RISK BASED SUBSEA INSPECTION PLANNING AND INTEGRITY MANAGEMENT BY USE OF FIGS® SENSOR

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1 Abstract

FORCE Technology has more than 20 years’ experience within corrosion management, and are applying our innovative tool, FiGS® to revolutionize subsea CP (Cathodic Protection) inspection and integrity management. FiGS® data combined with FORCE Technology in-house CP computer modelling software, provide our clients with status and life expectancy of the CP systems, opening up for a risk based approach to subsea inspection planning and corrosion management. Thus, moving away from today’s scheme where operators are performing periodic inspections based on fixed intervals. The technology can be applied to both buried and exposed items. Combined with FORCE Technology’s experience and expertise in the field of corrosion management, FiGS® provide the operators with full overview of the integrity of their subsea fields, and deliver the status and confidence needed to make qualified and cost-effective decisions in order to be ahead of unforeseen scenarios in the operational phase.

The FiGS® sensor is a non-contact inspection method, mounted on an ROV, AUV or AIV during the inspection. The sensor is extremely sensitive compared to other techniques used for CP inspection. The sensor is developed since 2007 in cooperation with Statoil, Shell and Gassco. 2017 was the first full-commercial year, and the sensor-system was fully booked throughout 2017. FORCE won Materials Performance award for “Corrosion Innovation of the year” for FiGS® in 2017 at NACE, New Orleans.

The paper presents a recent case where FG data and CP modelling have been used to perform an optimized CP retrofit design, cutting the retrofit costs with 50%. The experience from the FG survey and post processing of the data are valuable as input for optimization of future Risk Based Inspection (RBI) planning and integrity management of the pipeline system.

**Key words**: Field gradient measurements, subsea, pipeline, risk based inspection, integrity management.


2 Introduction

The main objective of integrity management of a facility is to ensure safe operation during the entire lifetime from installation to abandonment. In the petroleum industry, subsea installations are less accessible than topside installations during operation and thus dependent of reliable risk assessment and integrity management processes. Integrity management is an overall work process consisting of items such as 1:

- Identification of threats
- Assessment of risk associated with the identified threats
- Inspection, testing and maintenance planning
- Integrity assessment
- Mitigation, intervention and repair

Measurement of the cathodic protection level is a typical inspection activity during a planned subsea survey of these facilities. The cathodic protection level of structures can easily be measured with conventional CP probes, provided that the structure is not buried or otherwise covered, e.g. by rock dump. As for depletion of sacrificial anodes, this can be very difficult or even impossible to estimate by general visual inspection, e.g. due to poor visibility, the presence of marine growth and/or corrosion products. This is due to the anode being buried in seabed sediments or under rock dump (pipelines).

The cathodic protection level and remaining lifetime/depletion level of sacrificial anodes are parts of the integrity scope that must be documented during operation of subsea facilities. Also, information about the actual current density on steel (i.e. the cathodic current density required to maintain adequate CP) is of great value when assessing the future of a CP system. In case of lifetime extension, adequate corrosion protection must be demonstrated for the extended period of operation. Otherwise, CP retrofit is required.

An ROV operable field gradient (FG) sensor1 that can be used to map the electric field around structures has been developed. By combination with CP modelling and in-house CP modelling software2, the following information can be obtained:

- Measure direction of current (anodic/cathodic)
- Measure anode activity and calculate anode current output. Remaining anodes life can be estimated based on anode current output
- Detect coating damages (on structures with CP)
- Calculate current density on steel (coated/uncoated)
- Calculate CP current drain, e.g. to open pile ends, subsea wells, or to adjacent structures

1 FORCE Technology sensor FiGS®
2 FORCE Technology software SeaCorr™
3 Areas of use and results

3.1 3D inspection of subsea structures

3D measurements of field gradients (FGs) play a significant role in the evaluation of CP of complex subsea structures (e.g. x-mas trees, manifolds). It allows for accurate identification of the electric field distribution surrounding a structure, enabling the diagnostic of hot spots, which is challenging with traditional pointwise measurements. Recent tests and commercial surveys have validated the FiGS® in a 3D setup as a tool to inspect complex subsea structures.

CASE: FiGS® Inspection of SSIV

Introduction

The cathodic protection (CP) system for SSIV’s and manifolds are designed to last the entire service life of the structure and subsystems. However, deviations from the initial design philosophy during the operational phase may occur.

