CP retrofit and life extension based on CP inspection.

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Summary

Many of the existing oil and gas installation have been in operation for many years; several more than 30 years. Originally, these were designed for significantly shorter operational life, but are still in operation. The cathodic protection systems on all of these structures do naturally have a limited life and if under-protection and in worst case free corrosion occurs, this will have a major impact on remaining life. In order to check and secure these structures it is necessary to perform evaluations of the CP systems to check for possible life extension capacity and in worst case a CP retrofit solutions is necessary. In order to establish status of the CP system and make optimized life extensions and, if necessary, retrofit calculation, it is important that the quality of the CP inspection data is good. Possible life extension is dependent on actual anode status, estimated anode consumption and not at least effective current density for the structure. If these data is combined with CP modelling, the life extension and possible retrofit can be optimized from both a protection, installation and cost point of view. In order to get the necessary CP inspection data it is important to use sensitive CP inspection tool as e.g. FIGS (Field Gradient Sensor).
This paper describes CP design and optimization of life extension and CP retrofit where CP inspection data is combined with CP modelling. The new high sensitive field gradient tool is described and discussed

1 Introduction

When performing a detailed CP design it is required to follow a set of defined design rules to secure a safe system. There are several official design specifications and recommended practices both national and international [1]
These different design basis documents have been used over many years and are continuously updated. These documents present CP design guidelines and parameters to be used in design. CP design related to retrofit and use of actual CP inspection data is not well defined in the standards

This paper presents experience of using inspection data to evaluate and design CP for life extension and thereby required retrofit. FORCE Technology's BEM(Boundary Element Method) based CP modelling program, SeaCorr, has been used for the modelling evaluation.

2 Cathodic Protection for life extension and thereby necessary retrofit

2.1 General

This paper covers the FORCE Technology's ideas and experience related to CP retrofit design for jackets from the late 70thies up to today. As stated above CP retrofit is not clearly defined in any standards or specifications. One alternative is to use the CP design rules as defined in e.g. DNV [1]. This will give a robust CP retrofit solution, but also a very costly and conservative solution.

There are performed significant amount of CP inspections over the years. On some structures there are also installed monitoring system which collects valuable data. These data have to be properly analysed to be suitable to be utilized as basis for estimates of remaining CP life and/or for CP retrofit calculations.

2.2 CP retrofit based on existing standards

The design rules do have the necessary formulas and procedures to be able to calculate the anode retrofit requirements. The problems that may occur is typically as follows:

- Should CP retrofit design be based on all criteria regarding protection calculating from as for a new system? I.e. performing a design using all surface area (even if several parts of the jacket is protected by the time of retrofit), full current density (initial, mean and final) from the day of retrofit to planned design life
- If a structure is well protected, should initial requirements be based on mean current density?
- Coating breakdown can be calculated by using the approach and design parameters given in selected standards e.g. DnV (1)
- How should the anodes be distributed?
  - How can remaining anodes be accounted for?
    - Subtract remaining existing anodes from the calculated anode number?

A design performed on this basis will be conservative and very costly. This is described below and in reference /6/.

2.2 CP retrofit design based on inspection and monitoring (if available)

In order to perform CP design based on CP inspection data it is very important what type of data, quality of data and amount of data is acceptable.

The amount of data is important in order to give satisfactory statistical significance. If there are too few measurements per survey and/or too few readings in a historical perspective, it will e difficult to make a calculation basis for a retrofit design. Typical data required:

- Potential readings on stee (stab or grounded proximity)
- Potential readings on anodes
- Anode consumption
  - Preferably based on direct measurements of dimensions
  - Visual estimated
    - Can give deviation from observer to observer. Historical information have shown that such anode estimate on year = x can be larger than for e.g. year= x+2, which naturally is not possible
- Field Gradient (FG) readings to measure current (current density) on anodes and stucture
  - This requires a high sensitivity FG tool

Utilize the data as follows:

Potential readings and anode consumption estimates:

