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The Integration of Intrusive and Non-Intrusive Systems for Corrosion and Sand/Erosion Monitoring Using New Generation Data Management Software

Kjell Wold [1], Sean Hopkins [2], Tommy Jakobsen [3], Svein Erik Lilleland [4]

Abstract

On-line monitoring increases the amount of data to be handled significantly, and new monitoring technologies generate more complex information than before. The importance of a good and efficient system for data management and reporting of monitoring data is therefore increasing.

Roxar has introduced a new generation software (FieldWatch/FieldManager) that integrates intrusive and non-intrusive systems for corrosion monitoring as well as intrusive and acoustic systems for sand/erosion monitoring in one combined solution.

Combined with new measurement technology features, this will add to improved user friendliness and reliability of data for the non-intrusive FSM (field signature method) technology. The presentation describes and presents field data from the first installation of the new on-line electric field signature systems, and also presents how the FieldWatch software will improve the use and presentation of the data. Finally a new measurement feature for electric field signature measurements will be presented, and it will be discussed how this will improve detection and quantification of localized attacks in all directions.

The first field installation of the FieldWatch Sand Management software was done at Statoil's Heidrun field. Experience and field data from this installation will be presented and discussed.

1. Summary

On-line monitoring increases the amount of data to be handled significantly, and new monitoring technologies generate more complex information than before. The importance of a good and efficient system for data management and reporting of monitoring data is therefore increasing.

Roxar has introduced a new generation software (FieldWatch/FieldManager) that integrates intrusive and non-intrusive systems for corrosion monitoring as well as intrusive and acoustic systems for sand/erosion monitoring in one combined solution.

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The first field installation of the FieldWatch Sand Management software was done at Statoil's Heidrun field. Experience and field data from this installation will be presented and discussed.

2. Introduction

The oil & gas industry has seen a growing trend towards on-line monitoring rather than off-line solutions. There are a number of reasons for this:

- On-line monitoring generates real-time information, allowing remedial action to be taken at an early stage before damage takes place.
- On-line monitoring allows for more frequent data collection, improving the information level and accuracy of the monitoring data. Continuous, on-line data makes the correlation with other process parameters more convenient, providing additional information about why trends or changes takes place, and giving the user the necessary information to mitigate the problem correctly.
- On-line monitoring reduces the need for personnel involvement, which can be advantageous both for economic and operational reasons.

There is also a trend towards more complex measurement technologies, increasing the need for reliable and easy to use data management and reporting systems. Such complex information gives valuable additional data on the monitored system, but requires more powerful tools for analysis and presentation. FSM and advanced electrochemical technologies are both examples of techniques that provide more complex information, compared with traditional systems.

Finally, there is a trend towards integrated monitoring solutions, combining more monitoring applications within one integrated solution. Benefits include:

- That the same infrastructure (cabling, cabinets, software, etc) can be used for more monitoring functions.
- Integrated contracts for purchase, installation, commissioning, training and maintenance.

Figure 1 shows an example of an integrated monitoring solution, where traditional corrosion monitoring (hydraulic system), acoustic sand monitoring, a FSM for direct erosion monitoring, and acoustic pig detectors, are all provided as one integrated system. The displayed cabinet supports all these measurement functions, and all the measurement data is presented within the same software package, which communicates with the main control system. shows an example of an integrated monitoring solution, where traditional corrosion monitoring (hydraulic system), acoustic sand monitoring, a FSM for direct erosion monitoring, and acoustic pig detectors, are all provided as one integrated system. The displayed cabinet supports all these measurement functions, and all the measurement data is presented within the same software package, which communicates with the main control system.

Figure 1: Cabinet for an integrated monitoring solution for an offshore platform, covering corrosion probes, acoustic sand monitors, field signature measurement for erosion monitoring, and acoustic pig detectors.

3. Sand Monitoring Technologies

There are a variety of sand monitoring technologies used in the industry today. These include simple cylindrical probes, where sand erosion is measured as pressure increases when sand has eroded through the sand probe cylinder.

However, in the authors' opinions, the most important method today for sand monitoring is non-intrusive, acoustic sensors and intrusive probes, based on measuring sand erosion metal loss directly on the probe elements. These methods also provide continuous and real-time information to the user.

3.1 Non-Intrusive, Acoustic Sand Probes

Non-intrusive, sand monitoring systems measure acoustic impacts and noise, and the amount of sand particles in water, oil, gas or multiphase flow lines. The operational principle is based on an acoustic emission sensor, which is clamped onto the production pipeline downstream to a 90° bend.