These deviations include:

• More current drainage from the CP system to buried sections of the structures or connected systems, such as connected flowlines and pipelines

• Inactive anodes due to lack of electric connection to the structure

The structure below is a SSIV that was inspected with FiGS® in a 3D setup to provide detailed information about the integrity of the CP system on the structure, in order to determine potential distribution across the structure (see figure 1).

Figure 1: The left of the figure visualizes RAW data logged during inspection. The right shows all relevant RAW data overlaid the 3D model of the structure.
The data clearly showed that all the current measured was supplied by the connected pipelines. The original anodes places under the top cover was not supplying any current, thus either fully consumed or no longer electrically connected (see figure 2). Further vial inspection confirmed original SSIV anodes to be completely consumed.

**Figure 2:** The left model shows the direction of the current supplied from the connected structures. The right model shows detailed information on the current drained to the piles.

**Conclusion:**

The FiGS® inspection concluded the anodes on the SSIV was fully consumed and all the protection was offered by the connected pipeline. The potential plot of the SSIV also revealed an area of under-protection (high potential) that would be extremely hard, if not impossible to identify with traditional methods. Getting a traditional contact measurement done in this area, is very unlikely as the area is very congested and hard to reach.

**Figure 3:** identifies the flange (shown as red) to be under-protected with a potential of -760mV.
3.2 Pipelines

Apart from providing accurate readings at exposed pipelines, the precision of the sensor enables evaluation of the CP system and identification of coating defects on buried pipelines, without the necessity to excavate the pipeline. FiGS® surveys of buried pipelines enable the calculation of the potential profile of entire lines, providing a good basis for evaluating the protection level.

CASE: FiGS® survey of a buried Pipeline

Introduction:

Getting good information about the integrity of the CP system of a buried pipeline with traditional CP inspection methods has been very difficult. Often operators have relied on a very conservative and robust original design, and a lot of buried pipelines have never been fully inspected. FiGS® have finally provided clients with a method to get a full integrity assessment of the CP system without having to excavate. The FiGS® sensors have collected excellent data on pipelines buried even at 6 meters, and can be run in combination with traditional pipe-trackers.

Background:

An export pipeline that has been in operation for more than 30 years was inspected by the new FG tool in 2015. After rerouting to a new topside facility, the pipeline constitutes of a new section of length approx. 6.5 km flanged to the original pipeline. The pipeline is coated with concrete weight coating (CWC), and CP provided by sacrificial Zn anodes (original pipeline) and Al-based anodes (new pipeline section).

The pipeline is generally buried, but exposed sections have been externally inspected at regular intervals. The depletion of exposed anodes depends on distance along pipeline, but in one section, the anodes appeared to be almost completely consumed. Concerns were then raised regarding the state of the large number of buried sacrificial anodes on the pipeline. To excavate the number of anodes required to obtain statistically significant information about anode depletion was considered not an option. Hence, a rather extensive plan for CP retrofit was prepared, with a large number of anode sleds placed at regular intervals along the original pipeline.

Buried pipelines with CP are challenging to inspect with respect to protection potential level and consumption of anodes. A field gradient survey was performed on a pipeline that was generally buried, consisting of an original section with Zn-based anodes and a newer section with Al-based anodes. The FG survey confirmed that anode depletion was extensive in sections where the original pipeline was exposed to seawater, but indicated that depletion of buried anodes was rather limited (generally below 40%). The Al-based anodes within approx. 2 km of the connection to the original pipeline were seen to supply a significant amount of CP current to the original pipeline, resulting in high depletion level for these anodes.

The conclusions based on the FG survey resulted in an optimization of an anode retrofit design already prepared for the pipeline, reducing the number of retrofit sleds to be installed by approx.
50%. Hence, the use of the new FG technology benefited the pipelines’ operator both in terms of reduced cost, but also by reducing the duration of the retrofit operation. The amount of information obtained about the current status of the anodes allows for better predictions on the future status of a CP system that has been operating for decades, ensuring safe operation of the pipeline also in the future through a risk based inspection program.

CASE: Exposed pipeline inspection with Fast ROV

Background:

The objective of this survey was to evaluate the FiGS® (Field Gradient Sensor) and ascertain its operational envelope when used in conjunction with a Laser Imaging system on the Superior Fast ROV.

- Operational “distance from pipe” envelope of FiGS® (tested 1-5m above pipe)
- Operational velocity (tested at 0.5m/s and 1.2m/s)

The overall objective was to find a common operational envelope were both FiGS® and Cathx systems can work together, giving both good quality CP data and a wide enough corridor of high resolution images from the Cathx system.

