PILOT PROJECT: EVALUATION OF IIOT- BASED METHODS AND PROCESS FOR CONDITION MONITORING OF OFFSHORE ELECTRICAL DISTRIBUTION INFRASTRUCTURES

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Abstract - As Industrial Internet of Things (IIoT) connected technologies prove their effectiveness along the industry value chain, new solutions are now driving both digital transformation and new business models across enterprises. In Oil & Gas industry exploration and extraction processes, management of electrical distribution infrastructure assets is a key business area that stands to benefit. Monitoring of electrical systems has been implemented for many years using Intelligent Electronic Devices (IEDs) and Electrical Network Monitoring and Control Systems (ENMCS) allowing smarter operation.

Today, IIoT and predictive analytics are taking smart operations a step further and are leveraging data to enable better decisions that result in the reduction of unscheduled downtime, increased safety and optimized maintenance. Many details must be considered when implementing a smart electrical distribution system including IIoT sensors, data collection, communication infrastructure, cybersecurity and both on-premise and cloud-based monitoring services. This paper describes a current oil company pilot project taking place aboard one of their remote Floating Production Storage and Offloading (FPSO) vessels and examines the design considerations, issues faced, implementation strategies and new perspectives realized for next steps to be taken by the industry.

Index Terms — Asset management, electrical distribution, Internet of Things (IoT).

I. INTRODUCTION

A French-based global oil and gas energy provider was looking for new methods to enhance the availability of electrical infrastructure of their offshore floating production storage and offloading (FPSO) facilities and to contribute to Health Safety & Environment (HSE) targets.

The company strategy was to focus on the reduction of unscheduled downtime to reduce costs and production losses.

A. Fire Incident Risk Accelerates Search For Alternative Electrical Systems Monitoring Solution

All most all Petroleum Facilities experienced a significant outage, consequences can be more dramatic for offshore installations. Let’s take an example of a bad connection inside a Low Voltage (LV) emergency switchboard, this bad connection could lead to a fire inside the room, detected by the Fire & Gas system that would trigger an Emergency Shutdown (ESD) of the platform and all satellite platforms fed from it. The fire would have probably damaged part of the switchboard including some mechanical interlocks preventing return to normal operation. In such crisis situation, a lack of experience surrounding full manual black start procedures would lead to an extended period of time to restart the electrical network, leading to a subsequent production loss and environmental consequences like flaring.

According to the International Electrical Testing Association (NETA), an organization that serves the electrical testing industry, more than 25% of fires in electrical distribution/switchgear systems are due to insufficient tightening of bolted connections [1]. Over time these connections deteriorate or loosen (especially in harsh environments exposed to corrosive elements or vibrations as is common on an FPSO). A loose connection can lead to the generation of heat, thermal runaway and/or arcing, that can cause system downtime or, in some cases, fire. In the case of fire, downtime is often accompanied by equipment destruction.

On spot Infrared Thermography has been an answer for several years, but new HSE regulations, Electrical Standards are making thermography more and more impossible. The NFPA 70E [2] standard also recommends not to expose personnel to such electrocution risk.

Testing and validation of thermal monitoring emerged as a key requirement for the company’s planned pilot project.

B. Background

The pilot project (12 to 24-month duration) is being conducted onboard a 10-year old FPSO (deep offshore).

The FPSO itself is the size of an oil tanker but is furnished with a topside processing facility that is dense with both mechanical and electrical equipment. The vessel measures around 330 meters (1,083 feet) in length by 60 meters (197 feet) in width. The vessel is manned by over 250 crew members, and is connected to subsea wells. This FPSO was chosen due to the planned Full Field Shutdown (FFSD) which occurred end of 2018 (see Fig. 1).