Sand particles, transported with the flow, hit the pipe wall at bends in the pipeline due to inertia, generating noise propagating in the pipe wall. The monitor detects this noise and converts it to a digital signal, which is transmitted via the sensor power cable to the safe area electronics. The safe area electronics comprises a 24 VDC Power Supply Unit (PSU), a Calculation & Interface Unit (CIU), and an intrinsic safety barrier between the detectors in the hazardous area. The CIU is a Modbus slave unit that calculates sand production rates based on the sensor signal and built-in algorithms.

The advantages of the non-intrusive, acoustic sand monitor are an immediate response to changes in sand production; and easy and inexpensive installation.

Figure 2 shows the principle of operation of the acoustic sand monitor.

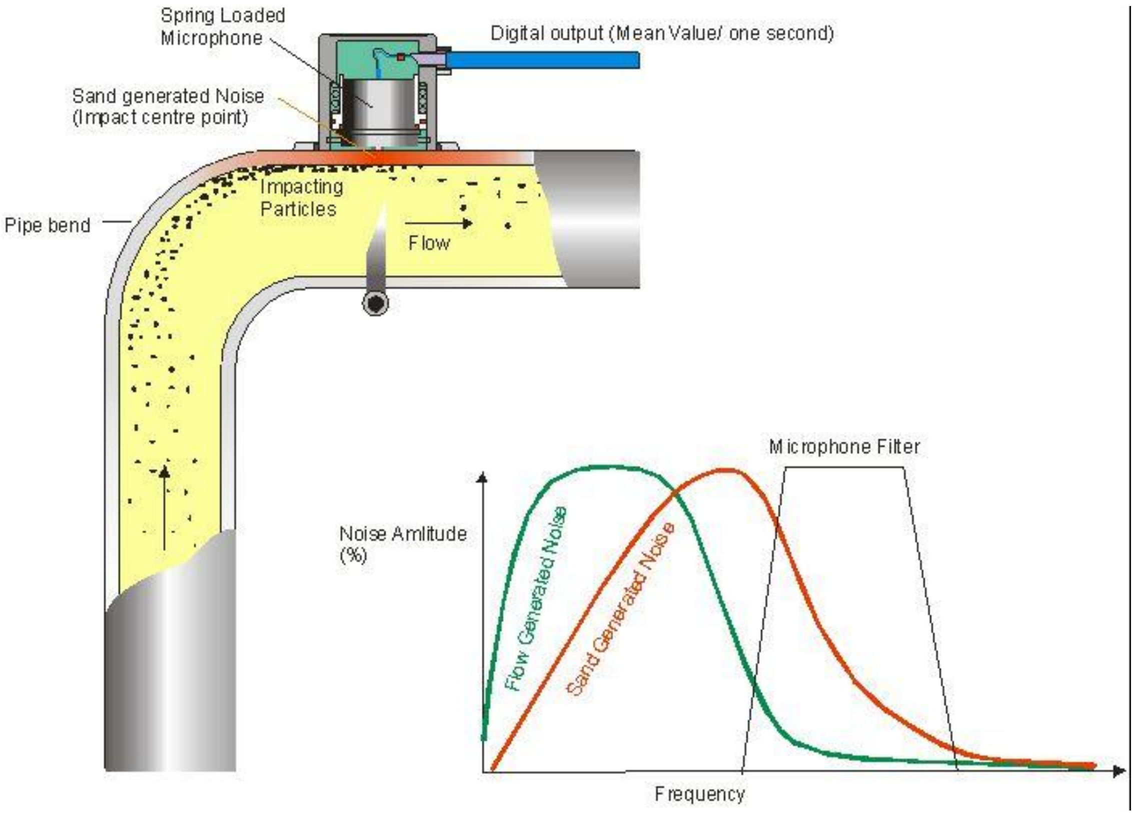

Figure 2: Principle behind the non-intrusive sand probe.

3.2 Intrusive, Erosion-Based Sand/Erosion Probes

Erosion-based sand monitoring provides the direct measurement of sand erosion. It can be based, for example, on the electrical resistance (ER) principle, where metal loss on the element is measured as increased electrical resistance in a sensing element exposed to sand erosion. Sand production rates can then be quantified by combining measured metal loss rates with average sand particle size and flow data. This is based on knowledge regarding the relationships between flow rates, sand production, sand particle size, and metal loss.

The same relationship allows for the calculation in other parts of a pipe system, based on erosion rates measured by the sand/erosion probe.

The authors of this paper believe that erosion-based sand probes should have multiple elements for redundancy, thereby generating more extensive information, and that the probe should be installed (if possible) in vertical sections of the pipe work, preferably more than 6 pipe diameters after a bend or flow obstruction. Such a position will ensure that sand is uniformly distributed in the flow, thus resulting in the most representative sand monitoring results.

