

Understanding Bonding, Earthing and Galvanic Protection

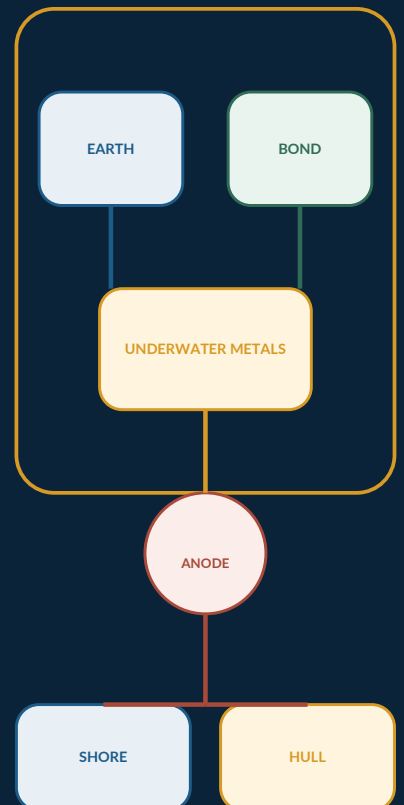
An owner's guide to fault-current paths,
underwater metals and corrosion control

Electrical safety and corrosion control
share some conductors, but not the same purpose.

Reliable protection depends on knowing
which path carries which current.

Absolute Marine

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FAULT PATH | CORROSION CONTROL

GUIDE OVERVIEW

What bonding, earthing and galvanic protection are designed to do

These arrangements create controlled fault-current paths, connect selected metal components and reduce corrosion of underwater metals. They overlap, but they are not the same system.

SCOPE	This guide describes common owner-level principles for steel, aluminium, composite and timber yachts. Exact bonding philosophy, cathodic-protection potential and neutral-to-earth arrangements are vessel-specific and should be verified from current drawings and competent testing.
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By the end of this guide, you should be able to:

- Distinguish protective earthing, DC negative, bonding and cathodic protection.
- Identify bonding conductors, earth connections, anodes, underwater metals and shore-isolation equipment.
- Recognise broken conductors, rapid anode loss, coating damage, stray current and incorrect neutral-earth connections.
- Understand why galvanic isolators and isolation transformers address different parts of the shore-power problem.
- Ask better questions during purchase, haul-out, refit, electrical work and offshore preparation.

CORE PRINCIPLE	Do not add, remove or combine bonding, earth, negative or anode connections simply because continuity appears desirable. The intended current path must be understood first.
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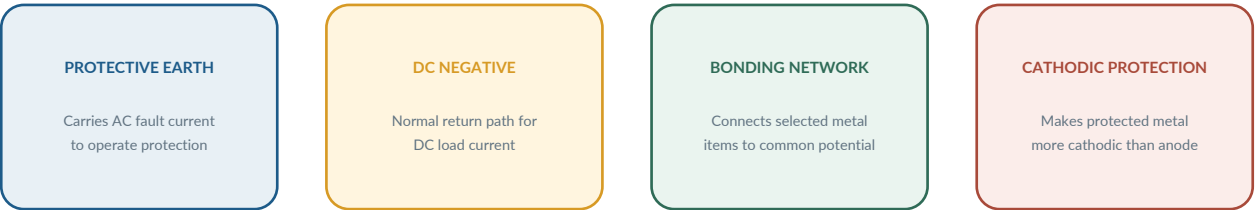
Safety

Fault-current and corrosion-control conductors may normally carry little or no current but become critical during an electrical fault. Work on shore earths, neutral bonds, underwater fittings or impressed-current equipment should follow a documented isolation and test procedure.

KEY CONCEPTS

Bonding, earthing and cathodic protection are different

The same metal fitting may take part in more than one function, but each path exists for a different reason and may require different materials, connections and test methods.



Controlled connection is useful; accidental current on the wrong path is not.

