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Iterative Electric Potential Adjustment of Damaged Naval Vessels Using the Onboard ICCP System

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Abstract

We present an iterative approach to adjust electric currents of the Impressed Current Cathodic Protection (ICCP) system to maintain a corrosion protective state of the hull of navel vessels. Therefore, the Underwater Electric Potential (UEP) signature as well as the electric potential distribution of a generic ship model are simulated using the Electric Currents (ec) physics within the AC/DC module. Using a simple mathematical formulation with a Matlab-based script, connected to the model via the LiveLink™ for Matlab®, the protective state of the vessel as well as of newly placed coating damages can be further ensured.

Simulation Setup

Ship model definitions

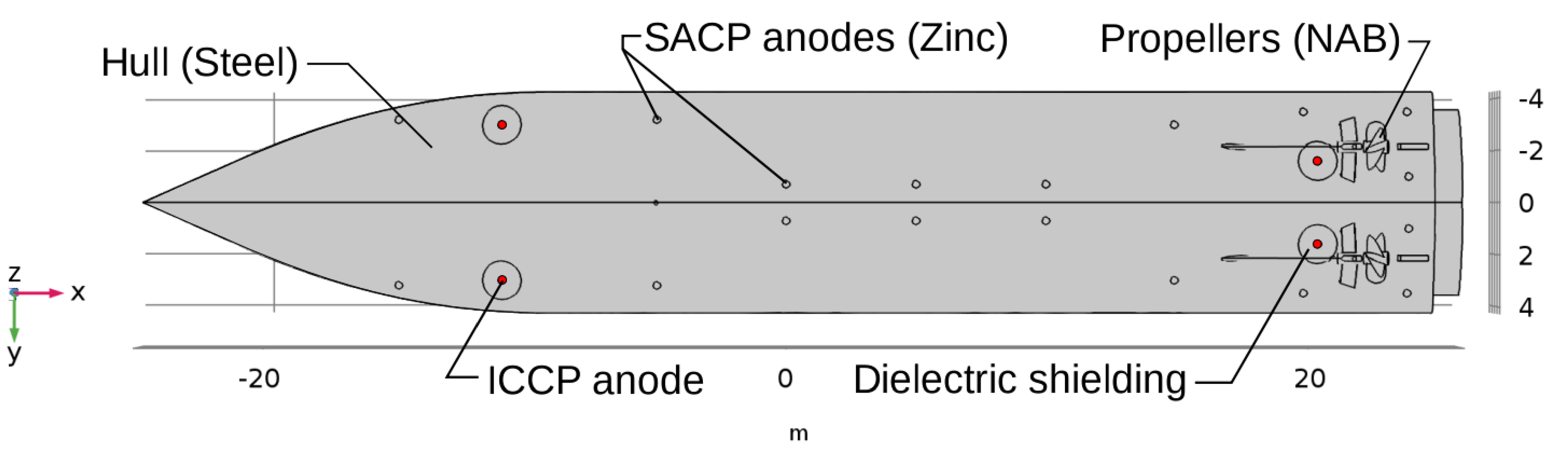

Fig. 1: Generic ship model to simulate the electric potential distribution along the ship's hull.

