure against vessel motion and short-circuit movement

VENTILATION

Controls heat, gas and manufacturer requirements

PROTECTION

Fuse close to source and covered live terminals

ACCESS

Inspection and isolation without unsafe contact

Area	Common weakness	Owner focus
Battery restraint and enclosure	Movement, damaged cases, exposed terminals, water entry or poor access.	Secure hold-downs, non-conductive protection, drainage and inspection in vessel motion.
Ventilation and heat	Gas or heat accumulates, cooling air is blocked or equipment sits beside hot machinery.	Chemistry-specific ventilation, temperature trend and no ignition source in gas path.
Main fuse or circuit protection	Too far from source, wrong interrupt rating, bypassed or inaccessible.	Correct type/rating, protected mounting and spare strategy without unsafe improvisation.
Cables and lugs	Undersized cable, loose crimp, corrosion, chafe or unbalanced parallel paths.	Full-length inspection, strain relief, support, voltage drop and thermal imaging under load.
Isolation switches/contactors	Seized, underrated, unclear, inaccessible or dependent on control power.	Normal position, emergency action, local/manual operation and safe reconnection procedure.
Negative and bonding arrangements	Unexpected shared return, loose connection or undocumented chassis link.	Current drawings, shunt placement and no bypass of monitoring or protection paths.

A LOOSE CONNECTION IS A HEATER

High resistance may show as voltage drop, discolouration, softened insulation or a hot terminal under load. Tighten only to the correct procedure and torque; damaged lugs or studs need proper repair.

MONITORING AND STATE OF CHARGE

Why voltage is only one part of the picture

Battery condition is best understood from voltage, current, temperature, charge history, cell information and demonstrated runtime. Every instrument has assumptions that can drift.

VOLTAGE
Shows electrical potential but not capacity alone

CURRENT
Shows charge or discharge at that moment

SHUNT / BMS
Counts energy and tracks cell or bank condition

TEMPERATURE
Changes limits and reveals abnormal heating

TREND
Combines data with load, time and known baseline

Measurement	What it can show	Limitations and owner focus
Open-circuit voltage	Approximate state of charge for some chemistries after sufficient rest.	Affected by recent charge/load and temperature; lithium voltage may remain flat across much of its range.
Loaded voltage	Voltage sag reveals current demand, wiring loss and possible capacity weakness.	Compare at a known load and temperature; include terminals, fuses and cabling.
Current / shunt	Real-time charge and discharge through the measured path.	Loads or chargers bypassing the shunt make state-of-charge calculations inaccurate.
Coulomb-counted state of charge	Estimated remaining charge based on current over time.	Needs correct capacity, efficiency, synchronisation and periodic validation.
Cell or module voltage	Imbalance or one weak unit hidden by normal total bank voltage.	Use chemistry-appropriate limits and investigate recurring divergence.
Temperature	Charging suitability, abnormal resistance, environmental stress or thermal event.	Sensor placement, high/low limits and comparison between units and connections.

CALIBRATE AGAINST REALITY	A display showing 100% can be wrong after ageing, partial charging or changed battery capacity. Periodically compare indicated energy with measured charge and discharge behaviour.
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CHARGING PROFILES

Voltage, current, temperature and charge stages

A charger controls voltage and current according to battery chemistry and condition. Incorrect settings can shorten life, leave the bank chronically undercharged or trigger protection unexpectedly.

BULK
Source supplies available current to raise state of charge

ABSORPTION
Voltage is controlled while current gradually falls

FLOAT / STORAGE
Maintains charge within chemistry-specific limits

SPECIAL MODES
Equalise, wake-up or balance only when specifically approved

Area	What can go wrong	Owner focus
Bulk current	Source exceeds battery, cable, alternator or cooling limits.	Maximum permitted charge current, source temperature and bank acceptance.
Absorption voltage/time	Too low/short leaves lead-acid undercharged; too high/long overheats or gases batteries.	Exact manufacturer values, temperature compensation and end-current criteria where used.
Float or storage mode	Incorrect continuous voltage causes corrosion, water loss or unnecessary high state of charge.	Chemistry-specific need, storage temperature and charger behaviour after load changes.
Temperature compensation	Missing, wrong sensor or wrong bank location applies unsuitable voltage.	Sensor attachment, cable integrity and charger response to hot/cold batteries.
Special charge modes	Equalisation or recovery mode applied to unsuitable chemistry or connected equipment.	Use only with explicit approval, isolation plan and monitoring.
Multiple charge sources	Different voltage targets or current limits create cycling, overcharge or confused displays.	Document priority, enable logic and compatible settings across all sources.