Term	Primary purpose	What it should not become
Protective earth	Provides a low-impedance fault path so a fuse, breaker or leakage device can disconnect supply.	A normal current-carrying conductor or substitute for DC negative.
DC negative	Returns normal DC load and charging current to the source.	An improvised hull return or hidden bypass around a monitoring shunt.
Bonding network	Connects selected exposed and underwater metal components according to design.	A reason to connect every metal object without considering corrosion or fault consequences.
Sacrificial-anode system	Allows a more active metal to corrode preferentially and protect connected underwater metal.	A substitute for sound coatings, correct alloys or repair of stray current.
Impressed-current system	Uses controlled DC output and reference electrodes to maintain protective potential.	An owner-adjustable battery charger or unattended system with failed reference monitoring.

LANGUAGE VARIES	Builders and standards may use earth, ground and bonding differently. Follow the vessel drawings and identify the actual conductor function rather than relying on a label alone.
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GALVANIC CORROSION

How dissimilar metals create an electrochemical cell

When two different metals are electrically connected in an electrolyte such as seawater, the more active metal tends to corrode while the more noble metal is protected.



Corrosion rate depends on alloy, area ratio, water chemistry, coating, temperature and electrical connection.

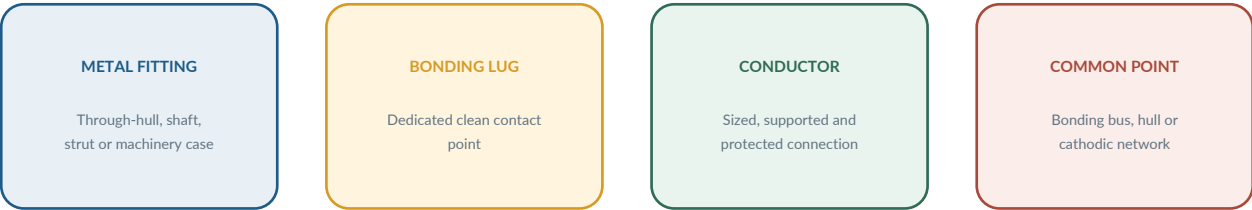
Factor	Why it matters	Owner focus
Metal potential	A larger difference between connected alloys can increase driving voltage.	Identify actual alloys rather than broad names such as 'stainless' or 'bronze'.
Area ratio	A small anodic area connected to a large cathodic area can corrode rapidly.	Small aluminium or steel fittings beside large bronze/stainless surfaces need careful design.
Coating condition	A coating defect concentrates current onto a small exposed area.	Inspect holidays, blistering and damage around shafts, fittings and anodes.
Electrical continuity	Broken or added connections change which metals share the galvanic cell.	Test to the design; do not assume more continuity is always safer.
Electrolyte conditions	Salinity, temperature, oxygen and pollution change corrosion behaviour.	Expect different anode life in fresh, brackish and salt water.
Time alongside	Shore-earth connection can link the yacht to marina structures and nearby vessels.	Review galvanic isolation and anode trend after long marina stays.

ANODES PROTECT CONNECTED METAL	A healthy-looking anode cannot protect a fitting that is electrically isolated from it. Equally, connecting unrelated metals may create a larger corrosion cell.
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BONDING NETWORKS

Conductors, connections and selective continuity

A bonding network may connect through-hulls, shafts, struts, tanks, machinery cases, lightning components or other metal according to the yacht's design. Its purpose and extent vary by hull material and construction.



Connection quality, routing and design intent matter more than the visual presence of a green wire.

Area	Common weakness	Owner focus
Bonding conductor	Corrosion under insulation, broken strands, chafe, unsupported span or undersized replacement.	Full-length inspection where accessible, secure support and compatible materials.
Terminal or lug	Paint, sealant, oxide or loose fastener creates high resistance.	Dedicated metal contact, correct hardware, corrosion protection and no live improvisation.
Flexible machinery connection	Vibration or mount movement fractures a rigid conductor.	Suitable flexibility, strain relief and no use as normal load-current return.
Through-hull connection	Clamp attached to a valve or hose component rather than the intended fitting.	Confirm builder design, material and accessibility without compromising the fitting.
Hull connection	Steel or aluminium hull return is poorly documented or altered during repair.	Current drawings, controlled weld/stud details and coating around connection.
Later modification	New equipment is bonded inconsistently or connected to the wrong network.	Review every metal installation, especially watermakers, stabilisers, thrusters and cranes.