Fig. 1: FPSO vessel in operation

II. IDENTIFIED PAIN POINTS

For oil companies, any unplanned downtime aboard the installation can lead to loss of production in the thousands of barrels per day (which equates to millions of dollars per day). The company was looking for a solution to mitigate electrical distribution downtime. Such risks included electrical equipment failures due to wear and tear and aging. Personnel onboard the FPSO are focused on oil extraction and processing operations. There is also a dedicated on-site team that performs required maintenance activities. One of the company's objectives was to utilize a new monitoring solution in order to better optimize maintenance manhours.

In order to assure the reliability and safety of their electrical systems, the company invited electrical infrastructure vendors to participate in a pilot project based on a data-driven approach.

The pilot project was originally initiated to address three areas of concern:

1) The monitoring of electrical bolted connections to prevent fire.
2) A costly and inefficient preventive maintenance process for switchgear and switchboards. This traditional approach to time-based maintenance proved outdated and was not capable of identifying problems before they occurred.
3) They required a system that would assure improved electrical system availability in order to ensure reliable operation and increased safety.

In order to better define the pilot project, the company embarked on a review of the current electrical systems on board the vessel. Two principal areas needed to be addressed:

a) Thermal monitoring of bolted connections.
b) Circuit breaker and contactor health monitoring.

III. RECOGNITION OF TECHNOLOGY ADVANCEMENTS

Traditional practices for monitoring and maintaining electrical systems are quickly evolving. Typical approaches for temperature sensing, for example, involve sporadic utilization of IR for the scanning of components. In the case of IR, an on-site technician has to open the switchboard and use an infrared camera in order to detect the abnormal temperature rise inside of the switchboard. This approach is complex and labor intensive. IR thermography is not possible to perform on MV cubicles without IR windows. Also, in the case of LV, proper safety procedures discourage the use of IR thermography on energized switchboards [4].

The company had decided to discontinue this practice because of technician availability issues, an increased potential for human error, and safety concerns.

New approaches for accomplishing these tasks now involve smart sensors, 24/7 online monitoring by a team of remote analytics experts, and the analysis of data trends to determine if equipment is experiencing temperature anomalies. The same principles are also applied for the monitoring of circuit breakers which provide much more insight regarding their health.

The oil company recognized that new technologies were enabling more flexibility and fresh perspectives for addressing their current pain points. They decided to explore a data-driven solution that would be capable of automatically collecting data on site and forwarding that data to the cloud where analytical models perform the work of reviewing the data. Once the data is collected, the analytical engine then flags the data and generates dashboard charts and graphs for easy interpretation (see Fig. 2). Experts then review the results. If an anomaly is detected, experts are in a position to validate the anomaly and provide proactive maintenance recommendations, thereby ensuring normal operation of the systems.

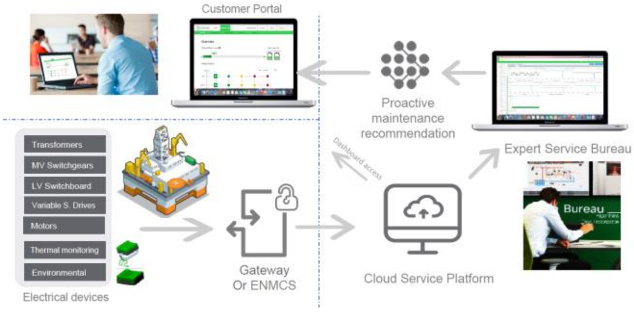

Fig. 2: Data flow between FPSO and Service Bureau

IV. PILOT PROJECT

The oil company's pilot project serves several purposes. The first is to test the vendor solution for taking accurate temperature measurements inside of electrical switchgear/switchboards. The second is to have onshore experts analyze the data gathered including data being generated from Intelligent Electronic Devices (IED). The experts use sophisticated analysis models, in order to deliver value in the form of higher FPSO electrical network uptime.

The pilot project is also being used as a mechanism for determining whether remote monitoring can serve as a suitable replacement for traditional monitoring methods and whether this new technology actually works in a real-world environment. Observations surrounding implementation conditions of this type of technology on a 10-year FPSO was also part of the research scope.