Geometry

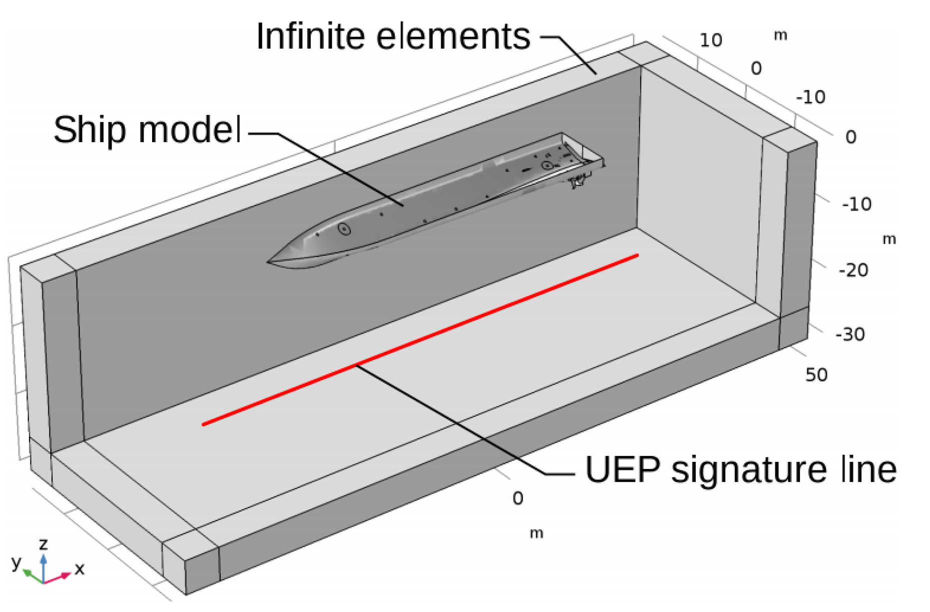

Fig. 2: Simulation setup in COMSOL Multiphysics®.

Nonlinear Polarization data

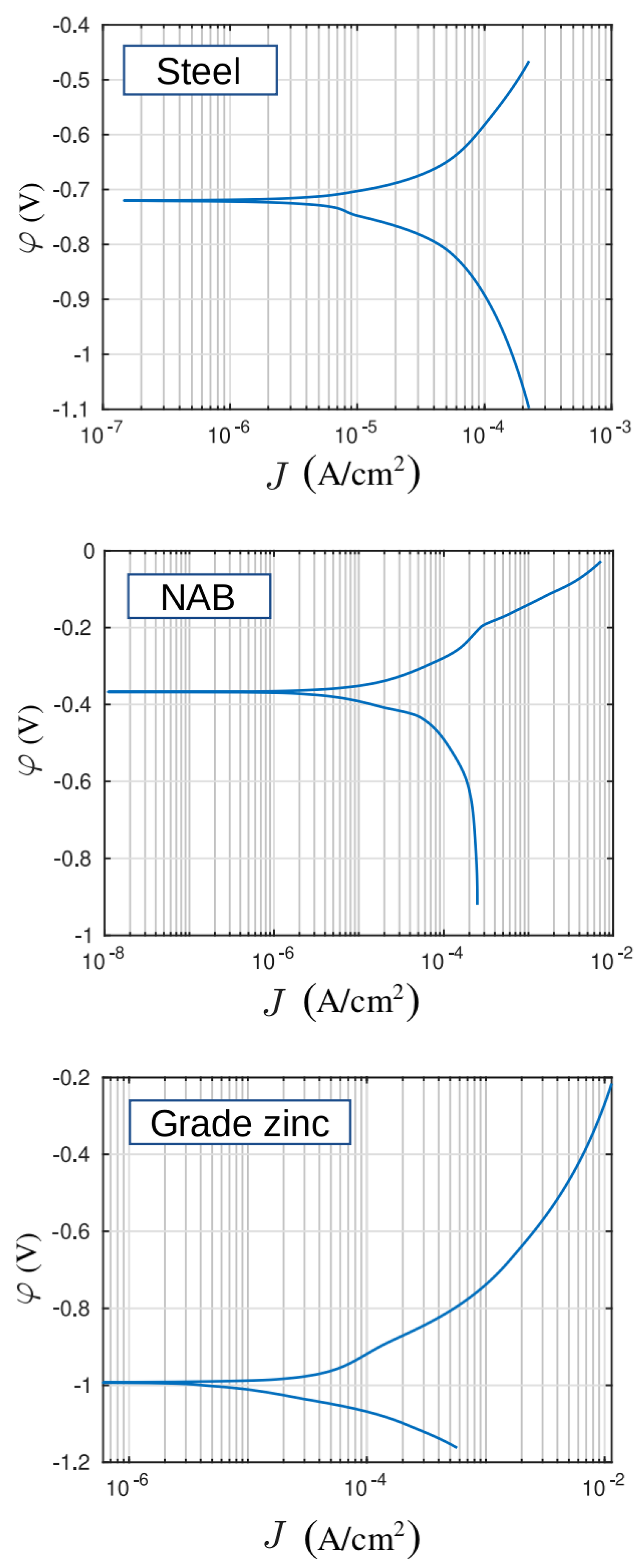

Fig. 3: Applied polarization data used on generic ship model.