CONTINUITY NEEDS A TARGET	A resistance reading is meaningful only when the intended endpoints, conductor route and acceptable condition are known. Randomly linking fittings can increase corrosion exposure.
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PROTECTIVE EARTHING

AC fault-current paths and source-dependent neutral bonds

Protective earthing connects exposed conductive parts to a controlled fault path. If a live conductor contacts a metal case, enough fault current should flow to operate the protective device promptly.



Area	What can go wrong	Owner focus
Equipment protective earth	Loose, corroded, undersized or omitted connection leaves the case unsafe.	Continuity, secure termination and no use as normal return conductor.
Shore protective conductor	Broken shore earth removes fault path or creates dangerous touch voltage.	Cable/inlet condition, polarity/earth indication and correct shore interface.
Neutral-to-earth bond	Missing or duplicated bond prevents correct protection or creates circulating current.	Bond location should change appropriately with shore, generator and inverter source.
Transfer switching	Neutral is not switched where required or source interlock fails.	Current drawings, source-change test and no informal bridge links.
Leakage protection	RCD/ELCI trips repeatedly, is bypassed or does not cover all relevant conductors.	Functional testing and investigation of the actual leakage path.
Metal hull connection	Protective-earth arrangement conflicts with corrosion-control design or repair.	Hull-material-specific design and specialist verification after modifications.

SOURCE SELECTION CHANGES THE BOND

The correct neutral-earth connection depends on which AC source is active. Adding a permanent bond because it 'stops a trip' can create shock, corrosion and circulating-current risks.

DC NEGATIVE AND ISOLATION

Normal return current, monitoring and unintended hull paths

The DC negative system carries normal battery and charging current. It may connect to bonding or hull systems at a controlled point, but that does not make every negative connection interchangeable.



A stray parallel return can bypass monitoring and place normal current on bonding or underwater metal.

Condition	Potential consequence	Owner focus
Negative return bypasses shunt	State-of-charge and current monitoring become inaccurate.	Trace all charger, inverter and load returns to the designed side of the shunt.
Normal current on bonding conductor	Voltage gradients and corrosion risk can develop on underwater metal paths.	Investigate warm conductors, voltage drop and unexpected continuity routes.
Hull used as return	Corrosion, unreliable connections and difficult fault finding.	Follow vessel design; do not create local hull returns during repair.
Multiple negative-bond points	Parallel current paths bypass protection or monitoring and complicate isolation.	Identify the intentional common point and remove only with specialist assessment.
Isolated or floating DC system	A first earth fault may not stop operation but reduces protection against a second fault.	Insulation monitoring, alarm response and correct test procedure.
Temporary jumper or emergency parallel	Can connect a faulted bank or place high current through an unsuitable path.	Use only documented connection points and remove after controlled recovery.

DO NOT CHASE ZERO VOLTS BLINDLY

Small measured voltages can arise from normal current, sensor circuits or galvanic potentials. The correct test method and reference point matter.

SACRIFICIAL ANODES

Material, placement, electrical contact and consumption

A sacrificial anode is selected to corrode preferentially and supply protective current to connected underwater metal. Its effectiveness depends on material, exposed area, location and electrical continuity.

ANODE MATERIAL

Chosen for water type and protected alloy

CLEAN CONTACT

Metallic connection to protected structure

CURRENT DISTRIBUTION

Position allows current to reach exposed metal

CONSUMPTION TREND

Wear pattern and rate show system behaviour

Anode quantity should be engineered: both too little and excessive protection can create problems.