Speed

A maximum speed of 1.2m/s was tested during this survey. There was no negative impact on the results. We are confident that a survey speed of 1.5m/s is feasible for FiGS®.

We can pinpoint the anode location to an accuracy of 1m at a speed of 1.2m/s.

![Figure 4: examples of anode peaks at different velocities and altitude of flight](image)

Conclusion:

There are enough measurement points related to the anode to recreate the curve shape and to perform a numerical integration of the signal at 1.2m/s. The two figures differ in appearance mainly due to the impact of measurement distance on signal strength.
Height of flight

The lowest FG value at which we can detect an anode / cathode with a reasonable certainty is approximately 0,15μV/cm

![Graph showing anode peaks detected on one section of the pipe with low anode activity.](image)

**Figure 5: Anode peaks detected on one section of the pipe with low anode activity**

Conclusion:

FiGS® is able to detect an anodic peak with an amplitude of approx. 0.15μV/cm. The respective current output of this anode is approx. 4.7mA (speed 1m/s and TOP 3.4m).

3.3 Jackets, monopiles and larger structures

Traditional methods of inspecting jackets, monopiles or other larger structures subsea is by measuring the potential, either by contact measurement (stabber) or by the use of proximity readings using a reference cell. The potential confirms if the structure is protected or not, but does not provide life expectancy of the system. FiGS® measures the current output of anodes, making sure they are working as they should, protecting the asset and for how long, the steel current density and drain to buried parts of the structure.

**Case: 3 Jackets**

**Background:**

*There is a hub consistent of three conventional steel jackets. The jackets were protected against corrosion by a distributed sacrificial anode CP system, mainly using Al-Zn-In anodes, but also with some Zn anodes, e.g. on mud mats. Use of coating was restricted to the lower splash zone region of the jackets.*

The jackets were installed in the 80’s with an original design life of 12 years. The conservatism of the original CP design has allowed for an extended service life for all jackets.*
The jackets have been inspected by conventional methods at regular intervals and the inspection data show that the jackets are still well protected. The visual inspection shows however that a considerable number of anodes exhibits evidence of cracking/spalling.

In order to improve the basis for the prediction of the future development of CP and the need for CP retrofit, a FiGS® survey was performed. The survey consisted of point measurements on anodes and on jacket steel. In addition, measurements were performed on open jacket pile ends. The FG measurements were interpreted by means of CP modelling using the in-house software.

*Picture 1: FiGS® making a steel current density measurement on jacket leg.

3.4 Entire subsea fields: Optimized planning, inspection & maintenance

FORCE Technology provides an integrated Cathodic Protection (CP) approach at a field level, enabling enhanced control of subsea integrity.

FiGS® data, in combination with CP computer modelling, provides the CP status and life expectancy of the anodes for entire subsea fields. By also measuring drain and interactions between the different CP systems, often connected with pipelines, FiGS® provides a detailed overall status of the field as well as effectively identifying areas of concern.
With FiGS®, maintenance- and inspection-operations can be planned risk based on a long-term basis, extending inspection intervals as well as optimising the offshore vessel time and minimising interventions.

**Inspection of buried pipelines**
Apart from providing accurate readings at exposed pipelines, the precision of the sensor enables evaluation of the CP system and identification of coating defects on buried pipelines, without the necessity to excavate the pipeline. FiGS® surveys of buried pipelines enable the calculation of the potential profile of entire lines, providing a good basis for evaluating the protection level.

**3D inspection of subsea structures**
3D measurements of field gradients (FGs) play a major role in the evaluation of CP of complex subsea structures (e.g. x-mas trees, manifolds). It allows for accurate identification of the electric field distribution surrounding a structure, enabling the diagnostic of hot spots, which is challenging with traditional pointwise measurements. Recent tests and commercial surveys have validated the FiGS® in a 3D setup as a tool to inspect complex subsea structures.

**FiGS® and pipe tracking**
The most recent upgrade of the sensor enables the use of FiGS® together with active pipe trackers (e.g. TSS440), without affecting the sensor readings. This new feature reduces the offshore time resulting in significant savings, mainly related to the vessel rental. The resolution of the FIGS® sensor also enables detection of pipeline sections where the pipe tracker is not a suitable tool, due to a high degree of burial.
4 References


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