The company decided to launch the pilot project in November of 2017. Then an engineering phase was launched in October 2018, in tandem with the scheduling of the second full field shutdown for this particular FPSO. The new application then went live in May of 2019.

A. Success criteria

The operational pilot project is scheduled to end in May of 2020, with the option to extend for one additional year. Over the testing period, the company is determining whether or not the solution is successful based on electrical system uptime efficiency gains.

Additional success factors will include improved safety of people onsite (fewer accidents), reduced need for preventive maintenance due to better equipment health status insight, the ability to perform condition-based maintenance through continuous remote monitoring, and the ability to perform predictive maintenance (acting before the failure).

In addition, should the pilot project prove successful, it will redefine the company's approach to asset management strategies towards a more data-driven and analysis-based model.

V. IMPLEMENTATION OF A SERVICE

The oil company's decision to digitize its electrical system condition monitoring approach involved several unique business perspectives. The first was to place an emphasis on what is called lean implementation. Many oil and gas industry projects are capital-intensive and often involve costly and disruptive technology replacements. In this case, focus was placed on digitizing only what was needed to achieve the goals of the pilot project (in this case, placing thermal sensors into existing switchgear cubicles and collecting relevant data inside the existing IEDs). The data gathered from the equipment was then sent to a cloud, where Service Bureau experts then analyzed the data. Reports are then shared with stakeholders via dashboards. The processing of this information is offered *as a service*. No new software was added on premise.

Another unique trait of the pilot project involved the sending of data from the FPSO vessel to an off-premise third-party cloud without compromising the cybersecurity. Across the oil and gas industry, companies are traditionally hesitant and reluctant to send data off site to a non-company owned cloud or public cloud. Many organizations are worried about potential cybersecurity risks, but the cloud can provide advanced benefits in comparison to on premise solutions.

Having the pilot project delivered as a service meant that analytics were performed within a cloud-based platform with no analytics-related work being executed on-premise. New analytics updates are also applied at the cloud level without any modification needed on site.

VI. INNOVATIVE SENSORS

One objective of the pilot project is to validate the thermal monitoring solution offered by the vendor. This innovative technology uses wireless and battery-less thermal monitoring sensors installed at each connection point to be monitored. This type of sensor does not require any wiring (see Fig. 3).

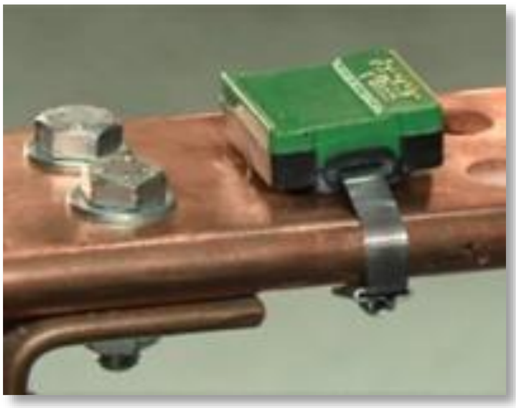

Fig. 3: Sensor shown without the tightening to demonstrate the ferromagnetic strip

A Negative Temperature Coefficient (NTC) probe (see Fig. 4) is included at the bottom of the sensor which is installed on the busbar in the vicinity of the connection.

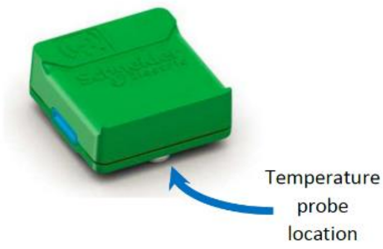

Fig. 4: NTC probe location

The sensor is powered by an AC electromagnetic field generated by the current through the busbar. A ferromagnetic strip is used to harvest the energy. When powered, the sensor will send the temperature measurement to a gateway using Zigbee Green Power (2.4 GHz radio frequency) every minute. Sensors need to be installed on each phase to detect any discrepancy that might occur. Encryption is used at the radio frequency (RF) level and a pairing process between sensor and gateway is required.