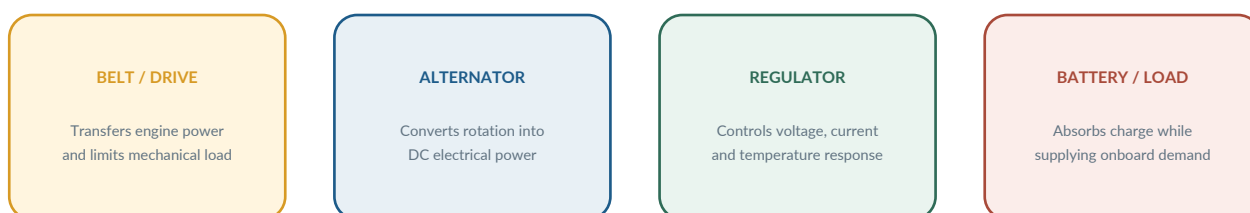
MORE CHARGING CURRENT IS NOT ALWAYS BETTER

High acceptance can overload alternators, belts, cabling or cooling even when the battery can absorb the energy. Treat the whole charge path as one system.

ALTERNATORS AND EXTERNAL REGULATORS

Charging from propulsion and generator engines

Alternators convert mechanical power into DC electricity. Large house banks can demand high current for long periods, creating heat and belt load beyond the duty expected from a conventional starting alternator.



Area	Common weakness	Owner focus
Alternator rating and duty	Nameplate current is treated as continuous output in a hot engine room.	Temperature derating, sustained output, ventilation and manufacturer duty limits.
Belt and pulley drive	Slip, dust, misalignment, inadequate wrap or excessive side load.	Correct belt type/tension, matched sets, pulley condition and spare strategy.
Regulator sensing	Voltage sensed at wrong point, poor negative reference or missing temperature input.	Battery-side sensing, cable drop, alternator and battery temperature sensors.
Current limiting	Lithium or large depleted bank holds alternator at damaging output.	Regulator limit, alternator temperature protection and DC-DC or dedicated charge control where appropriate.
Isolation while charging	Switch, fuse or BMS opens abruptly, causing a voltage surge or regulator fault.	Load-dump protection, pre-alarm and coordinated shutdown of charge sources.
Backup charging	Both engine alternators share one regulator, field supply or charge bus.	Identify what remains after one alternator, belt, regulator or bus connection fails.

ALTERNATOR TEMPERATURE IS USEFUL EVIDENCE

A bank may charge normally at first and then fall back as the alternator overheats. Record current and temperature through a realistic recharge, not only at start-up.

OTHER CHARGING SOURCES

Shore chargers, inverter-chargers, DC-DC and solar

A yacht may have several independent-looking charge sources. Their AC supply, DC protection, temperature sensing, communications and enable logic can still create shared dependencies.

SHORE CHARGER

AC-powered multi-stage charging

INVERTER-CHARGER

Combines AC charging and DC-to-AC conversion

DC-DC CHARGER

Separates banks and controls charge profile/current

SOLAR / OTHER

Adds variable renewable or specialist charging sources

Every source must agree on chemistry, temperature limits and what happens when another source is already charging.

Source	What to understand	Owner focus
Shore-powered charger	AC input, DC outputs, chemistry profile, bank priority and cooling.	Input protection, fan/temperature, output fuses and behaviour on low-quality shore power.
Inverter-charger	Shares hardware between AC charging and inverter operation.	Transfer switching, charger current limits, inverter loads and what happens after AC loss.
DC-DC charger	Controls current and voltage between alternator/start bank and house bank.	Input/output isolation, enable signal, cooling and capacity after one side is disconnected.
Solar controller	Variable source with chemistry profile and possible network control.	Array isolation, controller limits, shading, temperature and interaction with other chargers.
Hydrogenerator or wind	Output varies with vessel speed or wind and needs regulation/dump control.	Mechanical isolation, over-speed protection and safe shutdown.
Portable/emergency charger	Temporary device may lack suitable rating, protection or profile.	Approved connection point, chemistry compatibility, ventilation and supervision.