Area	Common issue	Owner focus
Material selection	Wrong alloy for fresh, brackish or seawater gives poor protection or rapid consumption.	Confirm manufacturer specification rather than choosing by colour or price.
Electrical contact	Paint, oxide, gasket or sealant isolates the anode from the protected metal.	Clean mounting interface and continuity confirmed after installation.
Anode location	Shielding, poor flow or distance leaves fittings under-protected.	Follow designed positions and avoid moving anodes solely for easier replacement.
Anode surface	Paint, fouling, hard oxide or incorrect coating reduces exposed active area.	Keep active face clean and never antifoul over the anode.
Consumption rate	Very fast loss suggests stray current, wrong material, large cathodic area or marina influence.	Record photographs, weight/percentage loss, water type and time afloat.
Uneven consumption	Poor contact, shielding, current concentration or different local exposure.	Compare all anodes and connected fittings rather than replacing the worst one alone.

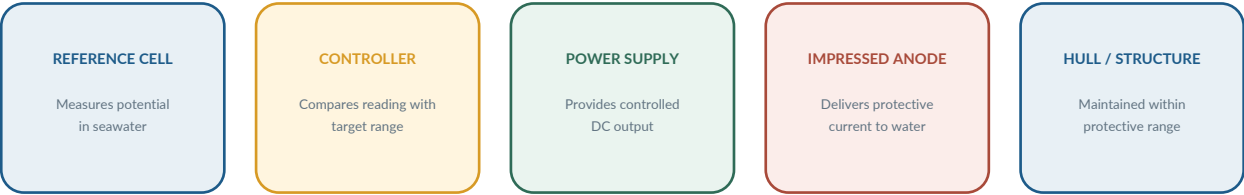
**MORE ANODE IS NOT
AUTOMATICALLY
BETTER**

Overprotection can damage coatings or create hydrogen-related problems on some metals. Follow the vessel's cathodic-protection design and measured potential.

IMPRESSED-CURRENT CATHODIC PROTECTION

Controlled protection for larger metal hulls and structures

Some steel or aluminium yachts use powered anodes and reference electrodes. A controller adjusts current to maintain the hull or protected structure within a specified potential range.



Area	Failure mode	Owner focus
Reference electrode	Ageing, fouling, damage or poor location gives false potential.	Calibration/replacement history, clean exposure and comparison with independent measurement.
Controller set point	Incorrect target or manual adjustment causes under- or overprotection.	Manufacturer and hull-specific limits; secure settings and alarm history.
Impressed anode	Damage, coating over anode, cable fault or seawater ingress.	Haul-out inspection, isolation test and no painting of active surface.
Power and alarm supply	System loses output silently after breaker, fuse or control failure.	Run indication, current trend, low/high potential alarms and backup procedure.
Docking or freshwater operation	Water conductivity and external electrical environment change required output.	Operating mode, alarm response and manufacturer guidance for location changes.
Interaction with sacrificial anodes	Additional anodes alter controller current and potential distribution.	Use the designed mixed system rather than adding anodes informally.

DO NOT ADJUST BY GUESSWORK

An impressed-current reading is meaningful only with a reliable reference electrode and the correct target for the hull material, coating and environment.

SHORE-POWER GALVANIC ISOLATION

Galvanic isolators, isolation transformers and marina connections

Connecting the yacht's protective earth to shore can complete low-voltage galvanic circuits between underwater metals, marina structures and neighbouring vessels.



A galvanic isolator and an isolation transformer do not provide the same degree or method of separation.

Equipment or issue	What it does	Owner focus
Galvanic isolator	Blocks small galvanic voltages in the shore-earth conductor while allowing fault current to pass.	Correct rating, fail-safe/monitoring arrangement, test history and no bypass path.
Isolation transformer	Creates a separately derived onboard AC supply and breaks direct shore conductive paths.	Correct neutral-earth arrangement, screen/earth connections, ventilation and load rating.
Autotransformer	Changes voltage but does not inherently provide galvanic isolation.	Do not assume voltage conversion means shore-earth separation.
Shore cable and inlet	Damaged earth, water ingress or overheated connector compromises safety and may affect corrosion.	Inspect pins, continuity, heat, seals and polarity/earth indication.
Parallel shore paths	TV, data, metal water hose, passerelle, second shore lead or charger connection bypasses isolation.	Review every external conductive connection, not only the main shore cable.
Marina fault or neighbouring vessel	External leakage current changes local water potential and anode consumption.	Compare unplugged/plugged measurements and investigate location-specific changes.