The advantages of intrusive, erosion-based sand probes are:

- The probe measures erosion directly, with erosion in other parts of the process calculated, when combined with flow data. There is also no need for calibration.
- Sand rates can be quantified when combining measured sand erosion with flow data and average particle size.
- The probe is reliable in most flow conditions and information can be found, even if the instrumentation system has been down for a while.

Multi-element sand probes are shown in *Figure 3* and sand probes installed through flanged hydraulic access fittings are shown in *Figure 4.*

Figure 3: *Multi-element sand erosion probes.*

Figure 4: Sand probe and sand monitoring instrument for monitoring of vertical pipe.

3.3 The Move towards Technology Integration

While traditionally being viewed as separate solutions for determining sand production, more and more of today's operators are seeing increased value by combining acoustic and erosion-based sand probes into one integrated asset management system. There are many advantages to utilizing two supporting technologies and generating an integrated workflow and reporting capabilities.

One benefit is the ability to derive the best from each technology. For example, whereas acoustic monitors provide an immediate response on sand production, they are complemented by the intrusive sand/erosion probes, which generate accumulated erosion data used to control sand production. Hence, a combined system will be superior, with respect to providing both fast information for process control and reliable erosion data for improved safety and integrity management.

Combining the two systems also ensures that no information is lost, if one system fails or if conditions are unsuitable. The results from the two measurement technologies can also be used for internal data verification and correlation, and for the setting of more reliable alarm systems.

In addition, combining acoustic detectors with intrusive sand probes might cover measurements of a wider range of sand with respect to particle size and velocity, since intrusive erosion probes only measure *erosive* sand. This could be beneficial for installations with limited sand handling capacity topside which are producing fine sand at low velocities. On the other hand, intrusive erosion probes give accumulated information about sand erosion/production over time, even in situations where immediate detection is not possible with acoustic sand probes.

Other benefits of integration include flexible calibration, where one system can be used to calibrate data from the other system through a single user interface. This can lead to more effective data comparisons and correlation of data from the field, and a better understanding of the reservoir management process.

It is not just acoustic and erosion-based sand monitoring that can be incorporated together. The Field Signature Method (FSM)[1], which measures corrosion or erosion directly on the pipe wall by detecting small changes in current flow due to metal loss, can operate alongside sand monitoring and be integrated into the same infrastructure, system configuration and user software. Corrosion monitoring can also be integrated into the same system.

Examples of recent systems include combinations such as: intrusive and acoustic sand monitoring; intrusive corrosion monitoring, acoustic sand monitoring, acoustic pig detectors and FSM in one integrated system; and an intrusive corrosion and sand/erosion monitoring system.

4. On-Line Field Signature Measurements

Electric Field Signature Measurement technology has been on the market for almost 19 years, the first commercial installation taking place in 1991 for offshore platforms in the UK. The technology is available both subsea and in a variety of topside versions.

As mentioned in section 3, the method is based on feeding an electric current through a monitored pipe or vessel section. The electric current sets up an electric field within the monitored object, and this field is measured as voltage drop values between sensing pins installed on the monitored object.

The first measurement defines 'the electric field signature' of the object, and later measurements are compared to that initial measurement. Uniform metal loss can be seen as a uniform increase in voltage drop between pairs of electrodes, whereas localized attacks can be seen as local variations in voltage drop variations. The accuracy of an electric field measurement system is (for uniform corrosion) in the range of between 0.03% to 0.5% of the pipe wall thickness, depending on the equipment, application and measurement frequency.

FSM measurements were discussed in a paper at the InterCorr conference, Recife, 2008 [1)] and will not be repeated in any great detail in this paper.

Since 2008, the first electric field signature on-line monitoring systems have been installed and commissioned, and the first data has been received. The background, installation and results from the first electric FSM installation at the Jamnagar refinery site in India was presented at the 13th Middle East Corrosion Conference and Exhibition [2).]

Some illustrations and typical data from this installation are shown briefly below. Please observe that the data presented in the figures below are using the previous software system, and not the new software discussed in section 5.

Based on the applications and experience from electric field signature measurement system installations, non-intrusive corrosion monitoring has become an important part of the refineries' system for optimizing production and its integrity management systems.