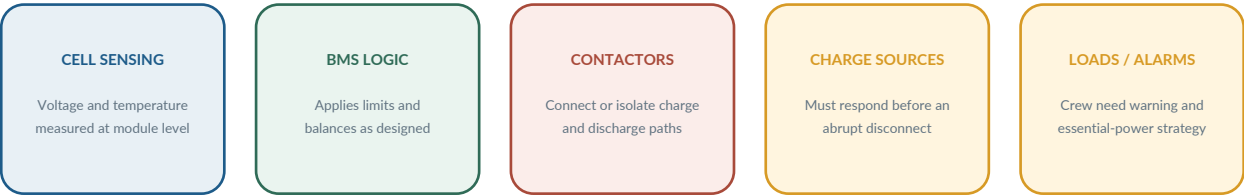
CHECK SOURCE PRIORITY AFTER A BLACKOUT

Some chargers remain disabled, current-limited or in fault after AC is restored. Confirm which source actually resumes charging and whether essential loads are already exceeding it.

BATTERY-MANAGEMENT SYSTEMS

Cell protection, contactors and system integration

Lithium installations rely on a BMS to keep cells inside voltage and temperature limits. A BMS protects the battery, but an abrupt trip can remove propulsion controls, navigation or charging unless the wider design is coordinated.



Function	Potential weakness	Owner focus
Cell-voltage sensing	Loose lead, failed sensor or one drifting cell gives false or recurring trip.	Cell trend, alarm history, connector condition and module balance.
Temperature sensing	Poor placement misses a hot cell or prevents charging when cold.	Sensor count/location, low-temperature charge inhibition and high-temperature action.
Charge/discharge contactors	Welded, failed, overheated or unable to reconnect safely.	Pre-charge circuit, manual isolation, replacement history and status indication.
BMS communications	Network fault prevents charger or inverter from respecting battery limits.	Fallback settings, hard-wired alarms, documentation and behaviour if communications are lost.
Alarm and pre-alarm	Crew receive no warning before essential loads or alternator connection is removed.	Audibility, bridge display, clear cause and time available to reduce load.
Emergency bypass	Improvised bypass defeats cell protection or creates uncontrolled charging.	Use only a documented manufacturer-approved emergency method, if one exists.

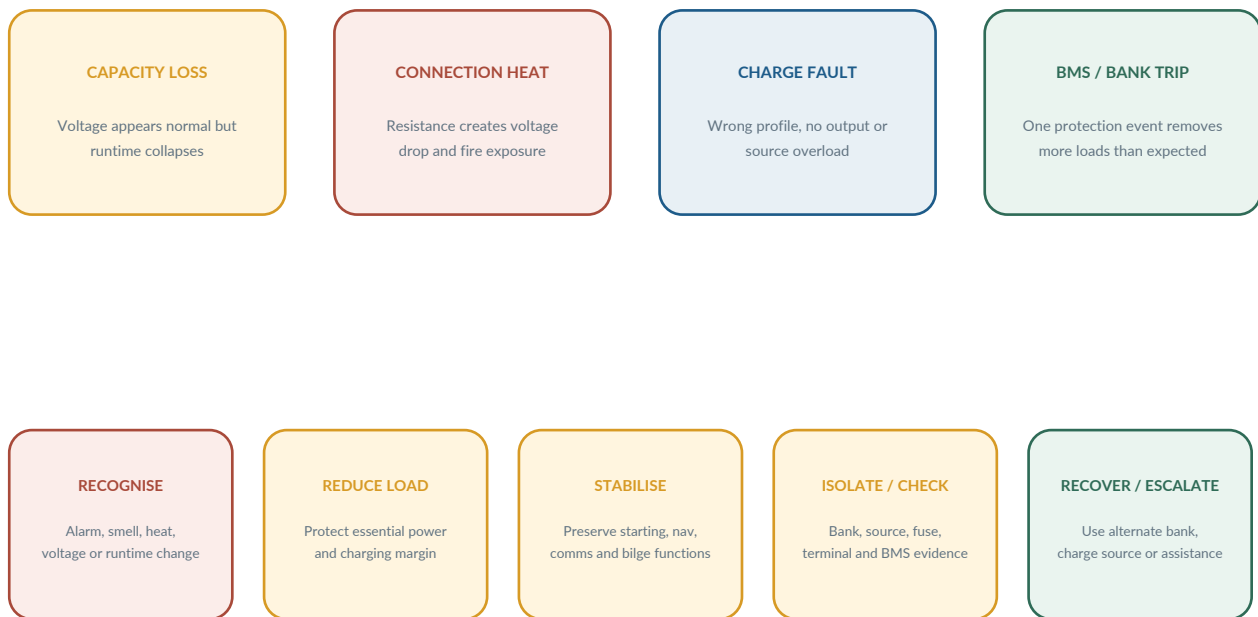
THE BMS IS NOT THE WHOLE SAFETY CASE

Safe lithium installation also depends on fusing, cabling, containment, detection, charge-source response, load separation and emergency procedures.