- Analyse the anode and structure potentials

- Use potential difference between anode and cathode. Divide this by calculated anode resistance ref e.g. DNV RP B401 [1]. Calculate maximum, minimum and average anode current based on the available data.
  - Estimate structure current density from anode current output. If historical data are available trending is possible
- Use the anode geometry estimates from visual inspection or geometrical measurements to estimate the anode consumption.
  - Average current per anode per year can be calculated. If historical data is available trending is possible

Field Gradient measurements

- Use FG data from anodes to calculate the current output per anode.
  - Estimate overall anode current. Estimate current density structure based on the anode current
  - Estimate anode consumption
  - Estimate consumption per year
- Use FG data from structure to calculate current density to the structure surface
  - Calculate overall current to the structure
- Check balance between current from anodes and current to structure. This can be used to check for current drain to:
  - Wells
  - Piles
  - Steel in mud
  - Drain to or from:
    - Pipelines – with separate CP system
    - Other connected structures – with separate CP system

2.3 CP retrofit design based on inspection and monitoring (if available) and CP modelling

A CP retrofit design has to be verified and CP modelling is an excellent tool for such check, but also for further optimization.

In 1990 there were presented a paper at the NACE conference [2] describing the CP retrofit process for a hybrid jacket (Impressed Current – IC and galvanic anodes). The jacket experienced two major problems:

- Anode consumption was higher than expected
- Over-protection was seen on pipelines connected to the jacket (remote IC system)

The IC output had to be reduced in order to avoid the over-protection and hence the high anode consumption would increase further. Therefore, it was clear that a CP retrofit was required. At first a CP retrofit design based on traditional methods was performed and this resulted in a very costly retrofit program. It was decided to search for alternative solutions. The following steps were undertaken:

- A detailed CP inspection
  - Potential readings on both anode and structure
  - Field Gradient readings: Using very sensitive system with dual reference cells which were rotating (T-sensor/CPPR – same principle as FIGS) to be able to find both structure current and anode current

- Combining survey data and CP modelling (by SeaCorr).
    - The system where time-step simulated and were checked year by year to find when and where under-protection occurred.
        - Size and level of under-protection where found
        - Required repolarization current and weight were estimated
        - Retrofit anodes were added in to the model and testing retrofit solution
            - Optimizing anode number, anode groups and positions
            - Optimizing time for retrofit
            - Optimizing IC anode output
    - The traditional CP design estimate had a projected total cost including installation of USD 10.2 to 12.6 million (year 1987). The optimized retrofit method based on CP inspection data and CP modelling resulted in an estimated maximum cost of USD 4.25 million i.e.a cost saving of USD 7.75 million.

In reference [9] another example of retrofit design based CP inspection data and CP modelling is shown. This is also a jacket with a hybrid CP system. The CP inspection combined CP potential readings on both anode and structure with measurements of anode dimensions. The data was used to calibrate the CP model and in order to get a correct relation between anode potential and structure potential, the current density of structure both to seawater and mud was adjusted. The average figure was found to end at around 30 mA/m2 on seawater exposed parts and 10 mA/m^2 on mud exposed parts. Drain to each well was fixed to 2.5 A. Results are summarized in Table 1.

Table 1 Comparison of model potential and measure potential

Model potential (mV vs Ag/AgCl)			Measured potential (mV vs Ag/AgCl)		
Maximum	Average	Minimum	Maximum	Average	Minimum
-885	-979	-1067	-909	-988	-1062

This model was then used to perform simulations for a proposed life extension. In addition, several what-if scenarios were simulated. Based on this it was found that there were no short term need for CP retrofit. One scenario where the intention was to extend CP life to 2020, the simulation showed that a retrofit was recommended to start around year 2014. At this stage the around 30% of the anodes were estimated to be depleted.

The method of combining CP inspection and CP modelling have been utilized on a large number of jackets in order to optimize (minimize) the required number of retrofit anodes. The most important design factor is the current density (or effective current density on coated structures).