Due to the technology used, the dielectric impact of the sensor needs to be assessed for all MV connections or for each type of switchgear.

Different gateways are available, including one able to concentrate up to 60 sensors and provide the measurement over Modbus. Simple RF engineering rules need to be applied in order to ensure the performance of the system. In operation, the RF performance (RSSI Received Signal Strength indication) is available on the receiver.

Another sensor measuring temperature and relative humidity was also considered to capture ambient conditions to evaluate the risk of condensation inside a switchgear. Both sensors use the same wireless technology but this second sensor is powered by a battery with up to 20 years autonomy. Data are pushed to the gateway every 2 minutes. Initially proposed to monitor the ambient conditions inside the rooms, the sensor was finally rejected for safety reasons due to a local requirement preventing the powering of equipment by battery (a requirement to shut down the sensor in case of gas detection).

VII. ENGINEERING PHASE

A. On-board system overview

Multiple operational systems are used onboard the FPSO. In terms of electrical network, the following systems play a core role:

- Power Distribution Control System (PDCS, the company name for the electrical Network Monitoring and Control System-ENMCS). This system is responsible for controlling the electrical network in order to feed the process. The PDCS allows functions like fast load shedding and is used at the electrical equipment level PLC (Programmable Logic Controllers) to monitor and control the equipment (using hardwired interface or through communication). The system is redundant. This system is used to operate the electrical network and only data available from the system is required for operation. Equipment maintenance considerations were not part of the specification at the time of the construction of the FPSO. In most cases, these systems only monitor a single-phase configuration (for example, current inside one phase and not on the 3 phases).

- Instrumentation Control & Safety System (ICSS, the company name for the combined process control system – PCS, and safety shutdown system – SSS). This system is responsible for controlling and operating the process and requires a close interaction with the PDCS to feed the process.
- Data Historian - The Data Historian is mainly used to collect and store all the process data including some of the key electrical parameters. Information from the historian is called a Tag. Historians are designed to be able to collect a large amount of data with millisecond accuracy and to store them efficiently over a large period of time.

All those systems are layered with cybersecurity measures at each system boundary (see Fig. 5).

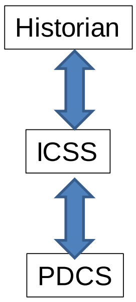

Fig. 5: Layered system overview (security measures not shown)

The company runs multiple historians, one on board the FPSO, one in their local headquarters and one in the company headquarters. These historians are updated permanently using historian to historian replications.

As a protection relay exerts a direct control on the circuit breaker, for example, direct connection to the protection relay or the PDCS are not possible for cybersecurity reasons. The company policy dictates that all electrical data from protection relays to be provided by the historian.

B. Condition monitoring data to be collected

The objective of the pilot project is to assess the health of the electrical equipment such as circuit breakers. Various data is provided by an IED that is fitted onto the equipment. For a circuit breaker, known circuit breaker monitoring data need to be collected. The parameters for data to be collected include, for example, the number of operations of that breaker, the cumulative breaking current from the circuit breaker, the opening time, and the charging time. During the engineering phase it was confirmed that those data were NOT collected by the PDCS.

C. Electrical network architecture

Most of the systems on board the FPSO are redundant on the A and B side switchboards (see Fig. 6). Main electrical rooms are spread over 3 locations, MV and LV equipment are also segregated. For ease of explanation, we will consider the MV and LV components as being housed in one electrical room.

One electrical room is located inside the hull. Two are located on the topside (inside of electrical/instrumentation buildings), one on portside, one on the starboard side, composing the A & B side configurations. The main electrical room inside the hull is not redundant but can be fed from both electrical/instrumentation rooms and includes an A & B bus arrangement.