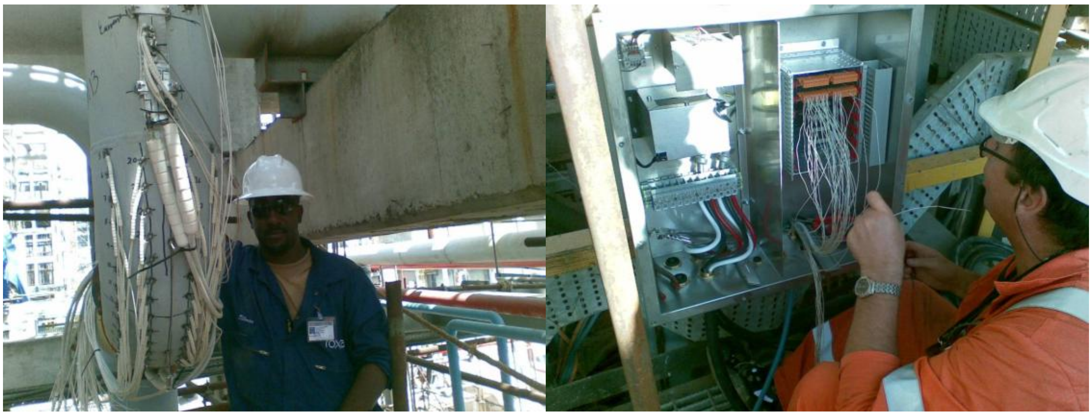

Figure 5: Installed sensing pins with field cables and termination in on-line instrument at the Jamnagar refinery site, India.

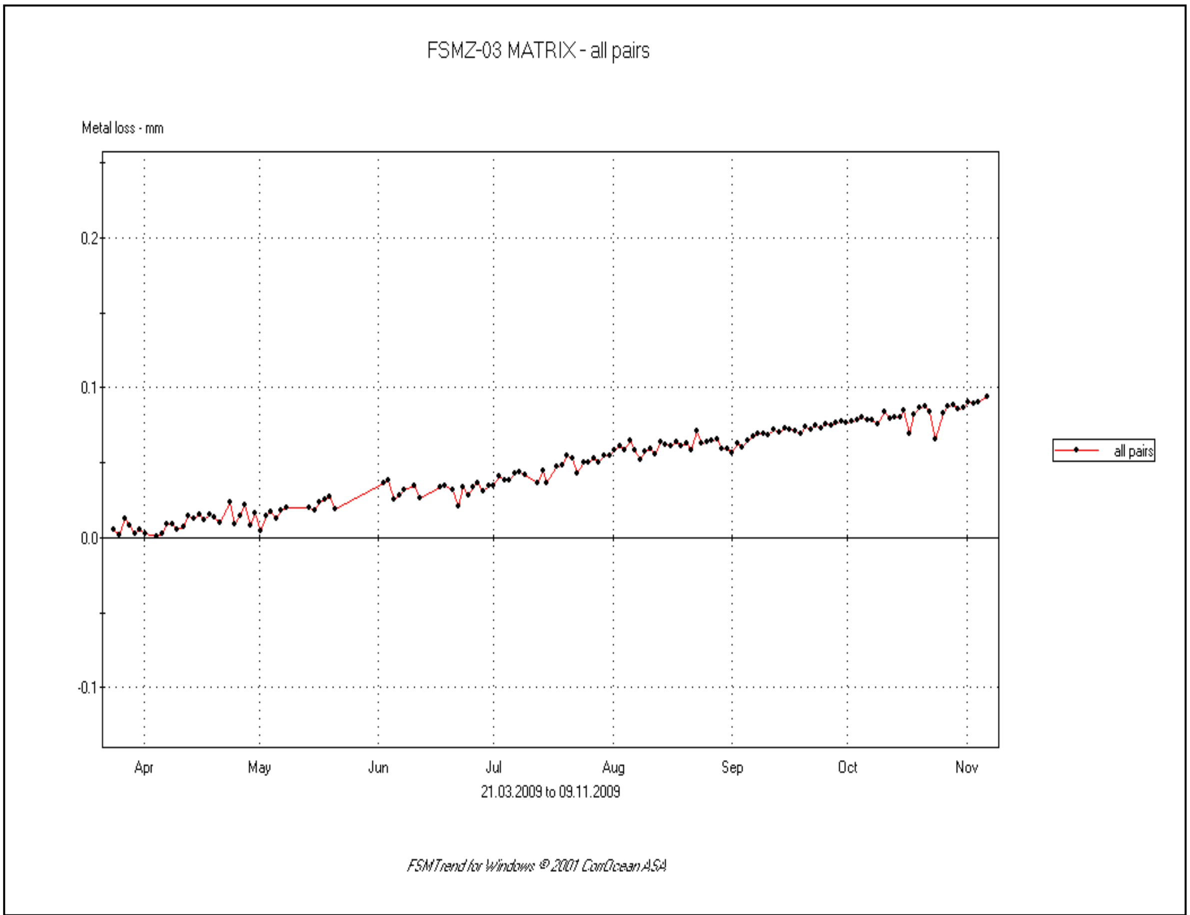

Figure 6: An example plot showing all sensing pin pairs for the on-line monitoring system at the Jamnagar Refinery. Measurements are taken every 16 hours.

