

AI for electric machine design and HI for marine charging

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Optimised DYnamics of High-Voltage Powertrains: Developing Sustainable Systems for Electric Vehicles

ODYSSEV

Key Components

ON-BOARD CHARGER
Up to 22kW

BATTERY PACK
Reconfigurable (400V/800V/1200 V)

INVERTER
AHXS Hybrid (Si + SiC)

ELECTRIC MOTOR
Optimisied for system (1200V)

Key Performance Targets

10 mins
20-80% Fast Charge

+20%
Driving Range Extension

-30%
Powertrain Energy Losses



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Vehicle Demonstrator

AI-/FEM-based optimization framework



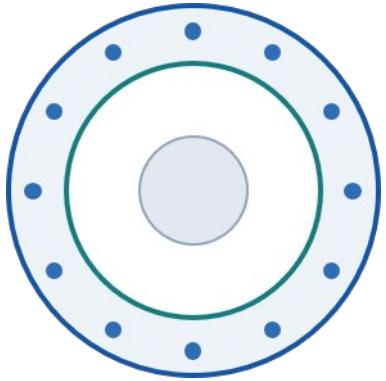
Funded by the European Union

Research Area: Variable Phase-Pole Induction Machine for EV Traction

Magnet-free traction-machine design • pole-changing operation • multi-operating-point optimization

Research Topic

Design and optimization of a magnet-free induction machine that can operate with two pole configurations while using the same electromagnetic hardware.



8-pole mode	4-pole mode
Low-speed / high-torque	High-speed / extended range

Research focus

- Electromagnetic design • Winding/rotor geometry
- Multi-speed FEA • Efficiency mapping
- Sensitivity, DOE, and multi-response optimization

Why optimization is challenging

- The same machine geometry must satisfy 8-pole low-speed torque and 4-pole high-speed operation.
- Three key operating points are evaluated: 1720, 3762, and 8669 rpm.
- Torque, efficiency, power factor, torque ripple, and current density must be balanced together.
- The goal is one common multi-speed design, followed by independent FEA verification.

Research workflow

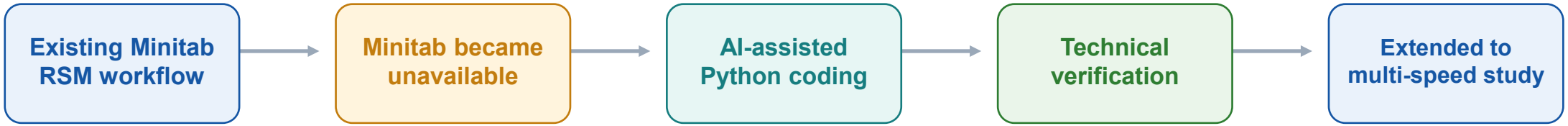
1. **FEA / sensitivity** — Select influential variables
2. **DOE / response models** — Approximate machine responses
3. **Multi-response optimization** — Balance competing objectives
4. **FEA validation** — Verify the optimized geometry

Key research question: How can one geometry be optimized across both pole modes and multiple speeds without violating the machine physics and design constraints?

Why I Started Using AI for Optimization Code

A practical need became an opportunity to build a **more flexible** and **reproducible workflow**

How the transition happened



What AI helped me do

- Generate and revise Python code much faster than writing every routine from scratch.
- Reproduce the previous quadratic RSM + desirability optimization methodology.
- Automate model fitting, optimization, CSV outputs, diagnostic plots and reports.
- Quickly modify factors, bounds, objectives and operating points.
- Explain errors and help debug data-column or plotting issues.

What still had to come from me

- Define the physics, design variables, constraints and meaningful response targets.
- Tell the AI about coupled variables—for example tooth width and slot depth.
- Check the mathematical model against the known Minitab/reference result
- Judge whether trends are physically reasonable—not just numerically “optimal”
- Validate the final candidate with the original electromagnetic FEA model.

AI did not optimize the machine by itself — it accelerated the implementation. The engineering decisions remained researcher-controlled.

Optimization Results, Productivity Gain, and Lessons Learned

One consolidated view: baseline-to-optimized performance across the studied speeds + implementation effort

Performance across all studied operating points

Each cell shows baseline → optimized.

