WAY AHEAD IN CORROSION CONTROL

Cathodic Protection Computer Modelling

Practical Approach-Study cases

DEEPWATER

stoprust.com

CP Modelling History
Various methods for numerical analysis

FDM: Finite Difference Method: Introduced in 1970`s
FEM: Finite Elements Method: Introduced late 1970`s to overcome FDM inability to handle complex geometries
BEM: Boundary Element Method: Most commonly used technique since 1980`s. Discretization on anode/cathode surfaces only and reduced equations and number of elements.

Common for all three methods: Numerical analysis with discretization of the electrolyte and/or the anode cathode surfaces into small elements by linear, quadratic or other equations to satisfy Laplace`s equation and relevant boundary conditions.

(Source: Roe Strømmen: Computer Modelling of Offshore Cathodic Protection-Method and Experience)

Successful modelling
Two important criteria

1. **Efficient**
   - ✓**Models may be complex geometries**
   - ✓**Geometry generation is time consuming**
   - ✓**Need to be efficient**
   - ✓**Choice of software important**

2. **Data input and interpretation**
   - ✓**Requires skilled personnel. A (multi discipline) team ensures correct modelling rather than being dependent on one person**
   - ✓**Important to to review modelling results, quality assure input**

Static simulations
Linearisation of potential vs. current density

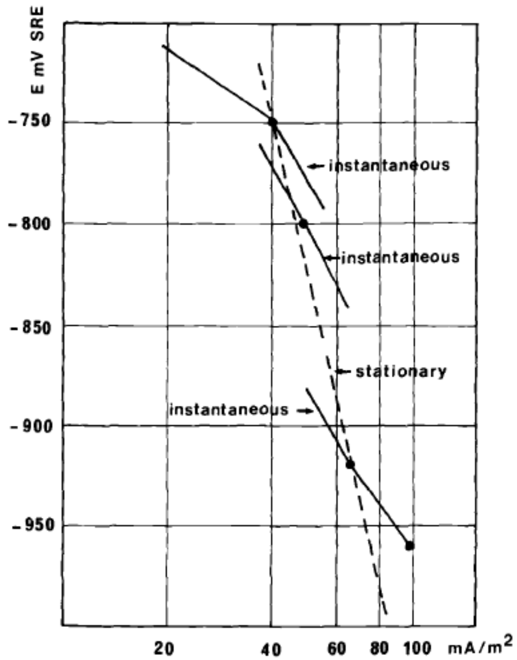


FIG. 4—*Measured polarization curves of the static and instantaneous types obtained from isolated steel specimens on an offshore platform* [1].

(Source: Roe Strømmen: Computer Modelling of Offshore Cathodic Protection-Method and Experience)

- **Linearisation of potential vs. current density widely used for static CP simulations**
- **FEM modelling: Solving numerical analysis with Butler Volmer Equation for "field data and design code parameters"**

Static simulations
Linearisation of potential vs. current density

$$i = i_0 \left\{ exp\left[\frac{\alpha_a nF\eta}{RT}\right] - exp\left[-\frac{\alpha_c nF\eta}{RT}\right] \right\}$$

Butler Volmer:

i_0 = exchange current density

αa and αc = charge transfer coefficient (cathodic and anodic)

n = numbers of electrons in the reaction

F = Faradays constant

R = Universal gas constant

T = Temperature

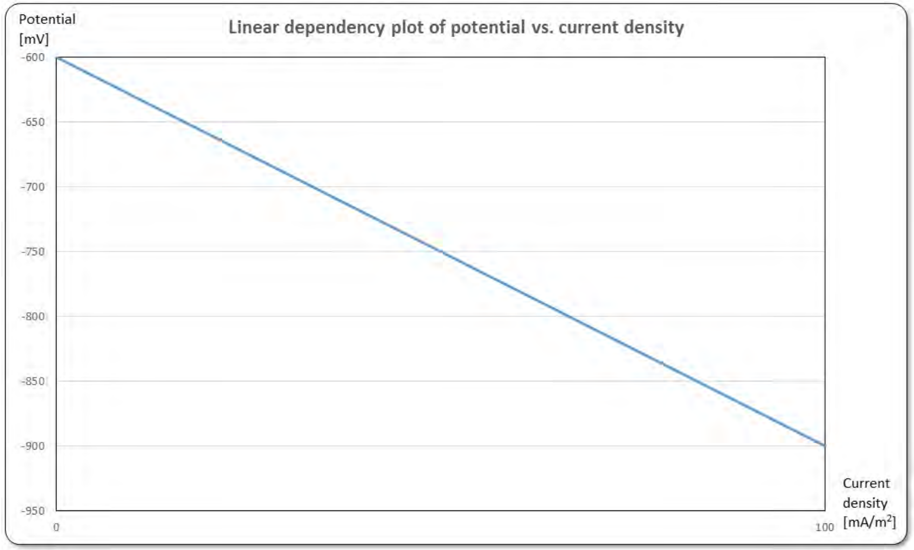
ή = activation over potential = $\eta=(E-E_{eq})$.

For constant temperature everything except over potential and current density is constant, which can be contracted / simplified into a single transfer coefficient → "XFER"

Static simulations
Linearisation of potential vs. current density

Linear equation simplified from BV:

$$E = E_0 - \frac{1}{XFER} \cdot i$$



Where:

E = potential vs. Ag/AgCl for cathode or anode

E_0 = for the cathode (steel) set to -600 mV / -1050 mV for GACP

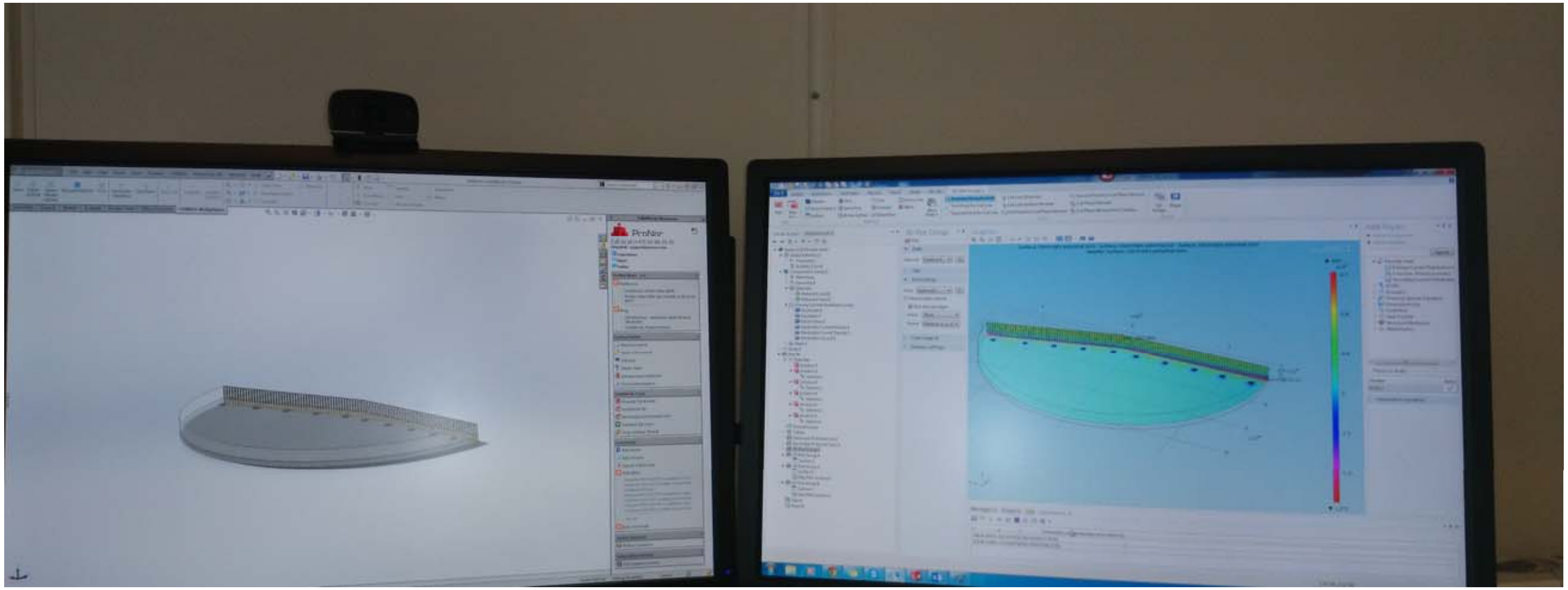
i = current density (positive for cathode and negative for anodes

XFER = transfer coefficient in ((mA/m2/mV))

- for bare steel with a transfer coefficient of 0,33 the current density at -900 mV will be 100 mA/m2 (e.g. DNV RP-B401 mean value)

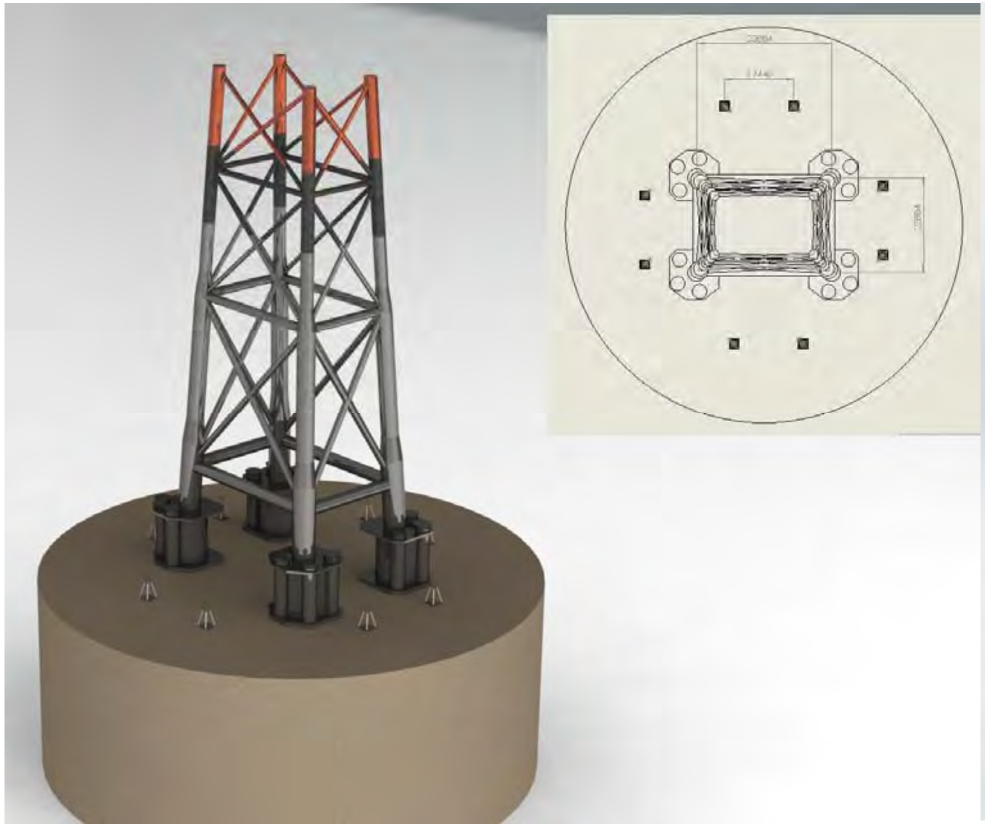
(Source: Nace paper no 2121-2013 (Wigen, Osvoll and Gouriou)

