Using Modeling to Interpret and Expand CP Survey Data

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ABSTRACT

Marine structures are frequently monitored or surveyed as part of an ongoing integrity management program to obtain data on corrosion potentials, anode consumption and in some cases field gradients. One objective is to determine how effective the CP system is at providing protection to the structure and another is to verify that sacrificial anodes are being consumed at a rate consistent with design assumptions. However it is not economic or in many cases even feasible to measure potentials on a complete structure or to collect data from all anodes, so the CP engineer is required to infer the condition of the overall structure from the available data.

In particular for structures with complex geometry, the accuracy of data collected may not be reliable, as for example potential readings obtained with a measurement probe can be affected by nearby metal surfaces, leading to significant error in the data collected particularly for field gradients. Similarly access problems can result in error if the probe cannot be oriented or placed on the structure or anode in the required location. These issues require the CP engineer to use his judgment to determine which data to use and which to discard.

Computer modeling has been used in the design of CP systems firstly to optimize the design, and secondly to provide assurance to the operator that requirements for anode life are met, and that the system will sustain the potentials required to protect the structure. In such a case the structure geometry and the anode design are supplied as data to the model and the model predicts the potentials and the anode consumption rates over the life of the structure.

However another application of modeling is to use it to convert information we can measure into the information we want to know. In particular modeling can be used to expand limited survey data into a prediction of potentials on all structural surfaces, and to provide data on the performance of all anodes.

A case study is presented in which computer modeling is used to evaluate data from a single survey, then to enhance the data to provide a view of potentials over the complete structure and to provide a view of consumption of all anodes.

Keywords: CP, Cathodic Protection, Modeling, CP Survey
INTRODUCTION

Marine structures are frequently monitored or surveyed as part of an ongoing integrity management program to obtain data on corrosion potentials, anode consumption and in some cases field gradients. One objective is to determine how effective the CP system is at providing protection to the structure and another is to verify that sacrificial anodes are being consumed at a rate consistent with design assumptions. However it is not economic or in many cases even feasible to measure potentials on a complete structure or to collect data from all anodes, so the CP engineer is required to infer the condition of the overall structure from the available data.

In particular for structures with complex geometry, the accuracy of data collected may not be reliable, as for example potential readings obtained with a measurement probe can be affected by nearby metal surfaces, leading to significant error in the data collected particularly for field gradients. Similarly access problems can result in error if the probe cannot be oriented or placed on the structure or anode in the required location. These issues require the CP engineer to use his judgment to determine which data to use and which to discard when assessing anomaly’s or the future maintenance of the structure.

The aim of the current work is provide a systematic way of addressing these issues through the use of computer modeling.

Computer Modeling

Computer modeling is frequently used in the design of CP systems firstly to optimize the design, and secondly to provide assurance to the operator that requirements for anode life are met, and that the system will sustain the potentials required to protect the structure over its lifetime. In such a case the structure geometry and the CP system design are supplied as data to the model and the model predicts the potentials and the anode consumption rates over the life of the structure. This data combined with design assumptions about factors such as coating breakdown can be used to predict the potentials on the structure over the design life and the consumption rate of individual anodes.

An example study is shown in Figure 1 where the model has been used to predict the potentials provided by the CP system over the structure life. In such a study the same assumptions used for the design are used to define the rate of coating breakdown in addition to data on the material polarization. Such a model provides a verification that the design will provide the required protection. Figure 2 shows the projected remaining life of the anodes predicted by the model at a point in time. The anodes are color coded on the model to show the variation of remaining life. This data can be used to optimize the number and location of the anodes to achieve a more uniform anode consumption.

Until the development of reliable computer modeling techniques the prediction of the detailed protection levels provided by CP systems was extremely difficult and relied on the skill and experience of the corrosion engineer and extensive post commissioning surveys. The development of modeling techniques has provided the necessary tools to predict the protection levels provided by a CP system as part of an up front design process. In this work the BEASY\textsuperscript{(1)} Corrosion and CP software is used to predict levels of CP protection.

\textsuperscript{(1)} Trade name
Figure 1: Predicted potentials on the structure over its design life. The picture shows the evolution of the structure from Year 0 on the far left, Year 15 in the middle and Year 30 on the right hand side.