There are limitations to how it is possible to save cost when optimizing a retrofit CP design. The most important is that the actual current density to the structure in question must be lower than the CP design criteria:

- For the Ninian Northern jacket the average current density was found to be 50 mA/m^2 [2]
- For 4 jackets in the Southern North Sea, the average current density ranges from 13 to 25 mA/m^2 [4]

- For a wellhead jacket in the North Sea with monitored anodes and fixed reference cells, were connected to data loggers for continuous data collection. Current density calculated from the monitored anodes ranges from 29.4 to 40.9 mA/m^2 after approximate 4 years in operation. The highest level assumes conservatively no current draine to wells and mud exposed steel.[3]
- North Sea Jacket with hybrid CP system the current density level is estimated to approximate 30 mA/m^2 [5]
- Another North Sea jacket with a hybrid CP system do show current levels from 10 to 20 mA/m^2 [6]. This was observed over several years.

CP design current criteria from RP B401 (table 10.1 and 10.2) is summarized in table 2

Table 2 Design current density requirements according to RP B401 [1]

Climate Zone "Temperate " (7-11 C)			
Depth	Current density (mA/m^2)		
(m)	Initial	Mean	Final
0-30	200	100	130
>30-100	170	80	110
>100-300	190	90	140
>300	200	110	170

As seen from the Table 2, the design current density are from 2 to 10 times larger than actual current density estimated, which indicates that there are room for optimization (minimization) of most retrofit design. It is however also obvious that there are variations from one field or jacket to another.

3 Inspection method to improve basis for CP retrofit

In order to be able perform a retrofit CP design the quality and availability of necessary data is very important. As described above, the structure current density is the most important factor in such design. A new tool, FIGS (Field Gradient Sensor) with a very high sensitivity has been developed [7, 8, 9].

Figure 2 shows the FIGS sensor

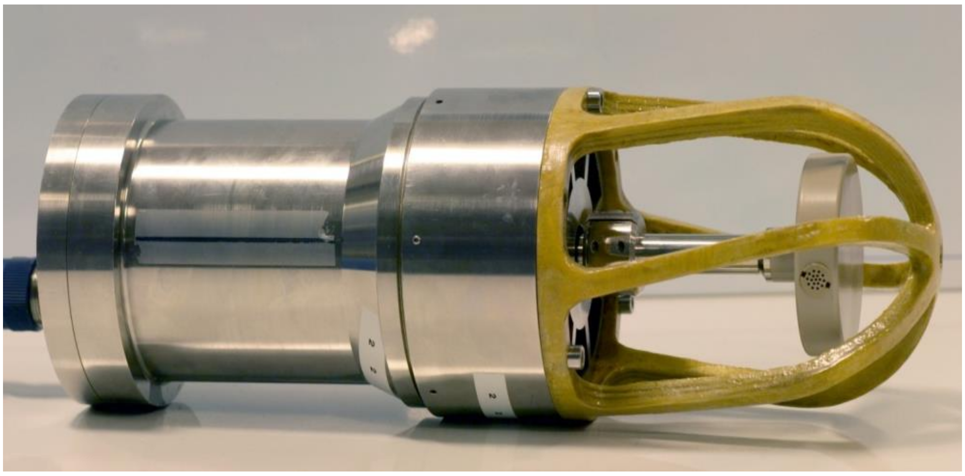

Figure 2: FIGS sensor

FiGS measures the electric field gradient vector and can detect electric currents in seawater. This by far surpasses all other field gradient sensors available in the market.

Electronics design and the use of special electrodes gives the sensor a theoretical detection level < 0.1µV/cm and a practical detection level of 0.1 – 0.2µV/cm, depending on operating conditions. The accuracy is 1% of reading.