Modelling Approach
3D structural software linked to commercial multiphysics software



- Eliminates need for pre-processor
- Allows import of complete models or building 3D models “from scratch”
- Live link to multipysics software with corrosion module-FEM analysis (implementing BEM Q1-2015)

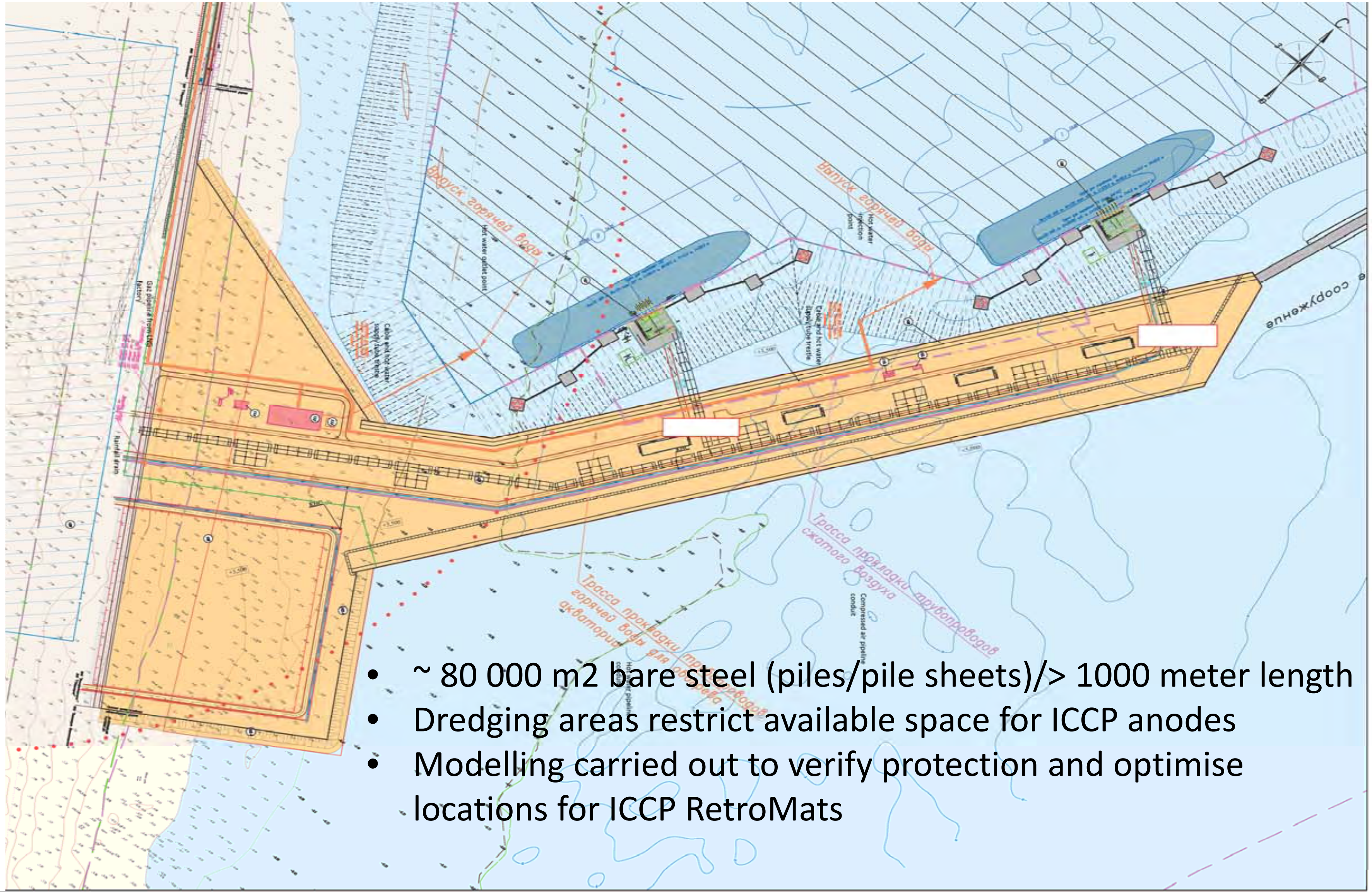
Local and Global Models



Global model of jacket with pile clusters.
Split in 3 environmental zones.
Remote galvanic anode sleds distributed around jacket.

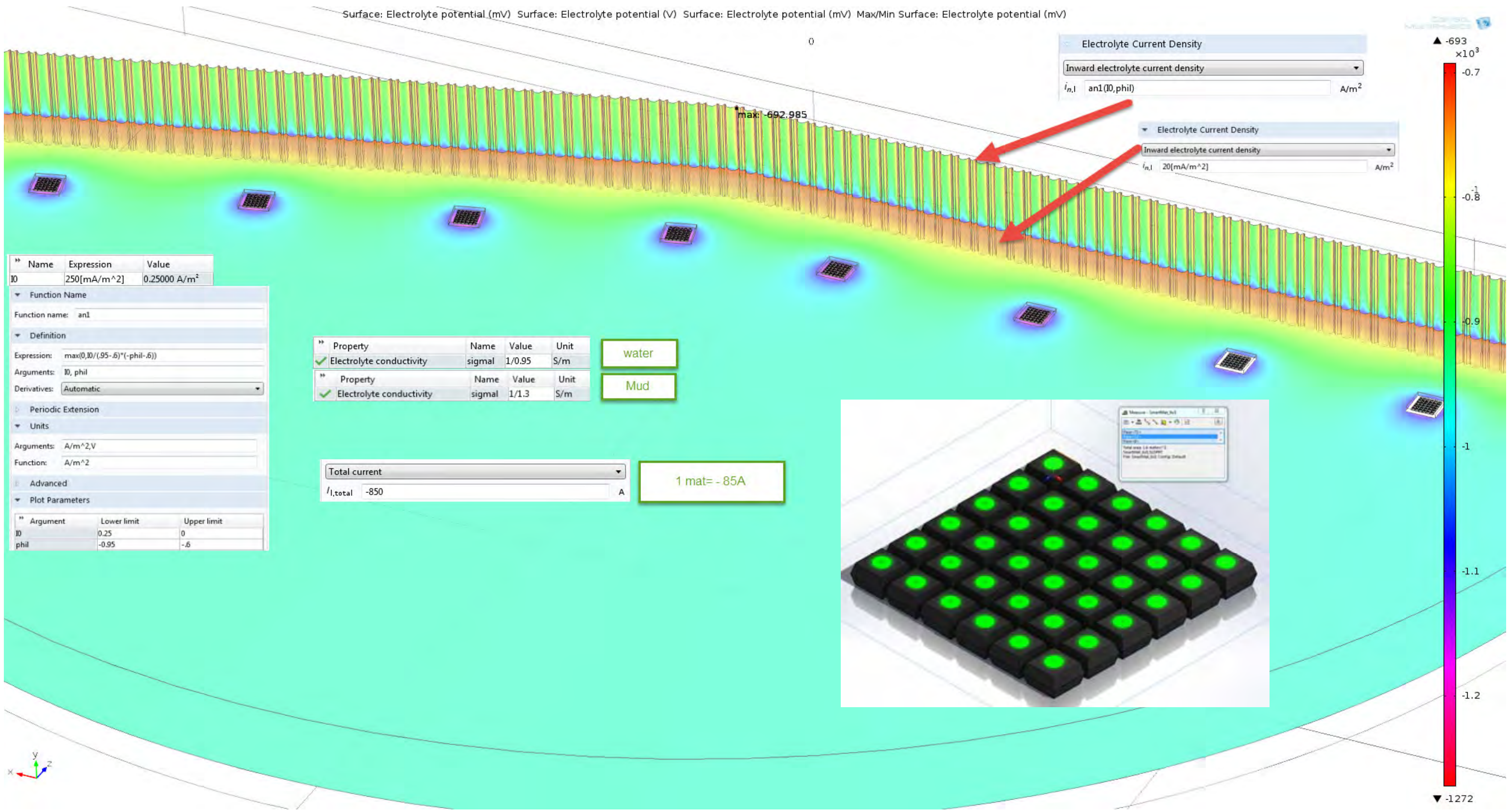
Local model of jacket section.
Yellow section is mud zone.
Galvanic anodes distributed on members.