Figure 2: Predicted remaining life of the anodes on the structure at a particular date. The variation in the anode life can be clearly seen on the scale where blue indicates approximately 13 years remaining life and red indicates approximately 20 years remaining life. On the left the anodes are shown without the structure for ease of viewing.
Operational Phase

Once the structure is commissioned information on the condition of the structure and the performance of the CP system is obtained by surveying the structure to obtain data on the potentials and in some cases field gradients. The number of locations where data is collected and the frequency of such surveys is very much dependent upon the operator and can vary significantly. Data is typically provided in tabular form and has to be assessed by the CP engineer along with other integrity data to identify anomalies (i.e. where the potential is outside the expected range) and to identify trends which may indicate that the design is not performing as expected. An example of typical data is shown in Table 1.

The accuracy of data collected may not always be reliable, as for example potential readings obtained with a measurement probe can be affected by nearby metal surfaces leading to significant error in the data collected particularly for field gradients. Similarly access problems can result in errors if the probe cannot be oriented or placed on the structure or anode in the required location. There also may be transcribing errors when the data is collated in addition to the accuracy of the measuring device itself. These issues require the CP engineer to use his judgment to determine which data to use and which to discard when assessing anomalies or the future maintenance of the structure.

Where a computer model has been developed it is often very useful to compare the model predictions with the data obtained from the survey to check if the structure is being protected as expected. This can provide data on whether the design assumptions regarding the coatings breakdown rates for example are realistic. The model can then be used to make updated predictions of the performance at the end of the design life based on the actual coating degradation rates.

<table>
<thead>
<tr>
<th>Contact Location</th>
<th>Potential (mV)</th>
<th>Field Gradient (µV/cm)</th>
<th>Anode Depletion (%)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z3 Riser</td>
<td>988</td>
<td>70</td>
<td></td>
<td>- Bend Interface</td>
</tr>
<tr>
<td>Z4 Riser</td>
<td>990</td>
<td>76</td>
<td></td>
<td>- Clamp</td>
</tr>
<tr>
<td>Z5 Riser</td>
<td>994</td>
<td>93</td>
<td></td>
<td>- Support North</td>
</tr>
<tr>
<td>Z6 Riser</td>
<td>984</td>
<td>174</td>
<td></td>
<td>- Support South</td>
</tr>
<tr>
<td>Z7 Riser</td>
<td>989</td>
<td>88</td>
<td></td>
<td>- Spool Upper</td>
</tr>
<tr>
<td>Z8 Riser</td>
<td>995</td>
<td>131</td>
<td></td>
<td>- Clamp</td>
</tr>
<tr>
<td>Z9 Riser</td>
<td>991</td>
<td>49</td>
<td></td>
<td>- End Fit Body</td>
</tr>
<tr>
<td>Z10 Riser</td>
<td>990</td>
<td>79</td>
<td></td>
<td>- End Fit Body (Lower)</td>
</tr>
<tr>
<td>Z11 Riser</td>
<td>995</td>
<td>79</td>
<td></td>
<td>- End Fit Body(Upper)</td>
</tr>
<tr>
<td>Z3 (FPSO) I-Tube</td>
<td>1004</td>
<td>-12</td>
<td></td>
<td>- Latching Mechanism</td>
</tr>
<tr>
<td>Z3 (FPSO) I-Tube</td>
<td>1011</td>
<td>104</td>
<td></td>
<td>- Upper Latching Mechanism</td>
</tr>
<tr>
<td>Z3 (FPSO) I-Tube</td>
<td>1077</td>
<td>12</td>
<td></td>
<td>- Spool Anode</td>
</tr>
<tr>
<td>Z3 (FPSO) I-Tube</td>
<td>1004</td>
<td>67</td>
<td></td>
<td>- Intermediate Flange</td>
</tr>
<tr>
<td>Z3 (FPSO) I-Tube</td>
<td>1099</td>
<td>33</td>
<td></td>
<td>- I-Tube Flange</td>
</tr>
<tr>
<td>Z3 (FPSO) I-Tube</td>
<td>1005</td>
<td>44</td>
<td></td>
<td>- I-Tube</td>
</tr>
</tbody>
</table>

It can often be difficult to interpret the data provided from the survey as the engineer has to be very familiar with the structure in order to interpret trends and localized areas of concern. For example increased current demand from anodes and more positive potentials can indicate the presence of damage, but it is difficult to identify the location and extent as well as the local level of protection provided without further investigation/surveys.