Speed	Mode	Torque [Nm]	Efficiency [%]	Power factor
1720	8P	828.5 → 883	65.62 → 67.95	0.628 → 0.705
3762	8P	53.09 → 57.32	**92.53 → 93.00**	0.782 → 0.809
8669	4P	39.98 → 41.77	**95.17 → 95.30**	0.928 → 0.930

1720-rpm validation: **Torque ripple 8.17% → 5.04%** **Current density 61.25 → 59.61 A/mm²**

At higher speeds, efficiency remains above 90%; the design trade-offs shift toward torque, power factor, and ripple.

Time/effort comparison

Indicative project experience — not a controlled benchmark

AI-assisted Python — **Hours**

to a working framework

Minitab — **Hours**

per study + repeated setup

Manual Python — **Days**

to code, debug and revise

Main gain: faster setup, modification and repeatable reruns — not a replacement for engineering validation.

Pros, risks, and the rule I now follow

Benefits

• Fast prototyping • reproducible workflow
• flexible objectives • automatic plots/reports
• easier debugging

Risks

• Plausible-but-wrong code • hidden unit/data errors • poor model fit • over-trust • confidentiality concerns

Guiding principle

- Use AI to accelerate implementation but define the physics yourself.
- Have a reference or expected outcome.
- Think critically, instruct specifically, inspect the model, and validate the final result with physics/FEA.

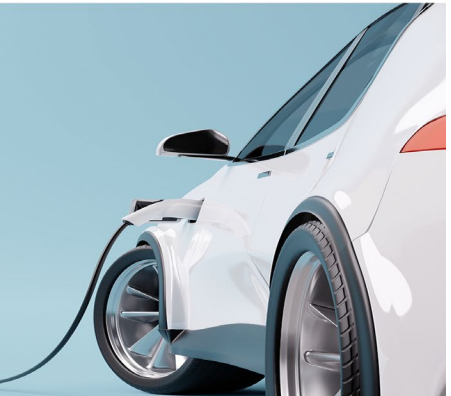
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Can we reuse land EV charging technology for small craft, and what breaks if we do?



The push and pull

- Road electric vehicle technologies are becoming well-defined.
- There are both standards and large commercial actors in the area.
- A lot of proven and well-established technology can (could?) be transferred to the marine sector.





Hypothesis & research questions

Hypothesis: the conflict is resolvable *architecturally* — active isolation of both the comms path and the LV control domain — not by picking one passive device and accepting its side effects.

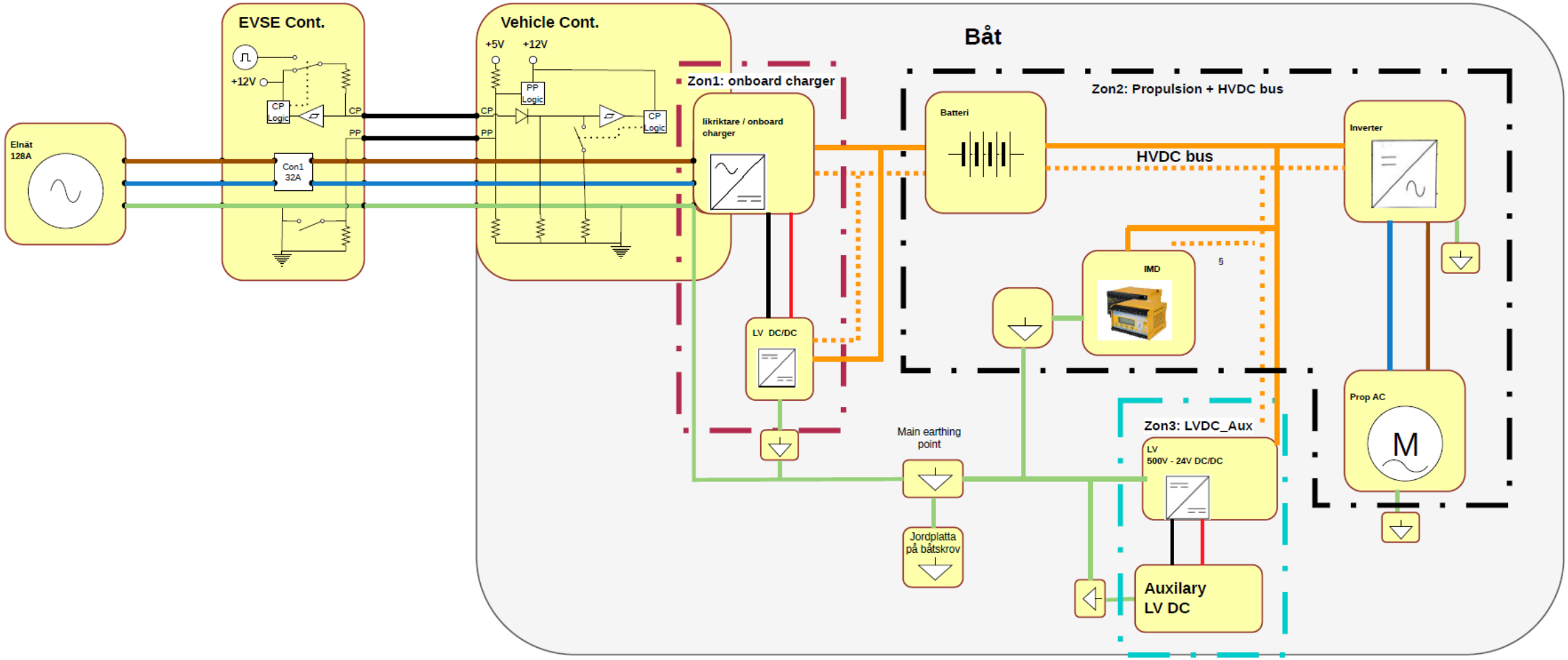
- **RQ1:** How large is the risk in practice? What leakage currents, and what gaps in standard protective devices (RCD, IMD), show up with real land-based EV hardware in a realistic marine configuration?