Project Case-New design
Artic LNG Offloading Port-Yamal LNG



- ~ 80 000 m2 bare steel (piles/pile sheets)/> 1000 meter length
- Dredging areas restrict available space for ICCP anodes
- Modelling carried out to verify protection and optimise locations for ICCP RetroMats

Project Case-New design
Artic LNG Offloading Port-Yamal LNG



Project Case-New design
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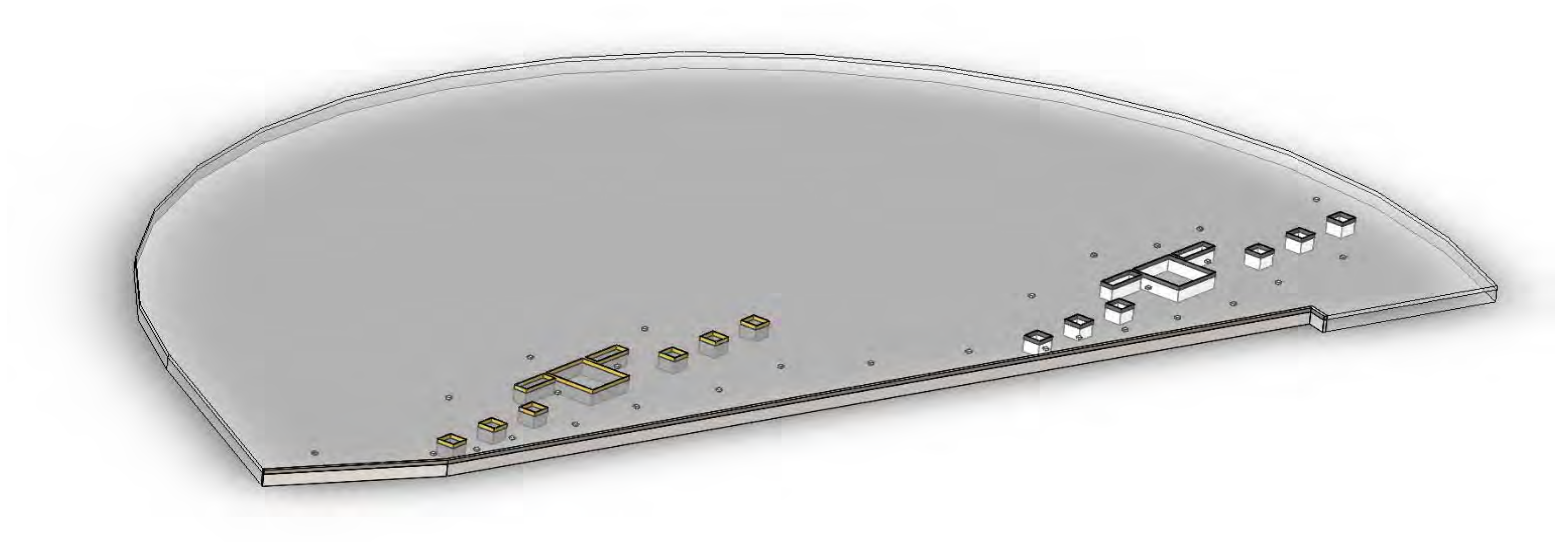

Project Case-New design
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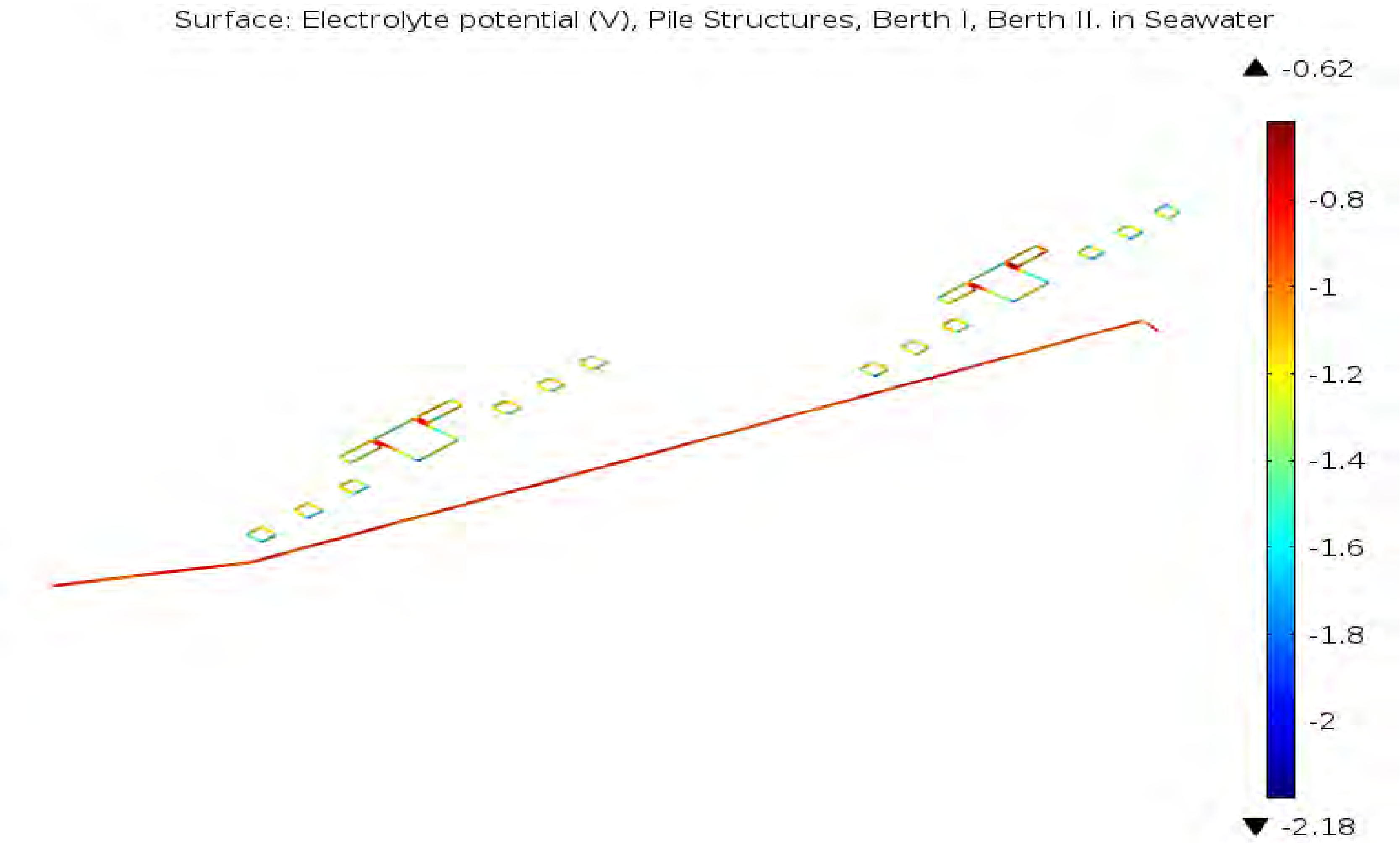
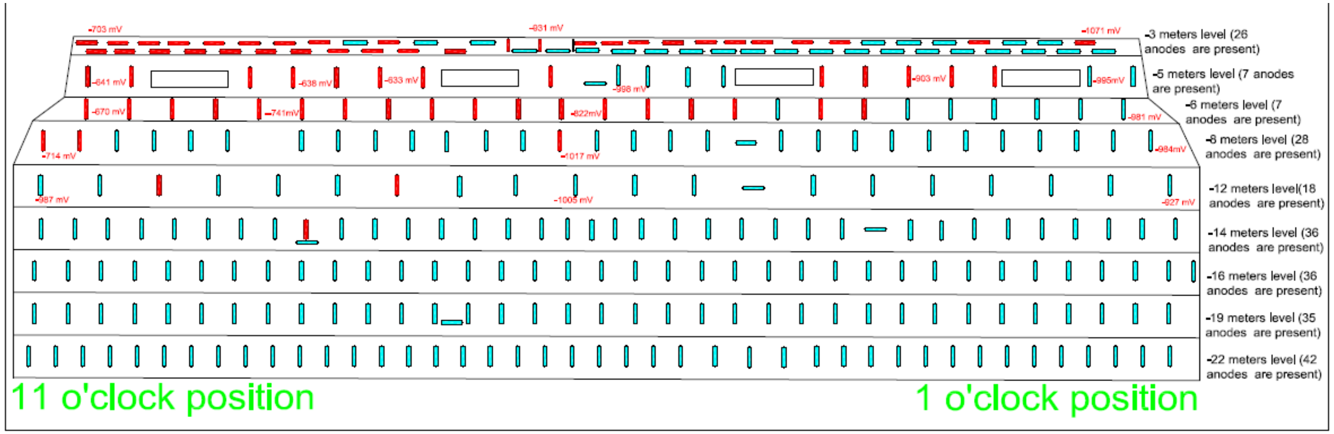


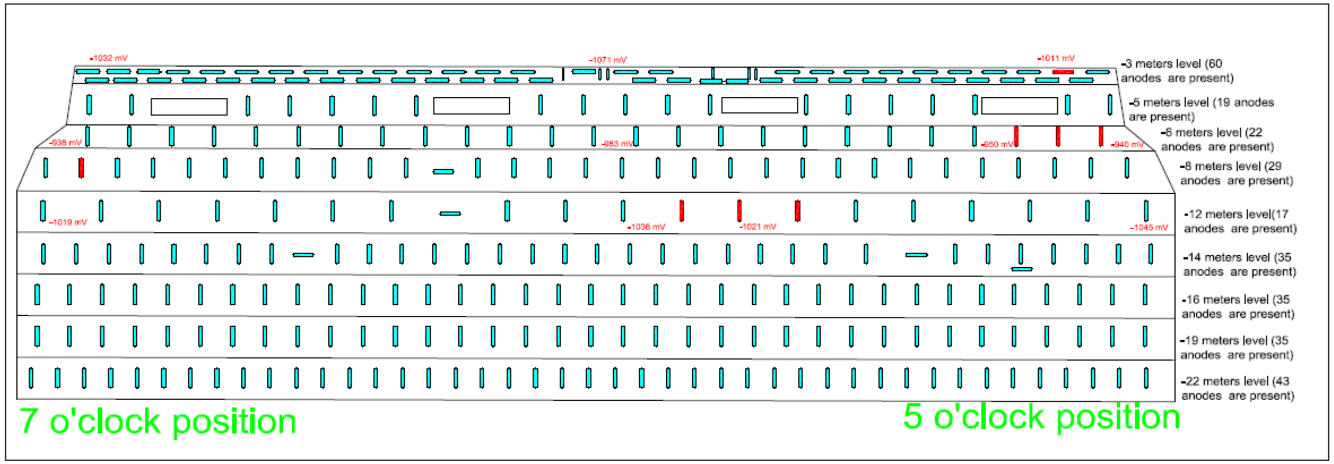
Project Case-Platform retrofit
Artic GBS Platform-Shallow waters