The sensor is intended as an addition to traditional CP surveys with potential measurements. The technology has a wide area of applications including, but not limited to:

- Measurement of current output from anodes
- Measurement of current density on structures (bare metal, coated metal and concrete) and pipelines
- Detection of coating holidays / defects on pipelines, including buried pipelines
- Measurement of current drain to buried structures such as piles and wells

Figure 2 shows results from a pipeline survey. The magnitude of the FG vector is very low, with main part of the readings below 1µV/cm with FG readings from damages between 1 and 2 µV/cm. This illustrated the high sensitivity of the FIGS sensor.

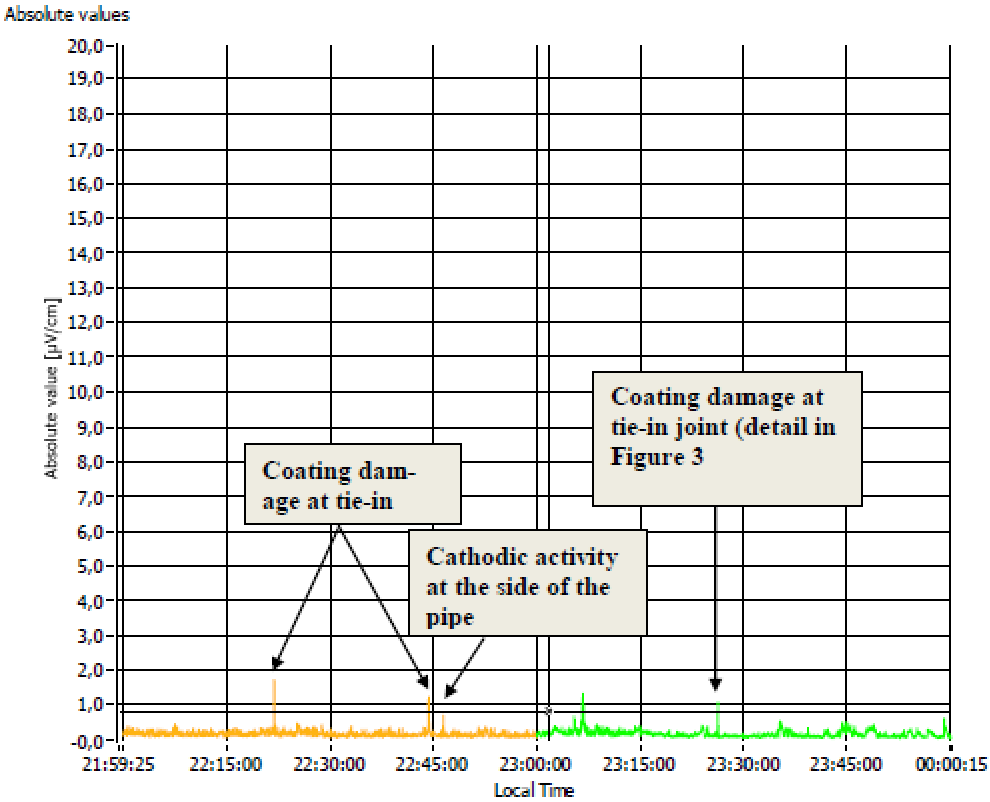

Figure 2: Field gradient absolute values along a 2 km section of pipeline, measured between 0.5 and 1 meter above TOP. These are unfiltered RAW data measurements.[7]

4 Conclusions and Recommendation

- Using standard CP design procedures and formulas for retrofit calculations will in most cases result in conservative and costly solutions.
- The use of CP inspection and monitoring data will improve CP retrofit solutions significantly and reduce cost. Combining this with CP modelling will provide a complete method for verification and minimization of retrofit solution
- The CP inspection data necessary to provide an adequate CP a retrofit design basis as follows:
  - Potential reading on anodes and structure
  - Anode output and consumption
    - Dimensional measurement of anodes. Visual estimate is possible, but not very reliable
    - Field Gradient (FG) readings on anodes, preferable with a high sensitivity FG tool, such as FIGS
  - Current density reading on structure
    - FG readings on structure surface. Again, a sensitive FG tool is required.
- Historical data and possibility fir trending can be very important, but this depends on the extend of the existing CP surveys

5 References

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