Numerical simulation and re-design optimization of impressed current cathodic protection for an offshore platform with biofouling in seawater

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In this work, a previous off shore platform was protected by an ICCP system with two auxiliary anodes for 10 years.

An auxiliary anode was found lost.

An ICCP re-design for this offshore platform in service was urgently optimized.
FIGURE 2 Schematic diagram of the placement of optimizing auxiliary anode locations of target zones: (a) one auxiliary anode, (b) two auxiliary anodes.

FIGURE 1 2-D geometries of Row 1–2 (a) and Row A–B (b) of an offshore platform. Dimension: mm
FIGURE 3 FE-SEM pictures of porous loose surfaces of the product and the reverse sides against the Leg A-1 in the depths of 20m (a and c) and 60m (b and d) under seawater.
Table 1 EDS results of biofouling deposits of the platform leg

<table>
<thead>
<tr>
<th>Element</th>
<th>C</th>
<th>O</th>
<th>Na</th>
<th>Mg</th>
<th>Al</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic%</td>
<td>6.85</td>
<td>71.99</td>
<td>0.84</td>
<td>0.82</td>
<td>0.86</td>
<td>1.61</td>
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</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>S</th>
<th>Cl</th>
<th>K</th>
<th>Ca</th>
<th>Fe</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic%</td>
<td>0.54</td>
<td>0.45</td>
<td>0.14</td>
<td>13.92</td>
<td>1.72</td>
<td>0.27</td>
</tr>
</tbody>
</table>
FEM calculations

The potential and current density distributions by FEM simulation are shown in Figure 4b and c.

FIGURE 4 (a) 3-D meshes of the offshore platform in simulation environment. The potential (b) and current density (c) distributions calculated by FEM simulation.
Optimization of anode locations

The population standard deviations ($\sigma$) was simulated by the following equation:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (X_i - \mu)^2}$$

The $\sigma$ values of potential and current density for increasing distance between the anode and the center of the platform had a decreasing trend in Figure 5.

FIGURE 5 Population standard deviations ($\sigma$) of potential and current density for different anode locations.
Effect of seawater conductivity

FIGURE 6 Calculated potential and current density distribution of Leg A-1 and Leg B-2 protected by ICCP with different seawater conductivities (3, 4, 5, 6S/m).
FIGURE 7 Calculated potential and current density distributions of Leg A-1 covered with 99, 95, and 90% biofouling, respectively.
Conclusions

● The off shore platform protected by ICCP was simulated by a 3-D FEM considering the influences of output current, anode location, seawater conductivity, and biofouling coverage rate.

● Biofouling inhibits the corrosion factors transport from seawater to steel structures.

● FE-SEM, EDS: magnesium oxides, biofouling deposits, and products of steel were doped with calcium oxides in the formation of calcareous deposit.
Conclusions

- FEM numerical model: An economical and effective ICCP system of a two anode ICCP was established.

- The ROV data monitored the potential distribution of the platform legs that well agreed with FEM calculated data.

- Numerical simulation of CP was an effective method to optimize the CP re-design and save the cost of CP engineering.