FAILURE AWARENESS

Common weaknesses and immediate response

Battery faults often appear first as reduced runtime, unusual charging, voltage drop, heat, smell, swelling, corrosion, repeated alarms or a bank that no longer supports its expected load.



Evidence or failure	Possible cause	Immediate thinking
Runtime falls unexpectedly	Capacity loss, changed load, inaccurate monitor, weak cell or chronic undercharge.	Protect reserve, compare actual load and test the complete bank rather than voltage alone.
Hot terminal, smell or discolouration	Loose/corroded connection, high current, damaged fuse or internal battery fault.	Reduce or isolate load if safe; avoid touching hot components and investigate fire exposure.
Bank will not charge	Source fault, open fuse/contact, BMS inhibition, wrong temperature or control setting.	Identify whether the problem is battery protection, charger input or the charge path.
Voltage rises abnormally	Regulator fault, wrong profile, lost battery connection or failed sensing.	Stop charging before connected equipment or batteries are damaged.
BMS or isolator opens	Cell limit, temperature, overload, short circuit or contactor/control fault.	Reduce load, preserve essential services and identify the trip cause before reconnection.
Starting bank weak after house use	Unexpected parallel link, failed isolator or domestic load connected to start bus.	Restore separation, use emergency parallel only as intended and preserve a restart option.

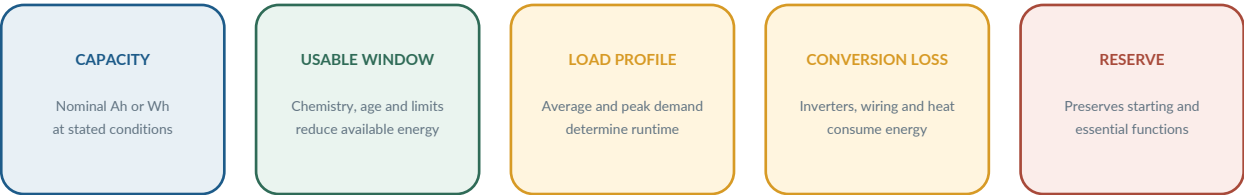
DO NOT NORMALISE IT

A charger that frequently resets, a terminal that is always warm, a bank that drops from full to low rapidly or a BMS alarm that clears on its own has an unresolved defect.

ENERGY BUDGET AND ENDURANCE

Turning bank capacity into realistic operating time

Offshore endurance depends on the energy that can actually be delivered while preserving starting and essential reserves. Average loads, peaks, inverter losses and recharge time all matter.



Area	What to include	Owner focus
Continuous DC loads	Navigation, communications, pumps, lighting, control systems and refrigeration.	Measure representative current rather than relying only on nameplates.
Intermittent and surge loads	Autopilot pumps, windlass, thrusters, compressors and start currents.	Peak voltage drop, protection rating and whether simultaneous operation is allowed.
Inverter loads	AC appliances plus inverter conversion and standby losses.	High-power domestic loads can dominate the energy budget even when used briefly.
Charging time	Source output minus live loads, charge acceptance and tapering.	A large charger does not guarantee a short recharge if absorption or temperature limits reduce current.
Reserve strategy	Starting, bilge, fire, communications and navigation energy kept outside normal domestic use.	Define load shedding before low-voltage protection removes loads unexpectedly.
Degraded operation	Runtime after loss of one charger, generator, alternator or bank.	Test a realistic reduced-load plan and confirm recharge from the remaining source.

PLAN AROUND NET CHARGING

A 100 A charger supplying 70 A of live loads restores the bank at only about 30 A before losses and tapering are considered.

MAINTENANCE STRATEGY

Inspection, testing, records and realistic spares

Battery maintenance should preserve capacity, secure connections, correct charging and reliable isolation. Replacing a bank without correcting the charging or installation fault often repeats the failure.