- **Originally fitted with GACP system**
- **In service for around 10 years**
- **Ice tear of avg. 10 anodes per year. Currently some 150 anodes lost**
- **Drop Cell surveys show increasing areas outside CP criteria**
- **Ice forming from -15 to +9 meter 5-7 months per year**

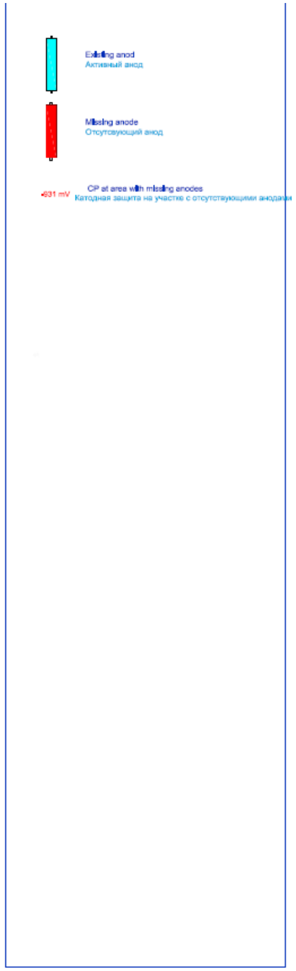
Project Case-Platform retrofit
Artic GBS Platform



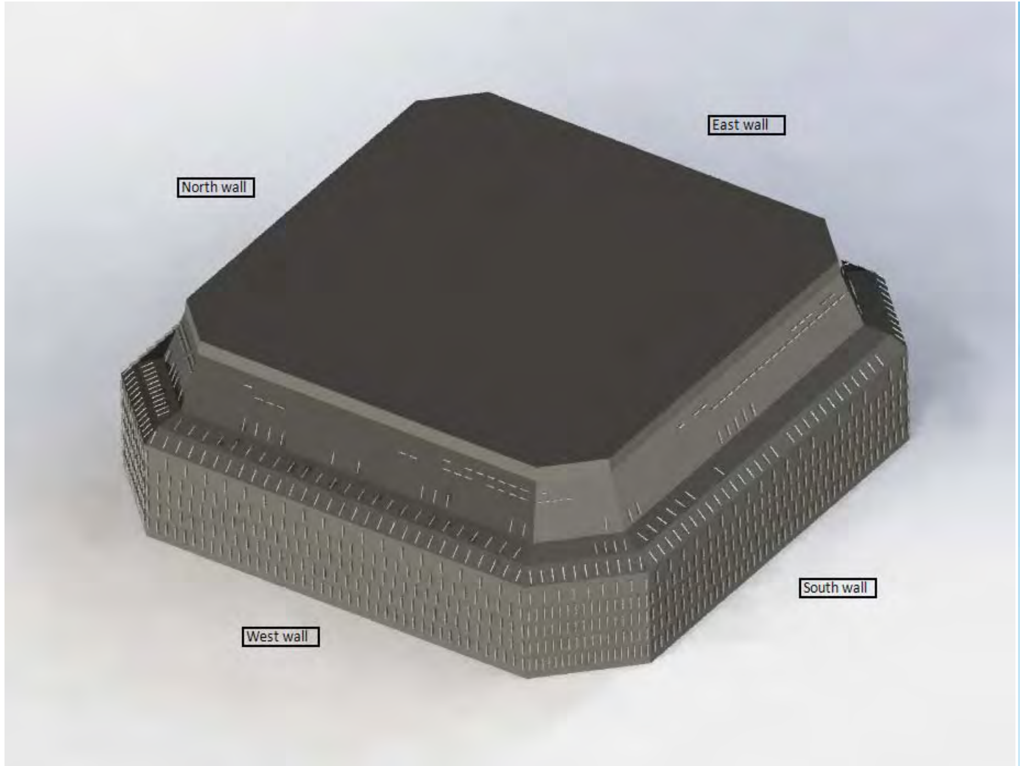
ANODES DISTRIBUTION. SOUTH WALL / РАСПОЛОЖЕНИЕ АНОДОВ. ЮЖНАЯ СТЕНА

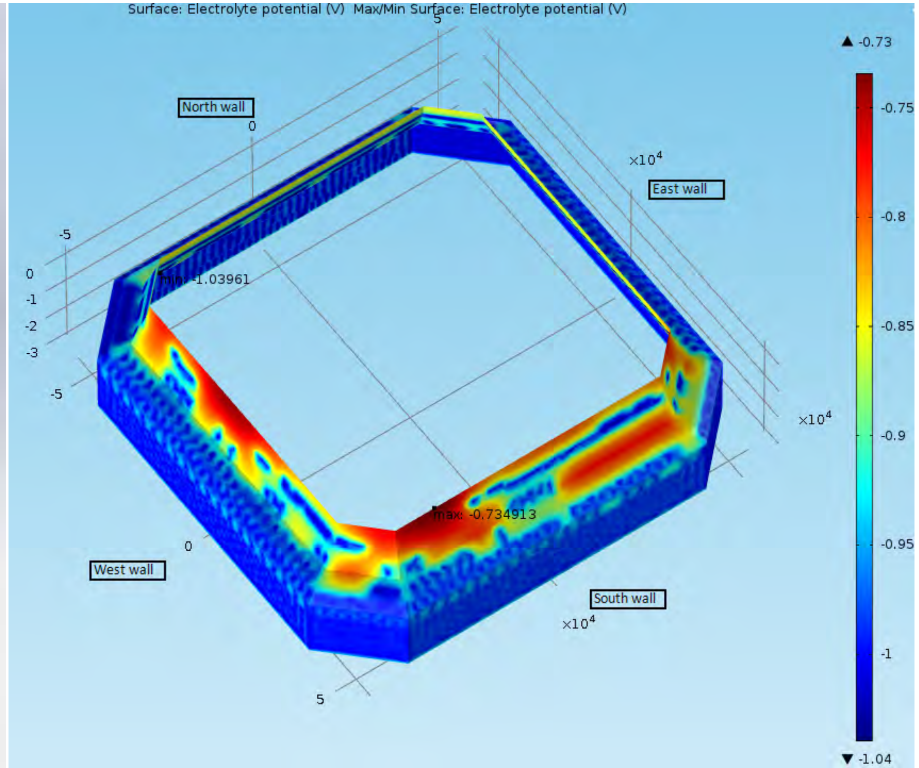


ANODES DISTRIBUTION. NORTH WALL / РАСПОЛОЖЕНИЕ АНОДОВ. СЕВЕРНАЯ СТЕНА



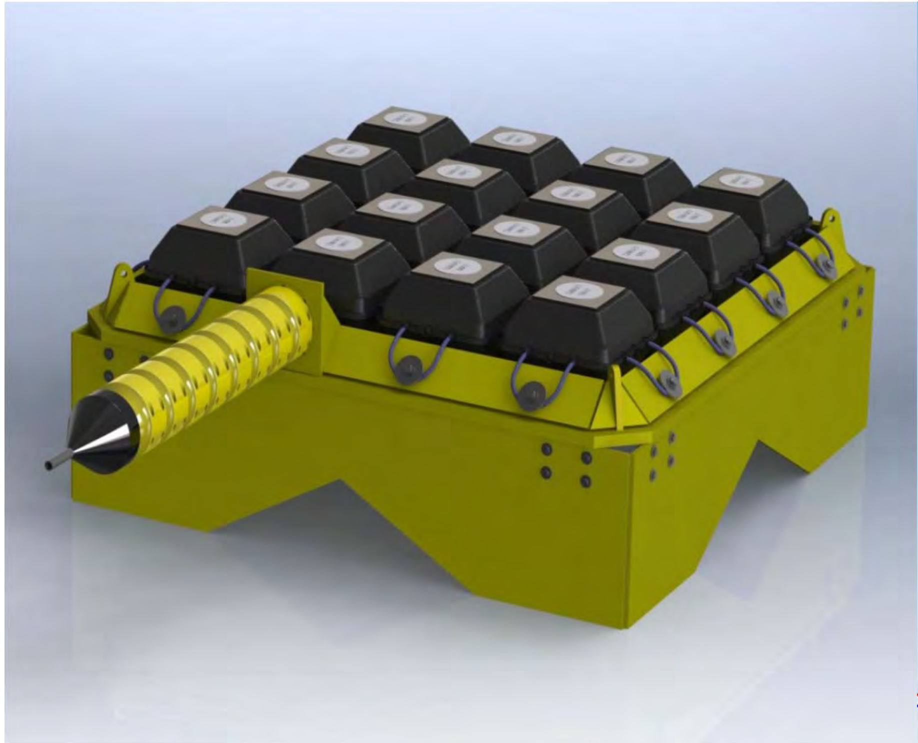
Project Case-Platform retrofit
Artic GBS Platform