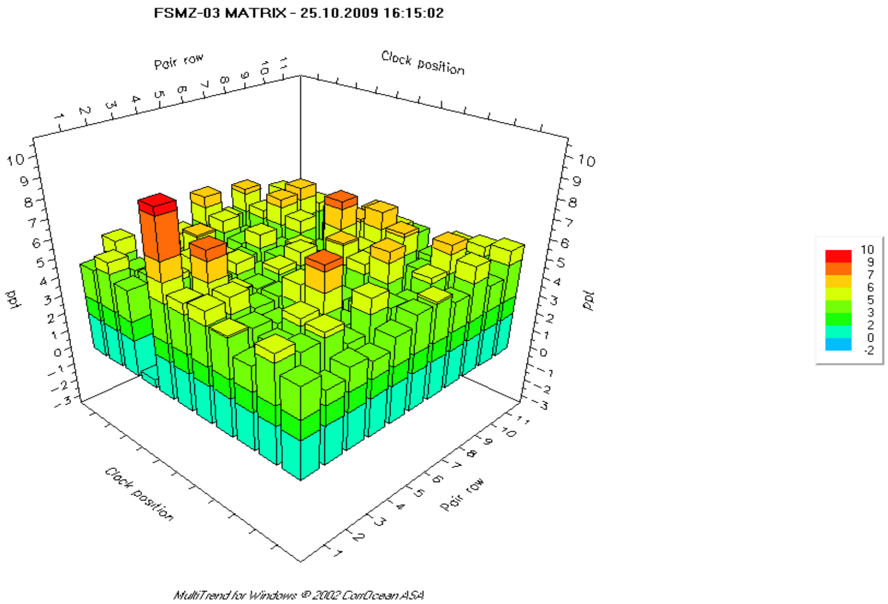

Figure 7: An example plot showing corrosion data for individual pin pairs in BAR graph on 25.10.2009 for the on-line monitoring system at the Jamnagar Refinery. Measurements are taken every 16 hours.

5. New Monitoring Software Solutions

5.1 A Two Level Field Monitoring Software Solution.

As discussed in the introduction to this paper, the requirements for field monitoring software increases with the level of complexity and amount of information that must be analyzed. Recognizing this, Roxar has developed a two level field monitoring software solution. Key components include:

- Application software for each individual monitoring system (sand monitoring, FSM monitoring, or flow monitoring)
- A field management software solution, combining the various software applications into one integrated data management system.

5.2 Roxar Fieldwatch and Roxar Fieldmanager

Roxar Fieldwatch is a specialized Windows-based field monitoring system which enables operators to ‘watch their fields’ remotely and which can handle intrusive and acoustic sand erosion sensors as well as corrosion monitoring sensors and pressure/temperature sensors within the same program system.

Data can be collected quickly from multiple locations and accessed through an intuitive user interface. The rapid retrieval and display capabilities of Fieldwatch also provide the user with the ability to quickly visualize data and identify trends and patterns or areas of interest for further analysis.

Real-time data can be accessed directly at the desktop via a graphical user interface and, if worthy of further analysis, transferred at regular intervals to Roxar Fieldmanager which, based at the field’s onshore control centre, provides a suite of more detailed analysis and interpretation tools and local storage for the data.

5.3 The Sand Management Module

Sand monitoring is now becoming a major element of the Fieldwatch system, allowing operators to be more proactive in taking the necessary remedial action to prevent sand interference, as well as the ability to access sand management data alongside other real-time field production data.

The sand management module was developed jointly between the supplier and Statoil. Statoil had increasing requirements for such sand management software due to:

- The growth in maturing fields, requiring more water (more sand) and more gas (higher velocities, and potentially more erosion damage). Hence, the need for sand monitoring had increased
- With an increasing number of sand monitors, the amount of data has increased significantly, and a faster/more efficient data management function was required.

The new software was developed and implemented by Statoil at their Heidrun field between 2008 and 2009. The Heidrun field is located in the Norwegian Sea on the Norwegian continental shelf. The field has been developed with a floating concrete tension leg platform (TLP) consisting of 56 well slots. The northern part of the field is developed with two subsea templates with separate flow lines connected to the TLP. Oil and gas production from the field started in October 1995.

As is the case with a number of StatoilHydro’s other maturing fields, the Heidrun licence is seeing an increase in sand production. There was a need to increase the field’s sand monitoring capabilities to allow for the maximum amount of sand without affecting production and to meet the challenges of increased water content and more gas (more sand and higher velocities).