Area	Good maintenance evidence	Why it matters
Battery condition	Model, age, serials, visual inspection, electrolyte/service data and capacity trend.	Shows whether units are matched, ageing consistently and suitable for continued duty.
Connections and cabling	Correct torque procedure, corrosion control, voltage drop and thermal inspection under load.	Prevents resistance, heat, fire and unequal current sharing.
Charging sources	Settings, current, voltage, temperature, alarms and full recharge behaviour recorded.	Confirms compatibility and identifies source derating or regulation faults.
Protection and isolation	Fuses, breakers, contactors, emergency parallel and remote isolation tested.	Limits fault energy and preserves controlled recovery.
Monitoring	Shunt configuration, capacity setting, synchronisation, cell/module data and alarm history.	Keeps state-of-charge and warning information credible.
Capacity / load test	Controlled test at known load with temperature, voltage and delivered energy recorded.	Demonstrates actual runtime rather than relying on age or resting voltage.

Useful spares and tools

- Correct fuses, breaker/contactor control parts, terminal covers and manufacturer-approved monitoring sensors.
- Suitable belt and regulator spares for critical alternator charging where owner replacement is realistic.
- Insulated tools, eye protection, spill-response equipment and chemistry-specific personal protection.
- Portable meter, clamp meter and temperature instrument used within competence and equipment ratings.
- Current drawings, charger settings, BMS instructions, emergency parallel/isolation procedure and specialist contacts.

WORK TO REFER	Live high-current work, battery-bank redesign, lithium integration, capacity testing of critical banks, BMS programming, damaged cells and persistent overheating require competent specialists.
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OFFSHORE READINESS

Buyer questions and readiness checklist

An offshore-ready battery system has demonstrated usable capacity, compatible charging, protected cabling, credible monitoring and a clear plan for preserving starting and essential power after a fault.

Area	Questions for purchase or survey
Identity and architecture	Are chemistry, age, configuration, voltage, capacity, duties and bank-separation arrangements documented?
Usable capacity	Is runtime supported by a recent capacity/load test or credible operating records rather than voltage alone?
Charging compatibility	Do alternators, regulators, chargers, inverter-chargers, DC-DC and solar settings match the installed batteries?
Protection and installation	Are restraints, ventilation, fuses, cabling, isolators, contactors and terminal protection credible and accessible?
Monitoring and alarms	Are shunts, BMS, temperature sensors, cell data, low-voltage alarms and displays accurate and understood?
History and support	Are replacements, BMS events, charger faults, overheating and capacity decline fully documented?
Degraded operation	Can the crew preserve starting, navigation, communications and bilge capability after loss of one bank or charge source?

Quick readiness check

	Readiness statement
☐	I can identify each bank's chemistry, voltage, capacity, duty and normal separation.
☐	Usable capacity and realistic runtime are supported by testing or credible operating records.
☐	All charge sources have compatible settings, temperature sensing and current limits.
☐	There are no unresolved hot terminals, corrosion, swelling, gas, smell or repeated alarms.
☐	Fuses, cabling, isolators, contactors, restraint and ventilation are current and accessible.
☐	State-of-charge, cell/module and temperature monitoring are calibrated and understood.
☐	Emergency parallel, alternate charging and load-shedding procedures have been considered and tested.
☐	More than one person knows the response to low voltage, overcharge, BMS trip and battery overheating.

KEY TAKEAWAY

A dependable battery and charging system combines demonstrated usable capacity, chemistry-correct charging, sound high-current protection, accurate monitoring, controlled isolation and a realistic essential-power strategy.

Guidance to consult

Use the current battery, BMS, alternator, regulator, charger and inverter manufacturers' instructions, together with vessel electrical drawings, fire procedures and applicable flag-state, coding, class, insurance and yard requirements.

Understanding Yacht Systems

Practical guides for owners, buyers
and offshore cruising crews.

AMTG-021

Understanding Battery Banks and Charging Systems

RELATED GUIDES

AMTG-003 Understanding Marine Electrical Systems

AMTG-004 Understanding Electrical Redundancy

AMTG-005 Understanding Generators and Load Management

AMTG-022 Understanding Inverters and Shore Power

AMTG-023 Understanding AC and DC Distribution

AMTG-025 Understanding Load Shedding and Blackout Recovery

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