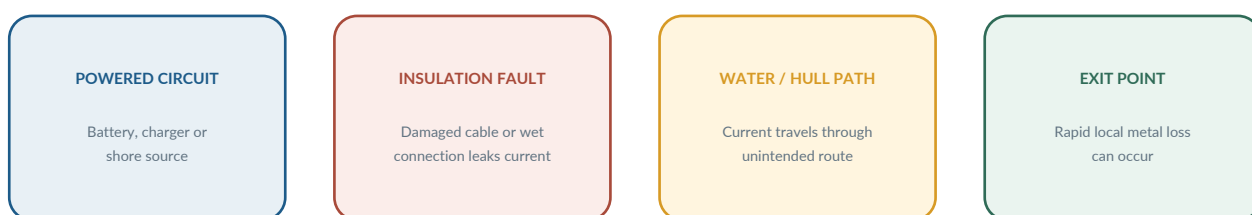
SHORE ISOLATION DOES NOT CURE ONBOARD LEAKAGE

A galvanic isolator or transformer helps manage external paths, but faulty onboard wiring, neutral bonds or DC leakage still require diagnosis.

STRAY-CURRENT CORROSION

When unintended electrical current accelerates metal loss

Stray-current corrosion differs from ordinary galvanic action. It is driven by current leaking from a powered circuit into the water or hull and can remove metal very quickly at the current's exit point.



Rapid, localised and asymmetric damage should prompt electrical investigation rather than simply larger anodes.

Warning sign	Possible interpretation	Owner response
Anodes disappear unusually quickly	Stray current, shore influence, wrong material or changed bonded area.	Record trend, disconnect shore where safe and arrange controlled electrical/potential testing.
Severe local pitting near one fitting	Current may be leaving metal at that location.	Inspect nearby DC equipment, wiring, pumps, sensors and cable penetrations.
Corrosion changes with one appliance on	Fault may be associated with that circuit or its water-connected equipment.	Do not continue repeated energisation; isolate and test professionally.
Shaft or propeller corrodes despite good anodes	Broken shaft bonding, isolated coupling, stray current or material problem.	Check intended continuity, brush/slip-ring condition and independent potential.
Marina-specific rapid loss	External leakage or shore-earth galvanic circuit influences the yacht.	Compare different berths, unplugged condition and neighbouring installations.
Hot or tingling water near yacht	Potentially dangerous AC leakage into water.	Keep people out of the water and seek marina/emergency electrical assistance immediately.

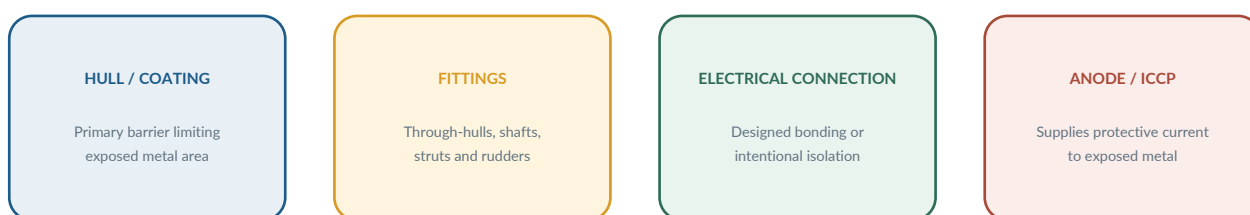
ANODES MAY HIDE THE SYMPTOM

Replacing rapidly consumed anodes can temporarily protect metal while the electrical fault remains. The cause must still be found.