Statoil’s experience using this software was presented at Nace 2010 [3)], with the main conclusion being that the new software has enabled Statoil to respond faster to changes in sand production conditions. This has thus allowed Statoil to secure control of significant sand production from a well, and establish maximum sand free production rates for production optimization.

Figure 8 shows the screen status in Statoil's platform control room and *Figure 9* demonstrates a sand burst. The diagram also outlines the software tools available. Note that there are three parallel readings from the different elements on the sand probe. The comparison of the measurements at each individual element, as well as readings of the reference element, is used to verify that the probe data is valid.

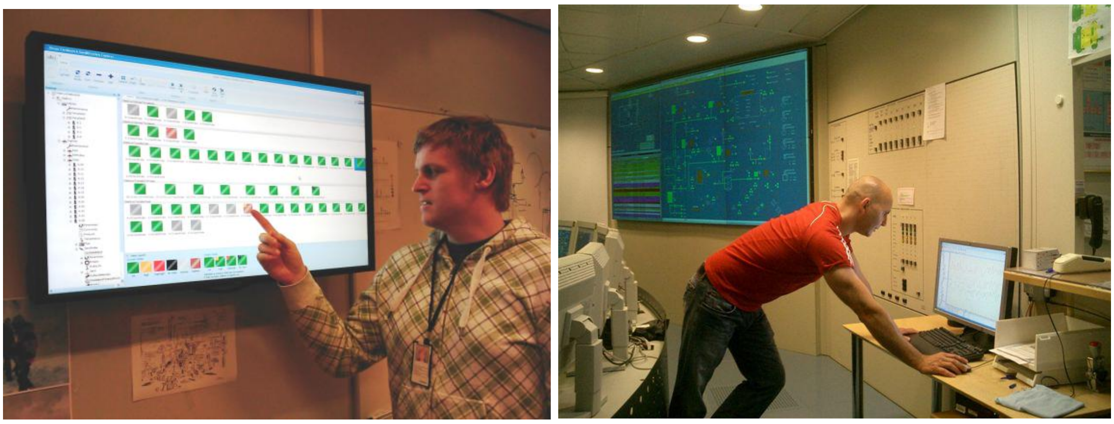

Figure 8: Sand Management software installed in the product optimization room and platform control room at Statoil. The screen shows the status of each sand probe by color code.