Another potentially important application of modeling is to use it to convert information we can measure into the information we want to know. Frequently it is not possible to conduct surveys at the time or location required. Therefore modeling can play an important role by expanding limited survey data into a prediction of the potentials on all structural surfaces, and to provide data on the performance of all anodes.

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From the discussion it is clear that modeling can have an important role in the integrity management of structures if it can be integrated with the survey and monitoring performed on the structure.

**CASE STUDY**

In this case study the integration of modeling and survey data is investigated to determine the value of such an approach.

**Computer Model Predictions**

The first step required is to develop a 3D model of the structure describing all the metallic surfaces, the coatings applied on each of the surfaces, the anodes and the electrical connections. In the authors' experience this model is often the first full three dimensional model of the asset describing the CP system and has a significant value in itself in collating and showing all the data and the possible interactions. Figure 3 shows the example structure.

![3D model of the structure showing the anodes etc](image)

**Figure 3: 3D model of the structure showing the anodes etc**

The model can be used to predict the detailed potentials on the structure as shown in Figure 4. In this case it was assumed in the data supplied to the model that the coatings would breakdown according to the design assumptions (e.g. 2% breakdown per year).
Visualization Of The Survey Data

The format of the survey data shown in Table 1 is not very convenient to display a comparison of the model prediction and the actual potentials measured. One solution is to add the model predictions of the potentials to the table and compare the results. However, this is not very effective in comparing trends and assessing the reliability of individual values. An alternative is to superimpose the survey potentials on the model itself as shown in Figure 5.

This has the following benefits

- An overall 3D view of the structure is available with the survey potentials and locations clearly identified
- The importance of any individual reading can be clearly seen
- Trends in local areas can be seen

The survey locations are shown as square blocks on the model and colored based on the potential. The scale to interpret the colors is shown on the right-hand side of the figure. On the computer screen, the engineer can visualize the structure and “fly” around it to view all the data.
Comparing Simulation and Survey Data

By comparing the simulation and the survey data two important elements of information can be obtained:

- Verification that the model is accurately predicting the potentials on the structure
- Identification of anomalies where the survey potentials are locally significantly different from the model prediction

If there is significant overall disagreement between the model predictions and the survey then there must be some error in the input data to the model. This is most likely to be associated with the coating breakdown factors assumed in the model. For example it could be that the coating is breaking down slower/faster than that assumed in the design. This can be modified in the model and new calculations performed until the actual coating breakdown factor is determined which provides good agreement with the survey data. Comparisons over time with survey data provide a clear indication of the coating breakdown. Based on this data new predictions for the end of life of the structure can be made.

If there is not significant overall disagreement then the model inputs are generally good and in agreement with the actual conditions on the structure. Therefore local disagreements indicate either measurement problems or that there is some local anomaly which requires further investigation.

Figure 6 shows the differences between the survey and the model predictions at the survey locations. From the scale on the right it appears that there is significant disagreement. However looking more closely it can be seen that one particular measurement is significantly more out of line than the others.
If this data point is excluded a new 3D display can be created where both the survey potentials and the model predicted potentials are displayed. Figure 7. In this type of display, locations where there are significant disagreements can be clearly identified and noted for further investigation.

Only certain locations can be compared as survey data cannot be obtained everywhere. Therefore this type of display can be used to infer the potentials at other locations on the assumption that, if there is good agreement nearby then the model provides a good basis for predicting the potentials etc in areas where measurements cannot be made.

**Using the Model To Extrapolate The Survey Data**

The final step is to display the survey data in the same way as the model potentials in the form of a 3D model. If it is assumed that the model is accurately capturing the behavior of the CP system then the computer model can be used to interpolate the data between the survey points onto the whole surface of the structure.
Figure 7: Survey and model predictions displayed on the 3D model

Figure 8: Difference Between Survey And Model Prediction Displayed on the 3D model
CONCLUSIONS

A case study is presented in which computer modeling is used to evaluate data from a single survey, then to enhance the data to provide a view of potentials over the complete structure and to provide a view of consumption of all anodes.

The integration of modeling and survey data provides significant benefits by:

- Clearly indicating anomaly’s where there is questionable measurement data as well as where the CP system is not performing as expected
- Quantifying the degradation of coatings to enable better prediction of the performance of the CP system over the whole life of the structure
- Providing 3D visualization of the survey data
- Extending the survey data to visualize the protection provided to areas where measurements cannot be made
- Providing data to improve planning of future surveys

REFERENCES