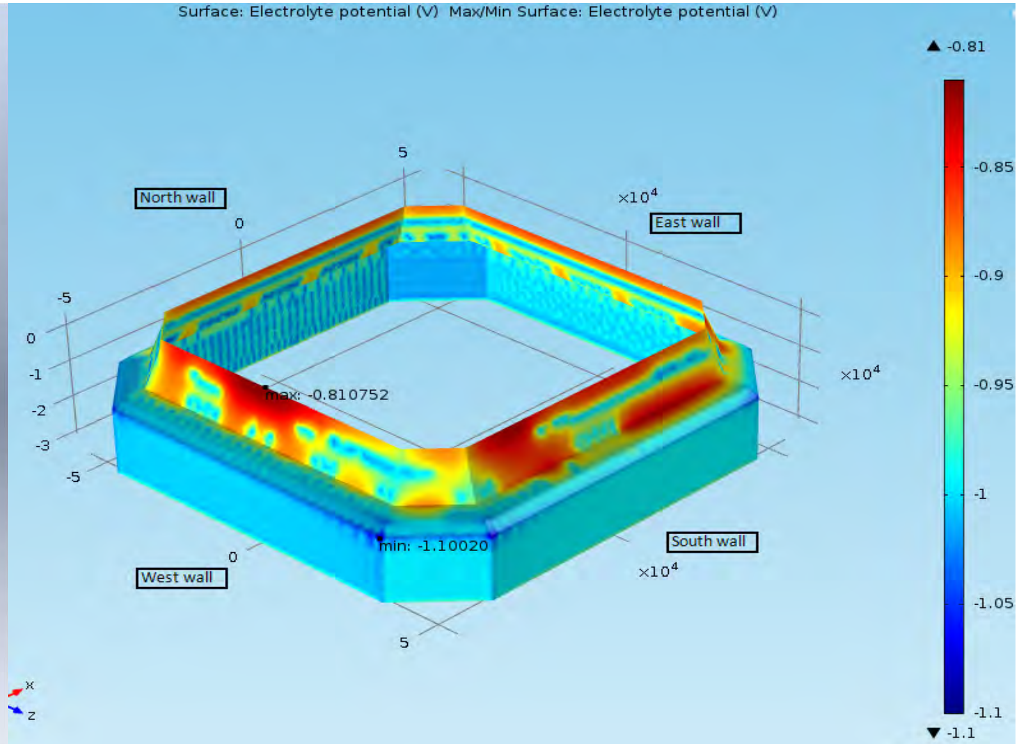




- **3D model generated based on structural drawings and anode distribution drawings**
- **CP analysis carried out to replicate inspection data show avg. current density around RP-B401 mean for Artic conditions**

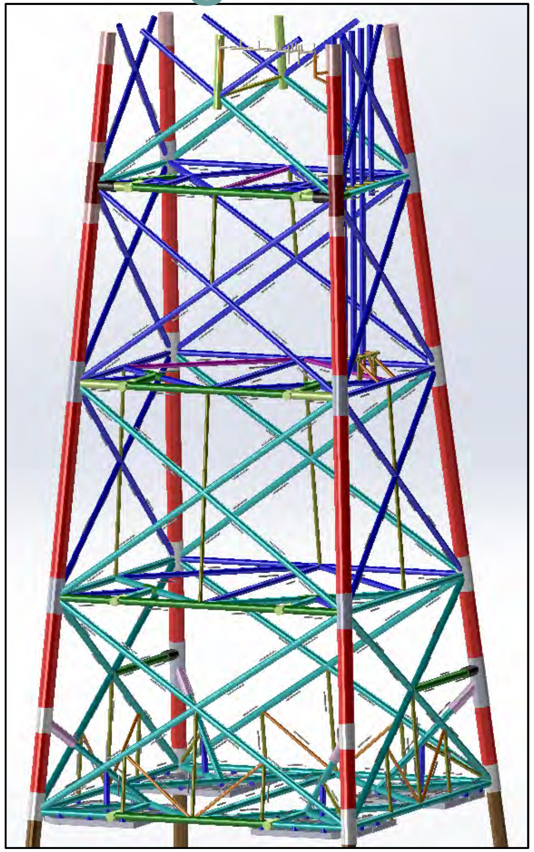
Project Case-Platform retrofit
Artic GBS Platform

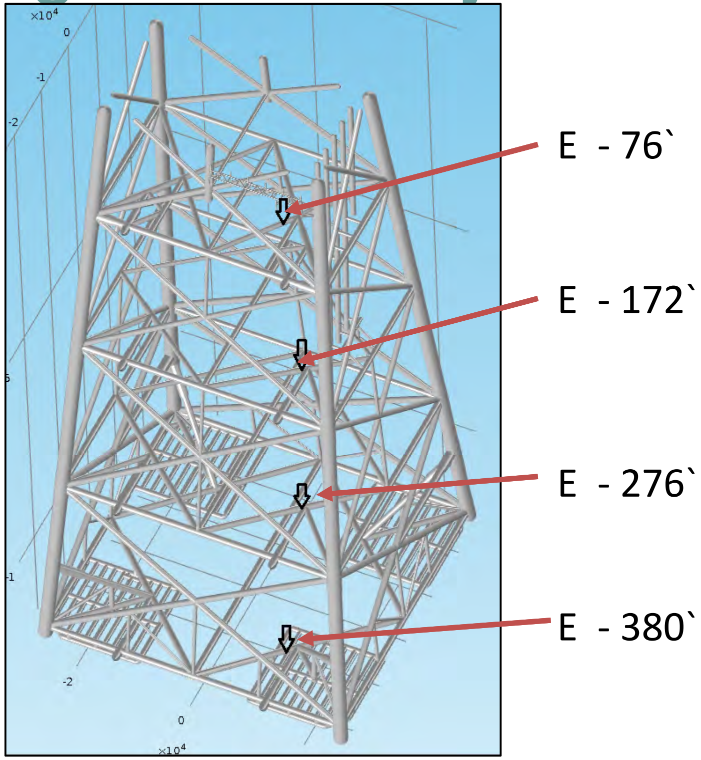




- **ICCP retrofit proposed using RetroMats due to shallow water and ice**
- **Preliminary simulations shows that an array 5-8 of 300 Amp. RetroMat will provide sufficient CP to the platform**
- **Still challenges with subsea cables and available J-tubes to be solved**

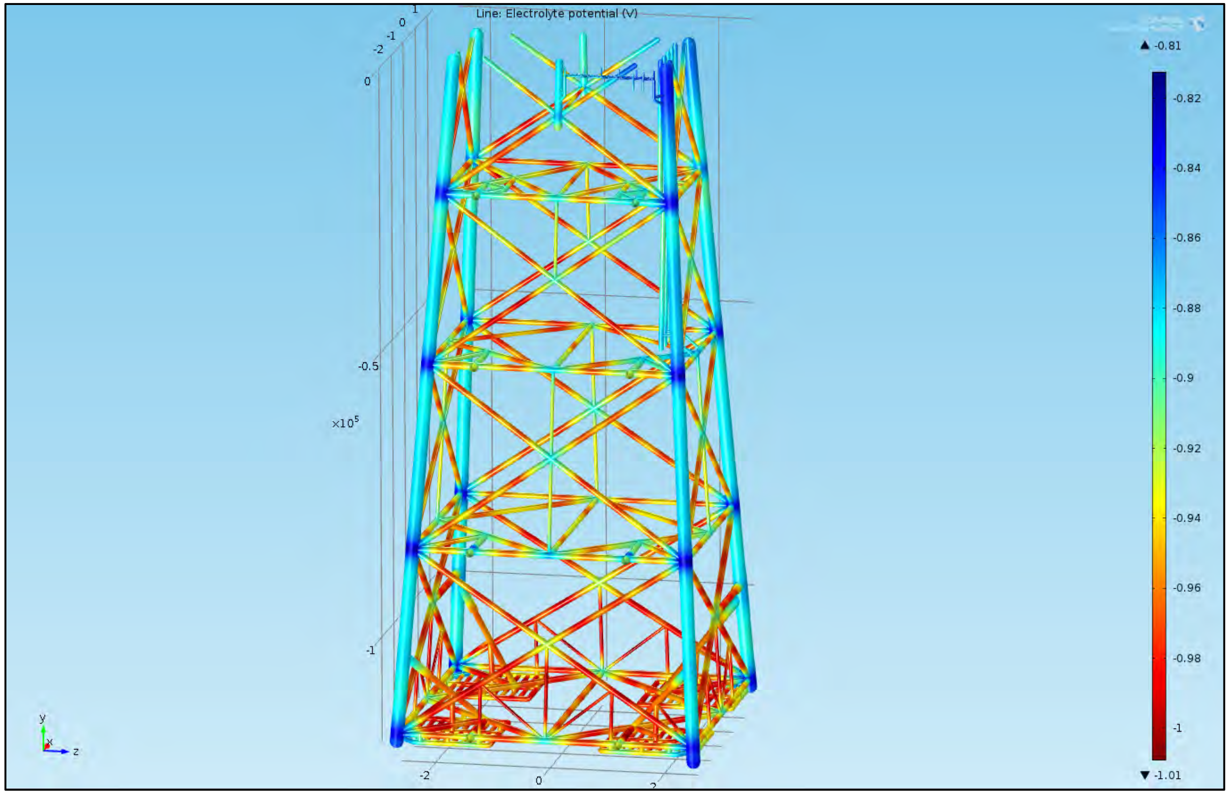
Validation of simulation results-approach
Utilising monitoring data from jacket





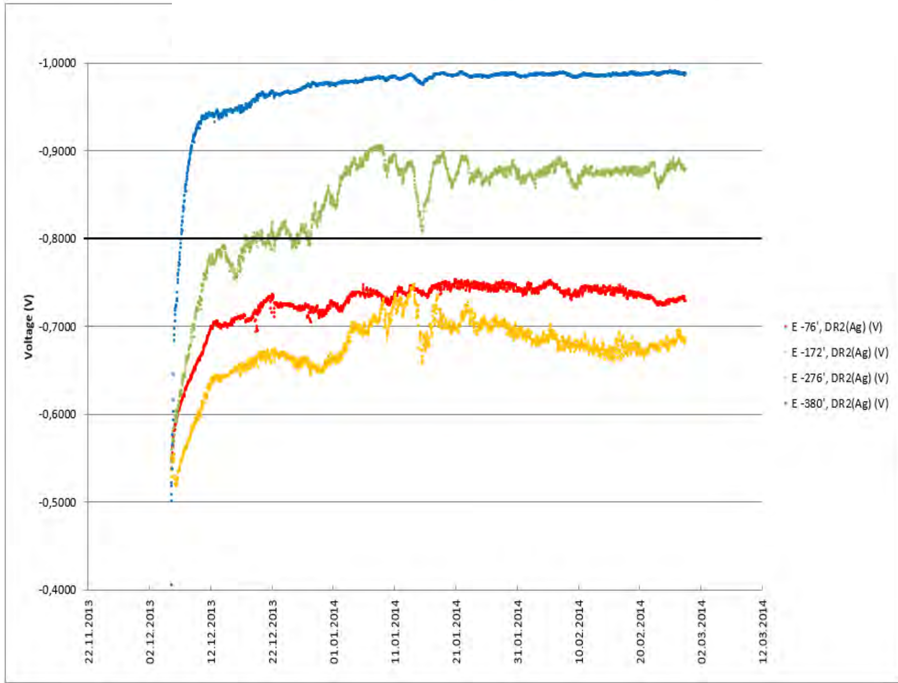
- **Jacket located on West African shelf**
- **GACP system monitored with potential and current density loggers**