- **RQ2:** What architecture resolves the CP/PE conflict without a single passive component?

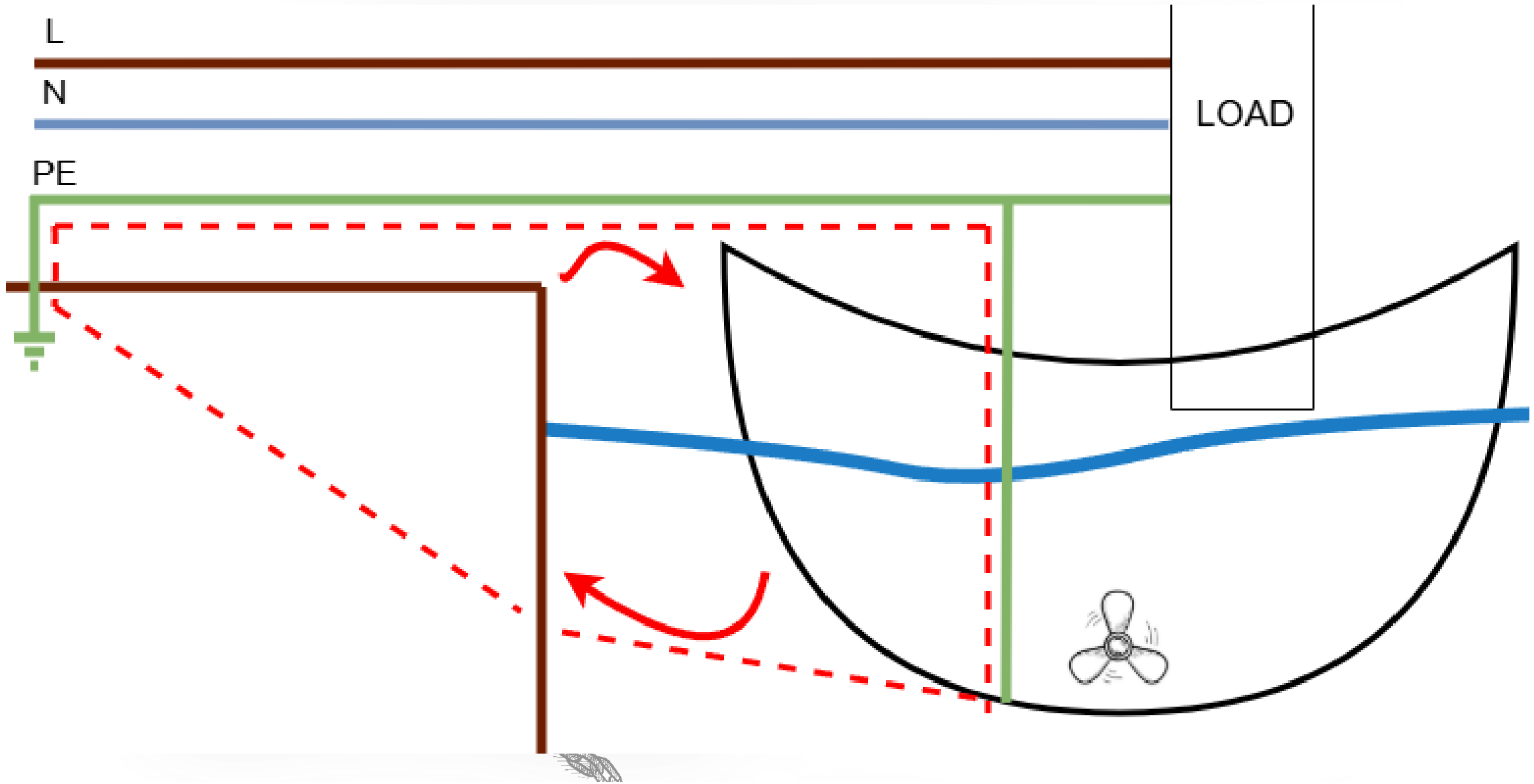




Pre-study activities

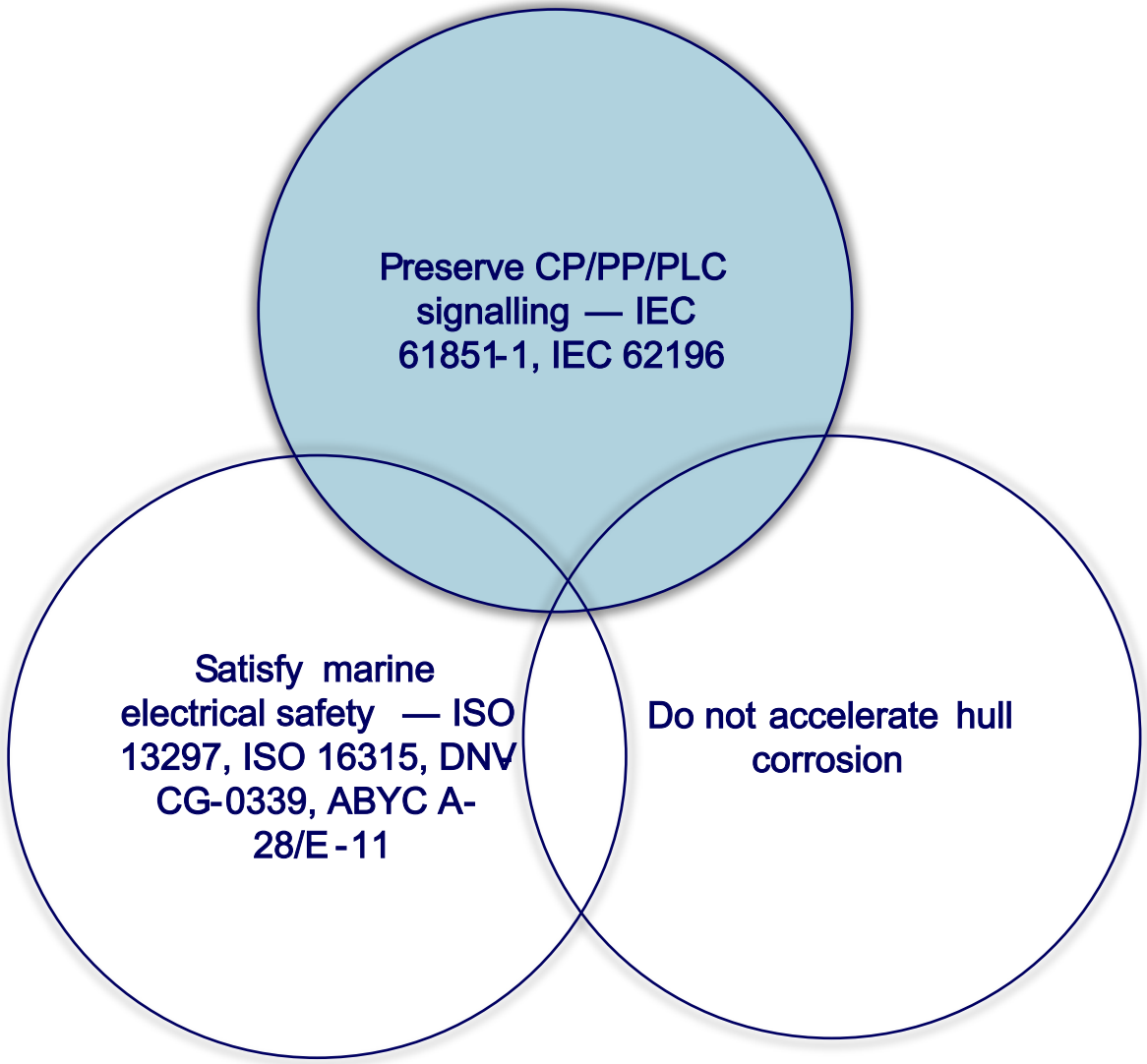


Result A — corrosion quantified and mitigated