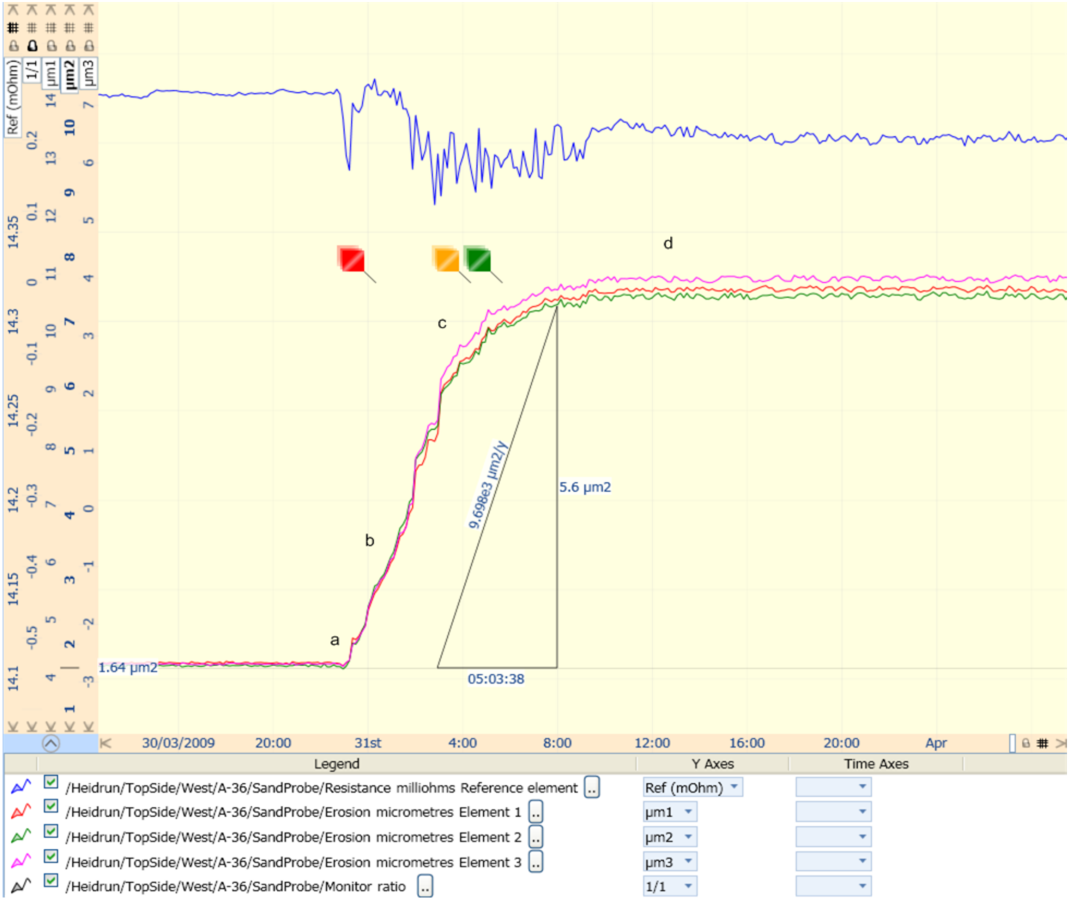

Figure 9: Metal loss curves for a Heidrun well during a sand burst.

The same software format can also handle corrosion probes installed at the platform, and possible future FSM installations can also be handled by FieldWatch/Field Manager data management, allowing an integrated software system which includes all sand and materials features.

5.4 Managing Electric Field Signature Methods

Based on developments in the sand management software, a software module for managing electric FSM was developed. The new FSM module has the same advantages as the sand management software in terms of data handling, but comes with other important improvements, including:

- A service console for system design, installation and commissioning (see *Figure 10*). This means that the same software is used from the detailed design of each monitoring location, in the installation and commissioning phase, and after installation in data management and reporting.
- New features and formats for data handling and reporting.

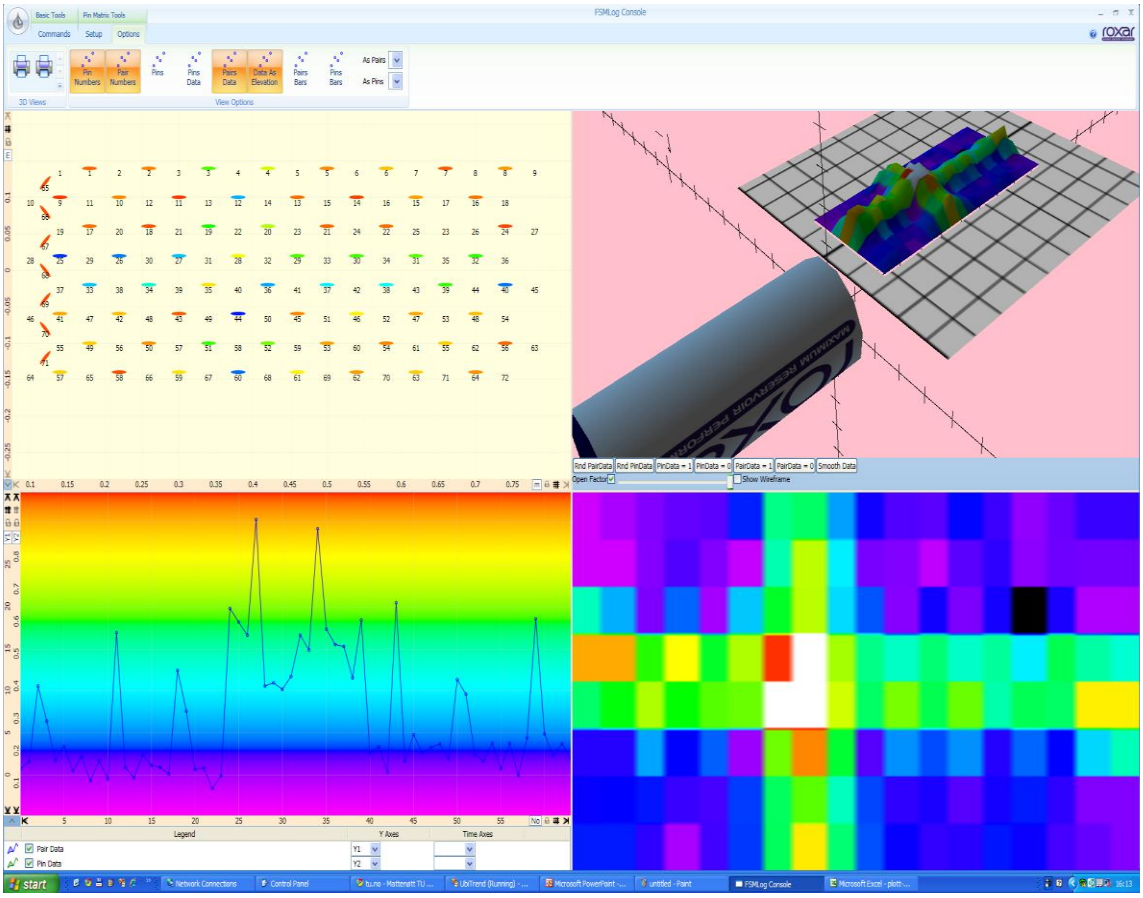

Figure 10: A display from the service console function of the software. The plots show the sensing pin matrix distribution for the pipe (top left), values for individual pin pairs (bottom left), and distribution of attacks on the pipe in two different formats (top and bottom right). Please note that the plot is from an intermediate version of the software, and final presentation for an industrial version may be changed.