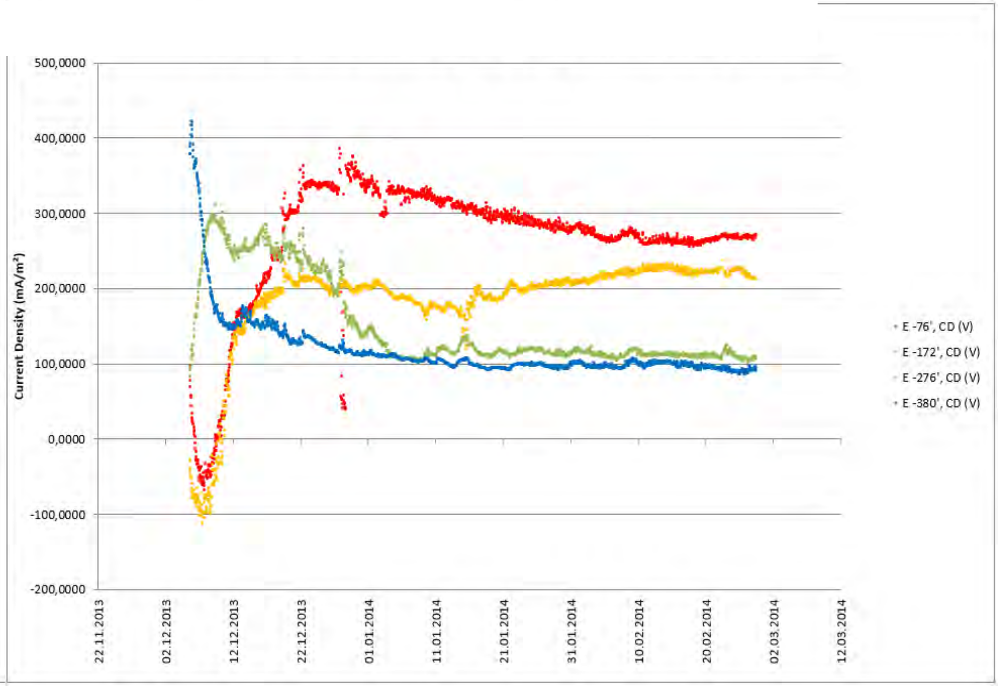
Validation of simulation results-approach
Utilising monitoring data from jacket



- **Poor design information. Apparently mean current demand is used; 65 mA/m2 for bare steel**
- **Static simulations based on design basis indicates sufficient CP**

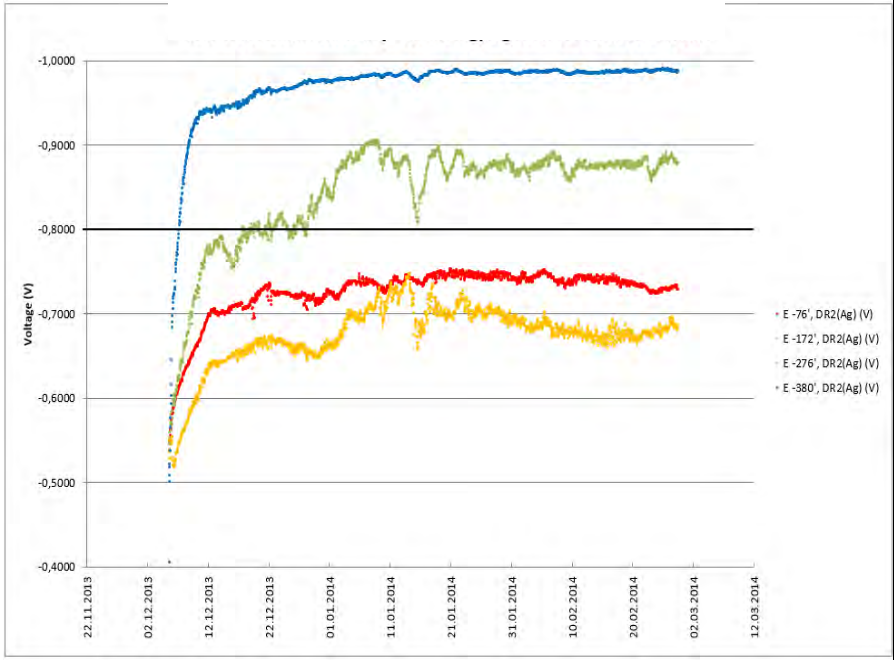
Validation of simulation results-approac
Utilising monitoring data from jacket

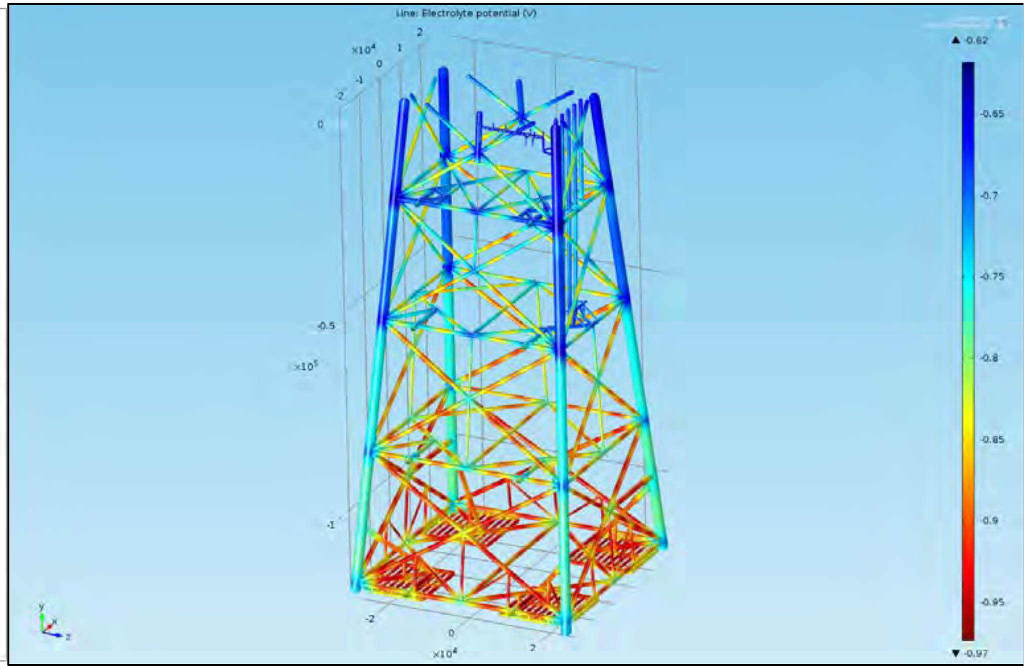




- **Potential monitoring show insufficient polarization for 4 first months on upper half of the jacket**
- **Current density logger show current demand stabilizing significantly higher than design**

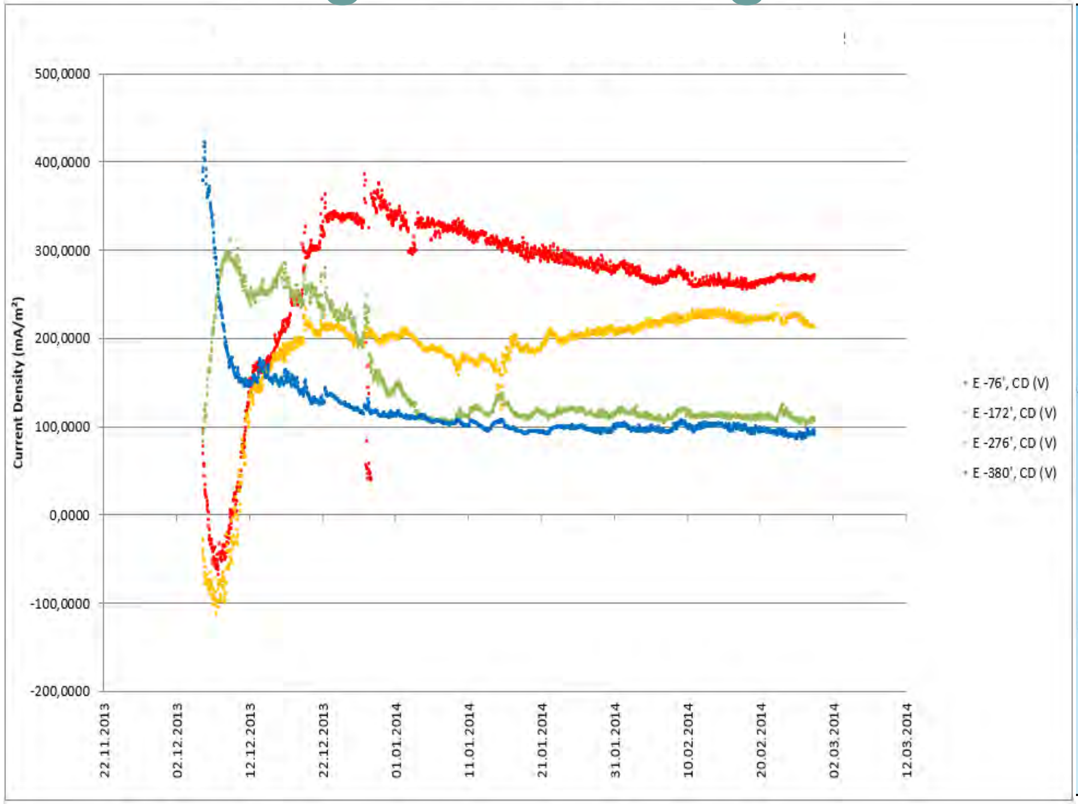
Validation of simulation results-approach
Utilising monitoring data from jacket