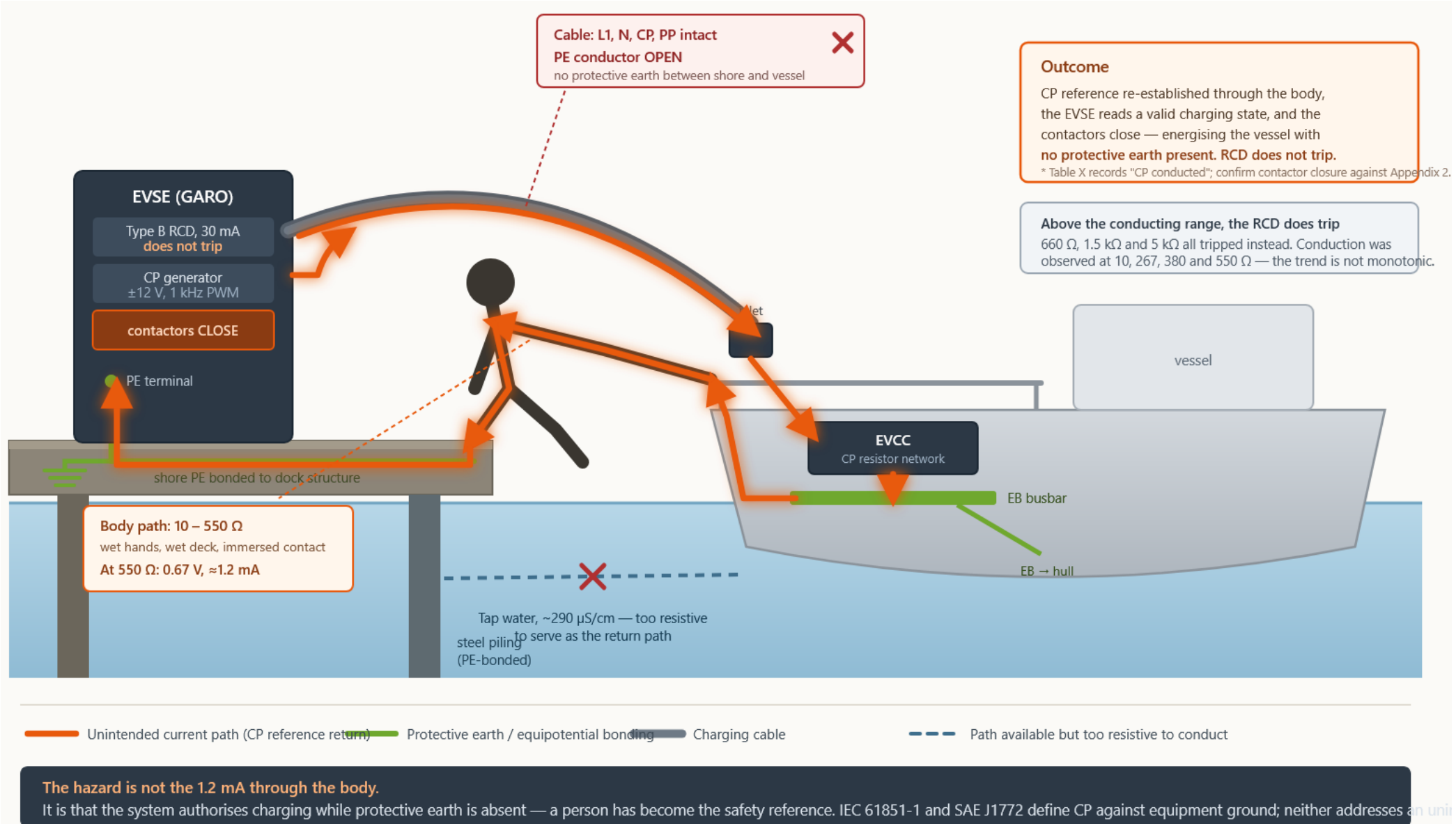


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The three-way conflict



Result B — the safety gap



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Study outputs

1. A working, reusable physical test rig which can be adapted for future work and demonstration

2. Two bachelor's reports
   - Quantified corrosion risk
   - Validated mitigation (incl. the ≥16 A rating)

3. A new, previously undocumented safety gap

4. A consolidated marine + automotive standards landscape, previously scattered

Thank you!