5.5 Cross-Feeding Technology

Compared to electrical resistance probes, FSM measurements provide a complex picture of electric field changes at the monitored object. This extensive information generates a more accurate picture of the actual corrosion at the object (for example, corrosion related to localized corrosion or weld corrosion).

However, experience has shown that there are cases where there may be limitations to the technology, and where particular forms of localized corrosion attacks may be underestimated.

Until now, electric field measurement systems have been based on feeding the current in one direction. This makes the system more accurate for defects that are perpendicular to the flow direction, and less sensitive to defects that are parallel with the flow directions. Attempts to compensate for this effect by measuring at pins at an angle have been tried, but the fundamental limitation – the distribution of the electric field – remains the same.

In order to improve the reliability of the measurement of defects in all forms and directions, a new cross-feeding technology is now being introduced (patent pending).

Feeding currents to the monitoring object in perpendicular directions will increase significantly the systems' ability to detect and define defects in all directions, and also improve the ability to quantify and describe the size and shape of localized attacks. The new generation of on-line FSM monitoring systems, provided by the originator of this technology, are prepared for cross-feed measurements.

Figure 11 from an early software version shows a plot from an electric field signature for an artificial attack consisting of one narrow, longitudinal groove, and one narrow attack perpendicular to the electric current direction, using the cross-feed technology. As demonstrated, both longitudinal and perpendicular attacks can easily be seen, with a similar resolution.

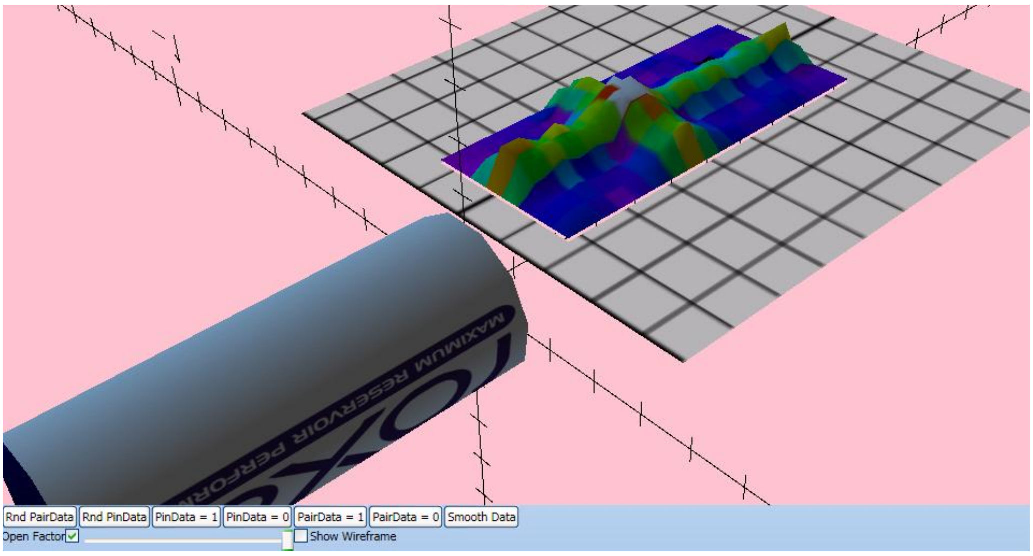

Figure 11

6. Conclusions

There is a trend in the market towards more integrated on-line monitoring systems, providing more data of increasing complexity. The needs for more powerful data management systems are growing accordingly.

The end goal is where corrosion monitoring technologies and acoustic and erosion-based sand sensors can be combined and integrated with new sand management and corrosion software, leading to increased monitoring, reliability and redundancy, more extensive information, and improved alarm settings. This goal is now being achieved.

This paper has demonstrated that a new generation of data management software is facilitating the integration process and providing new features and functions for improved data management, data analysis and reporting. Field testing of the new software for sand management has verified the usefulness of the system, allowing more real time sand control and optimized production. With increasing oil & gas production offshore Brazil, it is the authors' belief that the conclusions and learnings from this paper will have a major impact on flow assurance in Brazil over the coming years.

7. Acknowledgements

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