Ship model:

- length: 50 m
- width: 8 m

Simulation domain:

- length: 100 m
- width: 35 m
- heigth: 30 m

Simulation parameters:

- Electric conductivity of water: 2.8 S/m
- Depth of UEP signature line: 20 m
- Open-water condition using infinite elements with a layer size of 5m

Boundary conditions:

- Corrosion process simulated using the inward current density formulation:

$$J_n = -\boldsymbol{n} \cdot \boldsymbol{J}$$

Reference Scenario

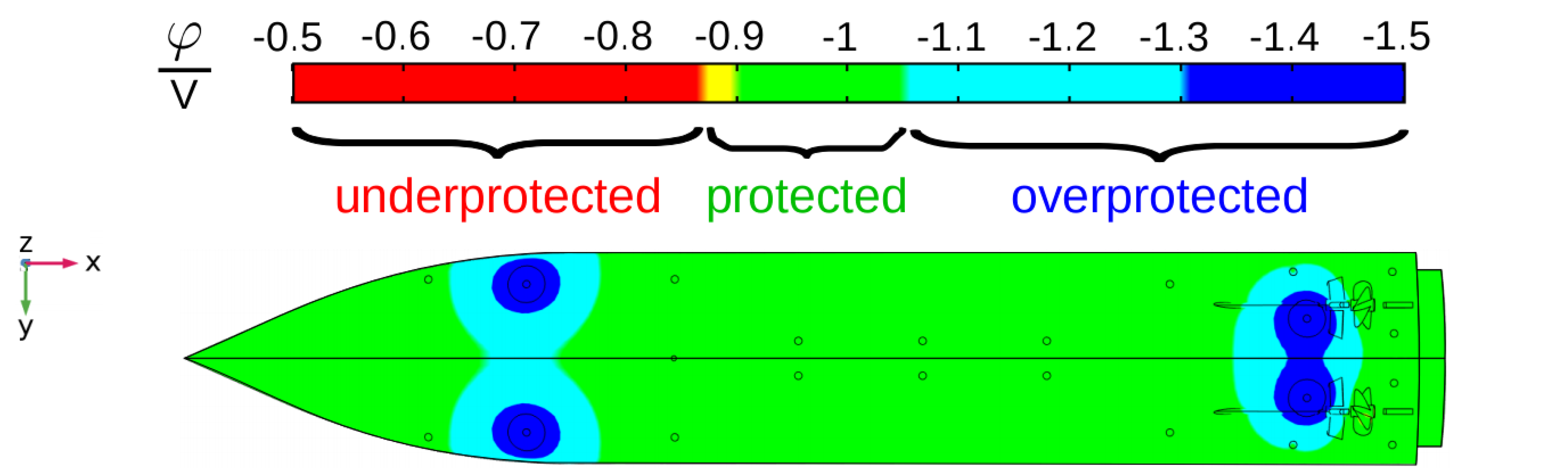

Fig. 4: Simulated reference scenario with imposed currents of 12.5 A for each individual ICCP anode to ensure a corrosion protective state of the naval vessel.