UNDERWATER METALS AND COATINGS

Through-hulls, shafts, propellers, rudders and hull material

Cathodic protection works with material selection, electrical design and coatings. Each underwater component should be assessed as part of the complete submerged-metal system.



Material compatibility and coating integrity often determine how much cathodic protection is required.

Component	Typical concern	Owner focus
Bronze or brass through-hulls	Dezincification, mixed alloy valves, poor bonding or isolated replacement parts.	Confirm alloy, pink/crumby metal, operation, continuity design and hose safety.
Stainless shafts and fittings	Crevice/pitting corrosion, oxygen-poor zones, local coating damage or poor shaft bonding.	Surface condition, crevices, shaft brush, anode position and impact history.
Aluminium hull or drives	High sensitivity to copper contamination, wrong anodes and over/underprotection.	Hull-specific specialist testing, coating condition and strict material compatibility.
Steel hull	Coating holidays, weld/repair areas and uneven protection over large surfaces.	Potential survey, anode/ICCP distribution and internal as well as external corrosion.
Propellers and struts	Large noble-metal area consumes anodes and may be isolated by flexible coupling.	Dedicated anodes, shaft continuity and erosion/cavitation distinguished from corrosion.
Trim tabs, stabilisers and thrusters	Mixed metals, moving joints, hydraulic/electrical equipment and local anodes.	Manufacturer anode plan, bonding straps, seals and service records.

**COATING CONDITION
CHANGES CURRENT
DEMAND**

A small coating defect on a large protected structure can concentrate corrosion or consume anodes quickly. Repair quality matters as much as anode quantity.

MONITORING AND TESTING

Continuity, potential, leakage and anode records

Useful testing separates electrical-safety checks from corrosion measurements. One continuity reading or visual anode inspection cannot describe the whole system.



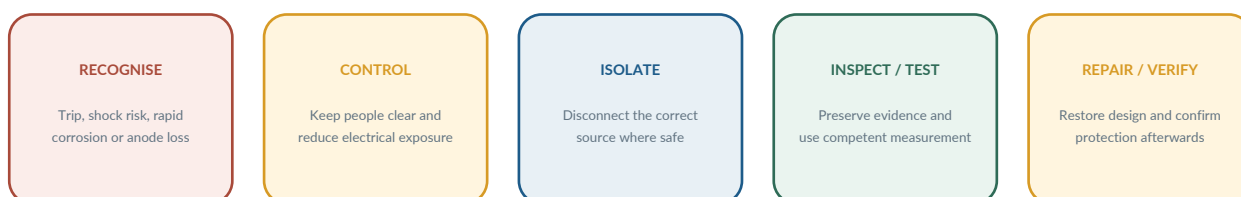
Test or record	What it can show	Limitations and owner focus
Visual anode record	Consumption percentage, uneven wear, fouling and damage.	Use photographs and dates; visual size alone does not prove correct potential.
Bonding continuity	Whether selected components are electrically connected.	Contact resistance, parallel paths and correct endpoints require a defined procedure.
Hull or fitting potential	Whether underwater metal sits within a suitable protection range.	Reference electrode, water type, shore state and hull material must be correct.
AC leakage / RCD testing	Protective-device function and current escaping the intended AC path.	Use competent testing; button tests do not prove every wiring condition.
DC leakage testing	Unintended battery current flowing into bonding, hull or seawater.	Requires logical isolation and awareness of legitimate sensor/electronic currents.
Shore connected vs disconnected	Whether the marina connection changes potential or anode current.	Compare safely under controlled conditions and include other external conductors.

TREND BEATS A SINGLE NUMBER	Record reference electrode, water location, shore status, equipment running and anode condition. Otherwise two potential readings may not be comparable.
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MAINTENANCE AND FAILURE RESPONSE

Owner checks, specialist work and immediate priorities

Corrosion-control problems may be slow and hidden, but stray-current or fault-earth failures can become urgent. Protect people first, then preserve evidence before changing the system.