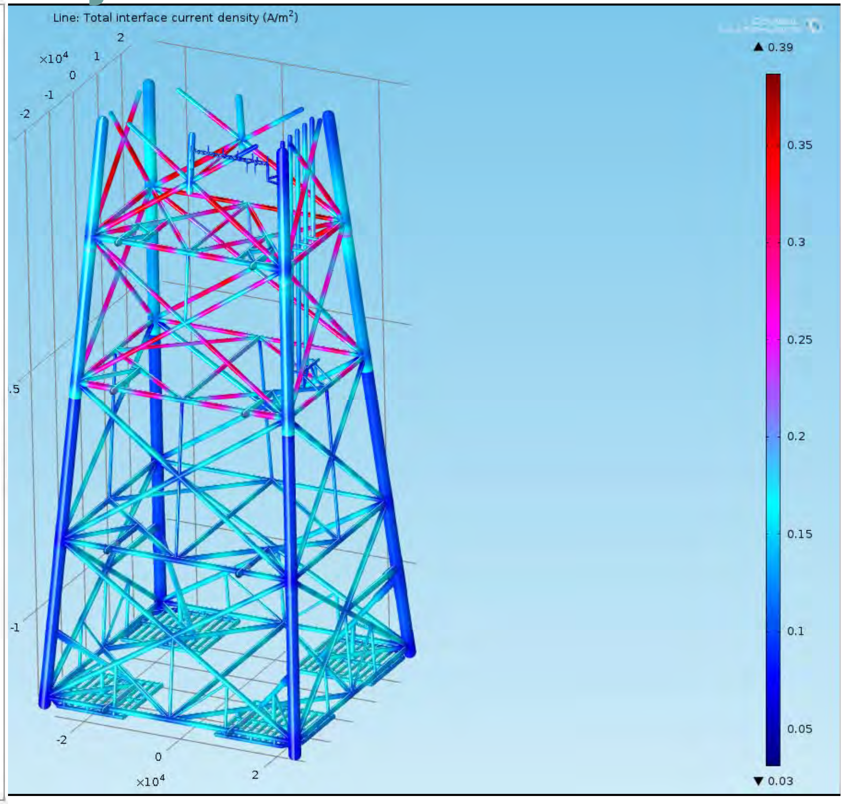




- **Modelling with field data to show good correlation with recorded and calculated potential profile when applying recorded current density and utilizing linear potential vs. current density relationship**

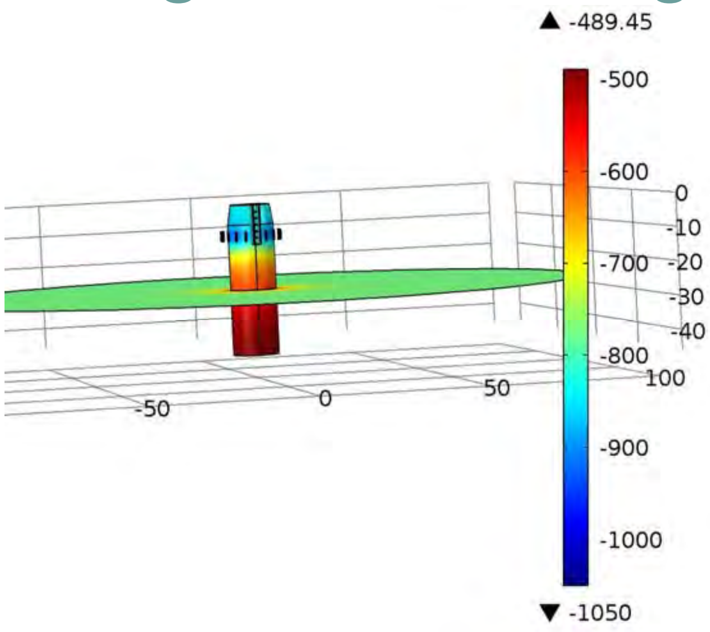
Validation of simulation results-approach
Utilising monitoring data from jacket





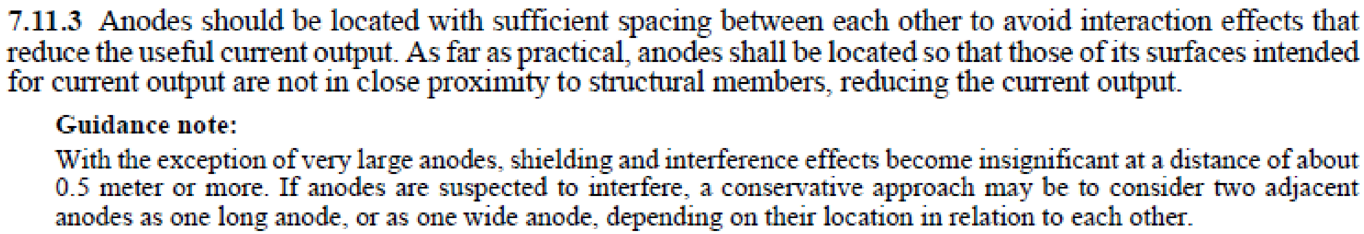
- **Modelling with field data show good correlation with recorded and calculated current density profile when applying recorded current density and utilizing linear potential vs. current density relationship**

GACP interference
Optimising anode configuration



Offshore wind Mono Piles: Experienced several inadequate CP systems due to anode configuration

DNV-RP B401 Very vague on anode interference:

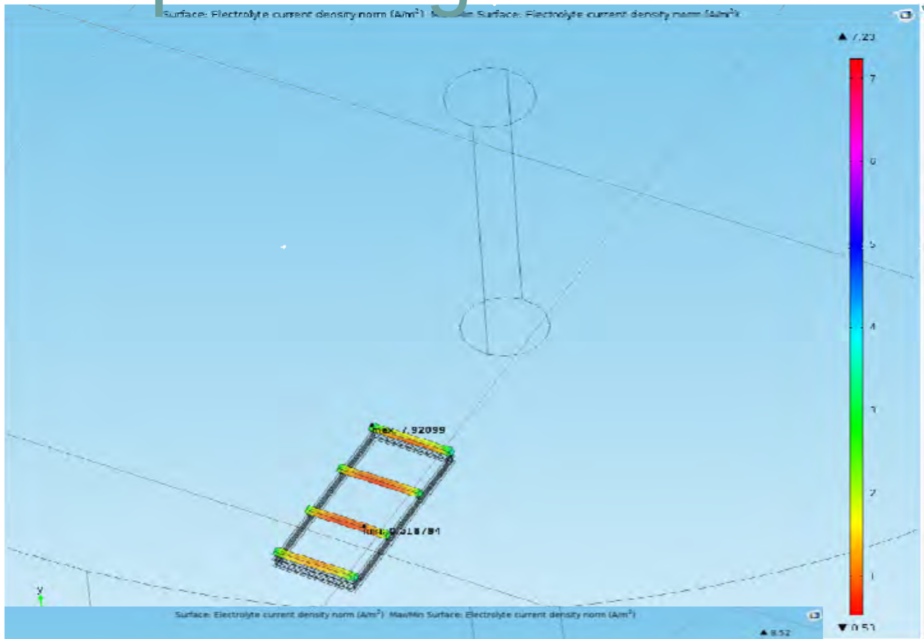


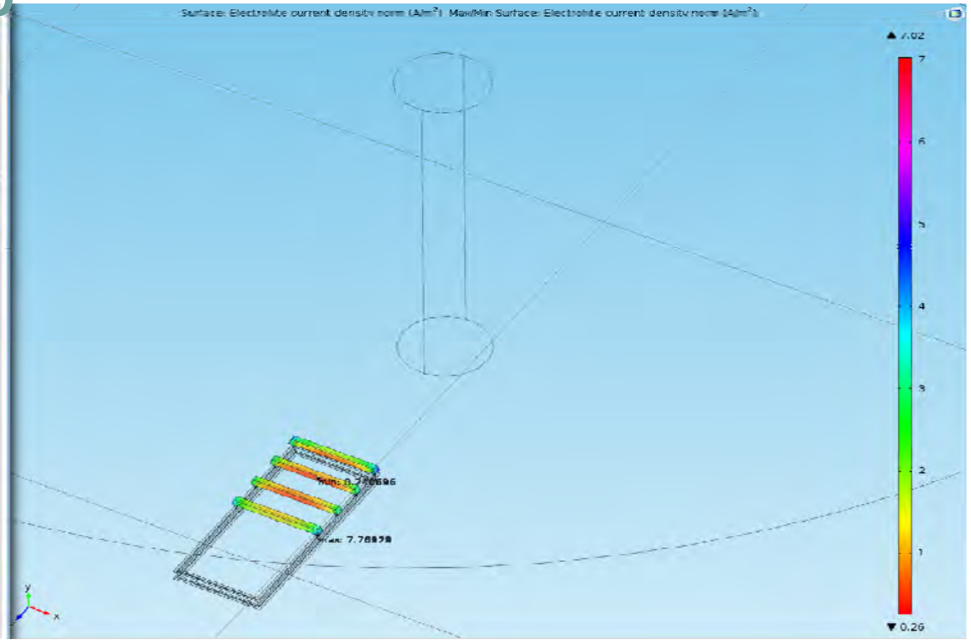
7.11.3 Anodes should be located with sufficient spacing between each other to avoid interaction effects that reduce the useful current output. As far as practical, anodes shall be located so that those of its surfaces intended for current output are not in close proximity to structural members, reducing the current output.