ICCP Current Adjustment

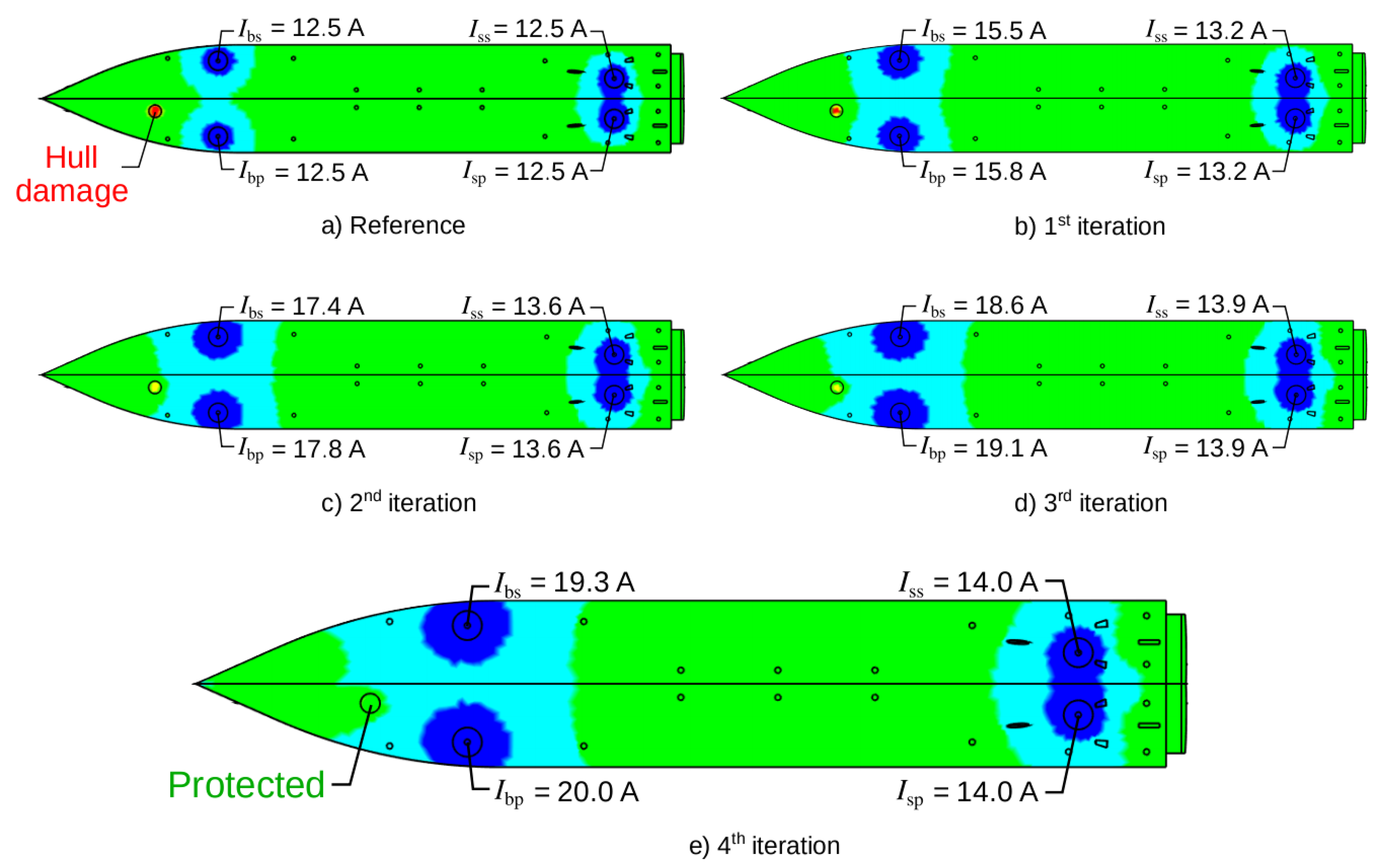

Fig. 5: Iterative ICCP current adjustment to maintain a protective state of the vessel after adding a hull damage which represents an under-protected area due to defective coating.