Area	Good maintenance evidence	Why it matters
Bonding connections	Clean secure terminations, supported conductors and continuity to intended endpoints.	Preserves fault and corrosion-control paths without accidental normal current.
Anodes and coatings	Correct material, measured wear, clean contact and repaired coating damage.	Allows meaningful replacement interval and avoids masking a fault.
Shore isolation equipment	Galvanic-isolator monitor/test or transformer inspection and source-bond verification.	Maintains shock protection while controlling external galvanic paths.
Shaft and moving bonds	Brushes, straps and slip rings inspected for wear, contamination and continuity.	Moving interfaces often lose contact before fixed conductors.
Electrical leakage	Trip history, insulation testing, DC isolation results and repaired water ingress documented.	Stray current can damage metal much faster than ordinary galvanic corrosion.
Post-refit verification	Potential, continuity and protection checks repeated after electrical or underwater-metal work.	Small modifications can alter several shared current paths.

Useful records and spares

- Anode photographs, material, location, replacement date and percentage consumed.
- Bonding diagram, earth/negative common points and shore-isolation documentation.
- Reference-electrode potential reports and results before/after significant repairs.
- Correct replacement anodes, bonding straps and manufacturer-approved contact hardware.
- Specialist contacts for marine electrical, corrosion and hull-material assessment.

WORK TO REFER	Neutral-earth changes, live electrical testing, hull-potential surveys, stray-current diagnosis, ICCP adjustment and structural corrosion repair require competent specialists.
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OFFSHORE READINESS

Buyer questions and readiness checklist

An offshore-ready system has a documented bonding philosophy, safe fault-current paths, correctly selected cathodic protection, credible shore isolation and no unexplained rapid corrosion.

Area	Questions for purchase or survey
Architecture	Are protective earth, DC negative, bonding and cathodic-protection connections shown accurately on current drawings?
Underwater metals	Are hull, shafts, propellers, through-hulls, stabilisers and thrusters made from compatible materials and protected as designed?
Anodes or ICCP	Are material, quantity, location, consumption and potential supported by records rather than visual guesswork?
Shore connection	Is a galvanic isolator or isolation transformer fitted, correctly tested and free from parallel bypass paths?
Electrical safety	Are source-dependent neutral bonds, protective-earth continuity and leakage protection credible?
Corrosion history	Are rapid anode loss, pitting, coating failure, marina-specific damage or previous stray-current events fully explained?
Supportability	Are drawings, test reports, reference cells, anodes and specialist support available for the intended cruising area?

Quick readiness check

	Readiness statement
☐	I can distinguish protective earth, DC negative, bonding and cathodic-protection functions.
☐	Current drawings identify intentional common points and the underwater-metal network.
☐	Bonding conductors, shaft bonds and protective-earth connections are secure and accessible.
☐	Anode or ICCP performance is supported by trend records and suitable potential measurement.
☐	There is no unexplained rapid anode loss, local pitting, coating damage or recurring leakage trip.
☐	Shore galvanic isolation is correctly installed, tested and not bypassed by another connection.
☐	Neutral-earth arrangements and leakage protection change correctly with the active AC source.
☐	More than one person knows the safe response to electric-shock risk, rapid corrosion or suspected stray current.

KEY TAKEAWAY

Dependable bonding, earthing and galvanic protection combines controlled fault-current paths, deliberate metal connectivity, suitable anodes or impressed current, sound coatings, effective shore isolation and evidence-based monitoring.

Guidance to consult

Use current vessel electrical and cathodic-protection drawings, hull-builder and equipment manufacturers' instructions, together with applicable flag-state, coding, class, marina, insurance and yard requirements.

Understanding Yacht Systems

Practical guides for owners, buyers
and offshore cruising crews.

AMTG-024

Understanding Bonding, Earthing and Galvanic Protection

RELATED GUIDES

AMTG-003 Understanding Marine Electrical Systems

AMTG-004 Understanding Electrical Redundancy

AMTG-021 Understanding Battery Banks and Charging Systems

AMTG-022 Understanding Inverters and Shore Power

AMTG-023 Understanding AC and DC Distribution

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