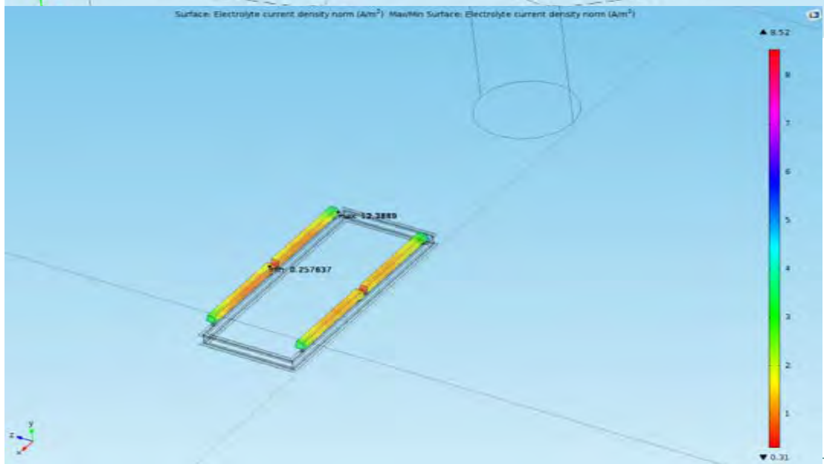
Guidance note:

With the exception of very large anodes, shielding and interference effects become insignificant at a distance of about 0.5 meter or more. If anodes are suspected to interfere, a conservative approach may be to consider two adjacent anodes as one long anode, or as one wide anode, depending on their location in relation to each other.

GACP interference
Optimising anode configuration

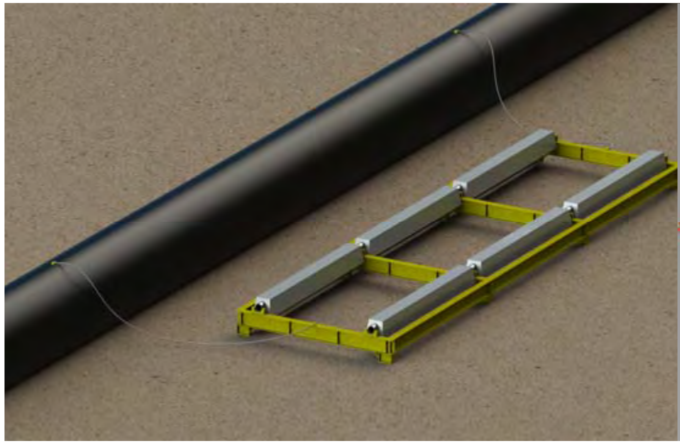




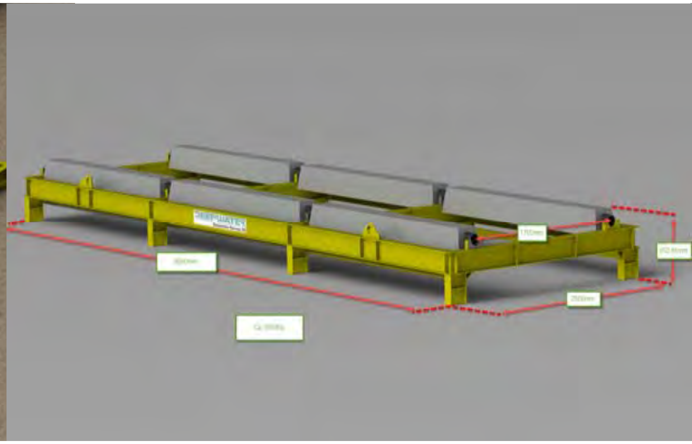


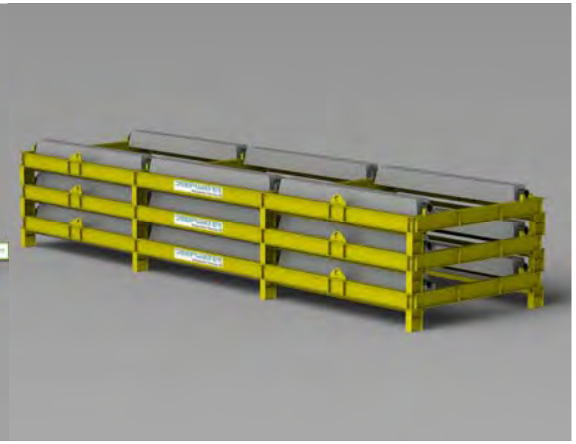
Larger anode requires larger inter distance
Modelling is a good tool to optimize anode configuration on structures and design of anode sleds

Extending project scopes
Multiphysics software allows complete studies

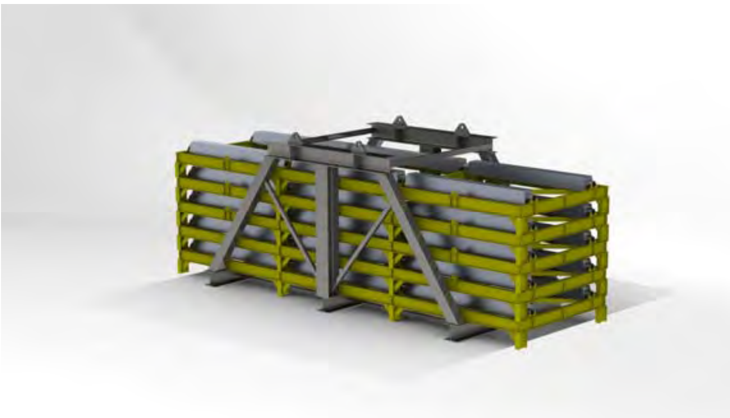


Pipe bundle retrofit

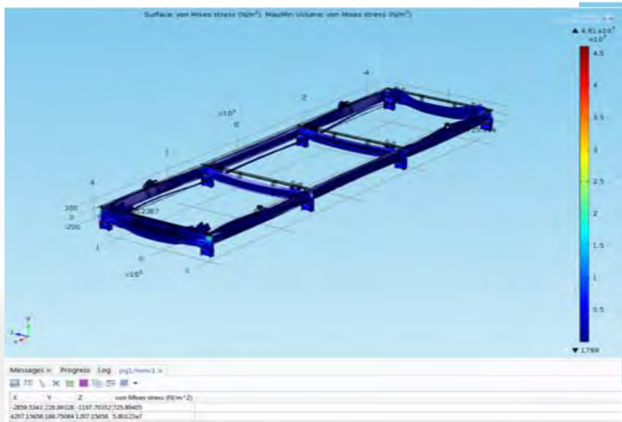


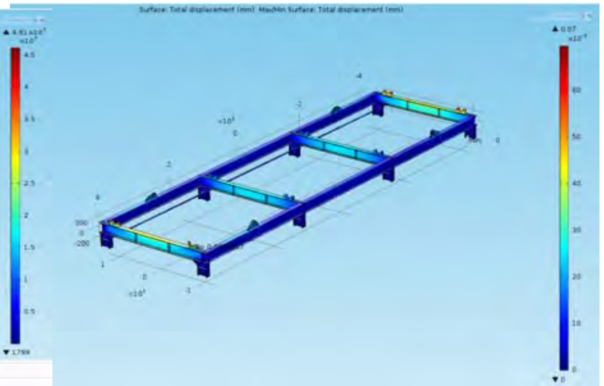


Client requires “pancake stacking” on deck



Stacking with sea fastening



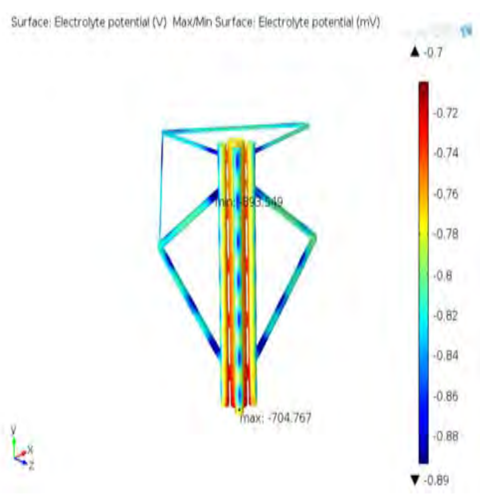


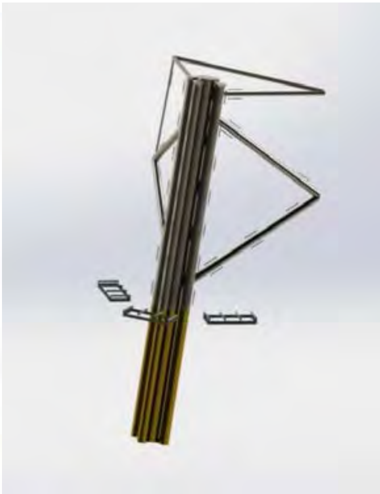
Modelling to optimise sled design and structural analysis

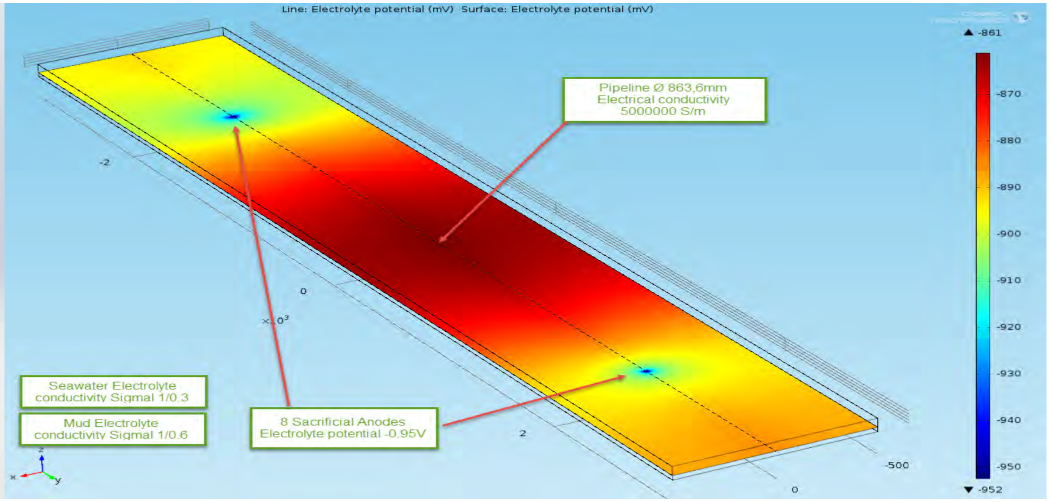
Summary

CP modelling allows efficient and trustworthy:

- **Verification of general CP design by design code (ref. offshore wind)**
- **Optimisation of retrofit projects and lifetime extensions**
- **Aid and optimisation of inspection planning**
- **“What if studies”**
- **Prediction of real development of the CP system (not necessarily as per given design code)**







Thanks for your attention