Formulation in Matlab:

$$I_{ICCP,new} = I_{ICCP,pre} + C \cdot \frac{\min(d_{abs})}{d_{abs}} \left(\frac{\varphi_{ref} - \varphi_{new}}{\varphi_{ref}} \right)$$

- $I_{ICCP,pre}$: Previous ICCP current
- C : Step size
- φ_{ref} : Reference electric potential
- d_{abs} : Absolute distance of damage to ICCP anode

$$d_{abs} = \left[(d_{x,anode} - d_{x,damage})^2 + (d_{y,anode} - d_{y,damage})^2 + (d_{z,anode} - d_{z,damage})^2 \right]^{1/2}$$

UEP signatures:

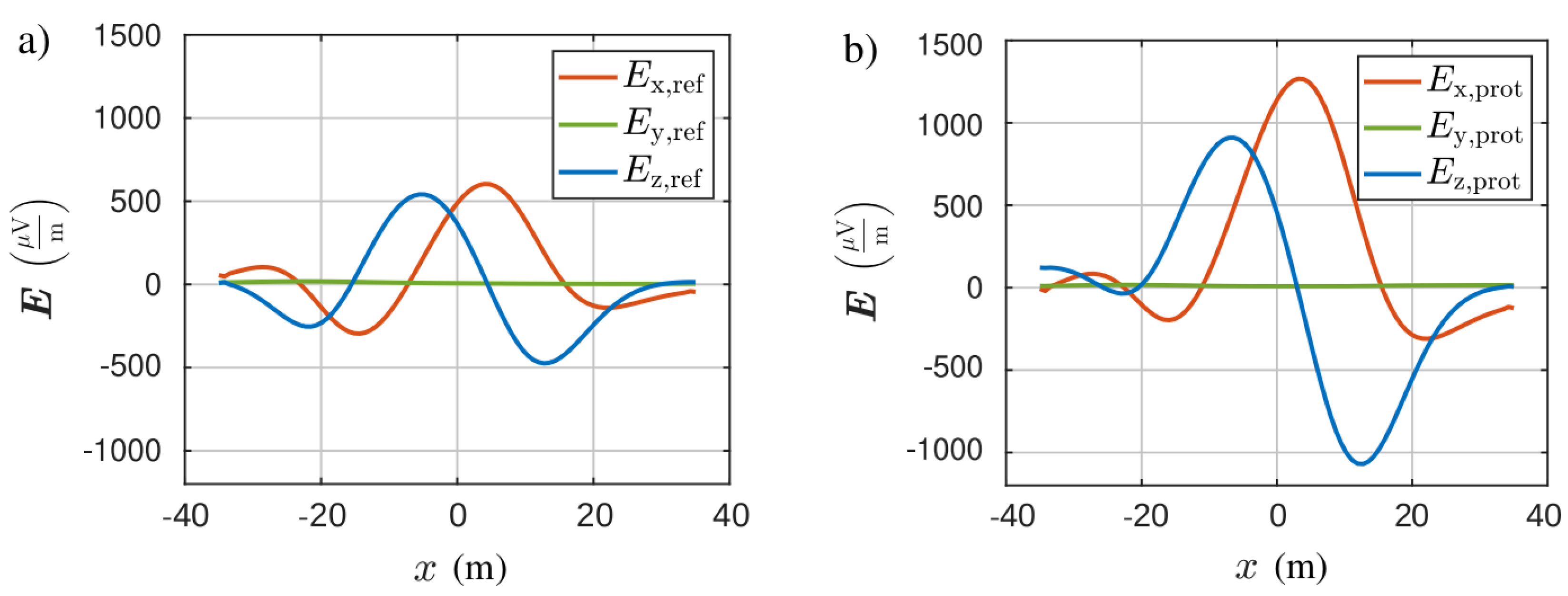

Fig. 6: Simulated UEP signature for the reference scenario a) and the adjusted ICCP system b). With the new ICCP currents the UEP signature nearly doubled.

Conclusion

- **Iterative ICCP adjustment using a simple mathematical formulation is possible**
- **UEP signature highly influenced by the ICCP system**
- **Results give good insight in the functioning of an ICCP system**