The electrical network includes the following voltage levels:

-13.8 kV with the gas turbines

-6.6 kV

-400 VAC

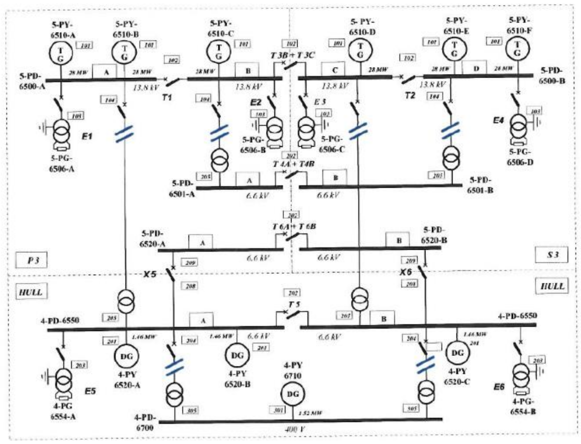

Fig. 6: Single-line diagram overview of the on-board electrical system

The 13.8kV and 6.6kV switchgear have been supplied by two different equipment manufacturers.

D. Site equipment selection

The 6.6kV switchgears are mainly composed of metal clad components fitted with circuit breaker and vacuum contactors that have been selected for the pilot project because sensor applications on those type of switchgear were previously validated. A total of 20 MV circuit breaker cubicles and 20 MV contactors were selected in the three electrical rooms.

In order to prove the viability of sensor technology on LV, three LV Motor Control Center (MCC) switchboards were also included, mainly on the main incomings. One switchboard inside each main electrical room was selected.

E. Initial proposal

The initial plan was to follow the same principles as the current configuration. This meant:

- Adding the thermal sensor measurements to the PDCS and updating the PDCS configuration to collect the missing data from the IED.
- Updating the ICSS to collect the above data from the PDCS.
- Updating the historian to collect the above data from the ICSS.

For the company, executing such a plan would have meant implementing multiple changes in an existing operational system by multiple contractors as each system was provided by a different vendor. The company reached the conclusion that a pilot project implemented in such a manner was not feasible for budgetary reasons.

F. Proposed implementation

The company and vendor worked on an alternative design compliant with company policy which consisted of:

- No modification to the PDCS nor the ICSS. Instead, a dedicated collection system leveraging the PDCS PLC would be implemented. Data was to be collected by an existing OPC server on site that would feed the historian. The company would then push the data from the IED.
- As no remote action was possible on the sensor itself, the company decided to implement a dedicated IIoT network without any connection to the process network, leveraging the company telecom network to send data directly to the cloud [5]. This represented the first pilot project testing of a truly integrated IIoT solution on board an FPSO.

G. Thermal monitoring

The on-premise infrastructure is quite simple. Depending upon the number of sensors and the size of the switchgear/switchboard, a number of Zigbee receivers are used. The receivers used provide a serial interface to a Modbus TCP gateway for each switchboard/switchgear to ease interconnection (see Fig. 7).

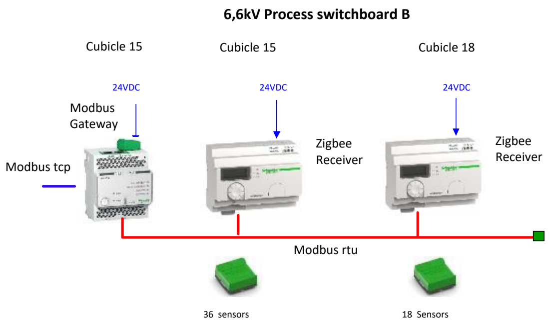

Fig. 7: Local hardware to collect sensor information (6kV B switchboard)

These types of equipment configurations have been added in some of the LV compartments of the MV cubicles and on some of the auxiliary compartments of LV switchboards.

Spare bare fibers were used to connect each TCP gateway to a central cloud gateway located in the telecom room of the FPSO, as were fiber optic switches. The company telecom network has been configured by several company IT teams to allow the data to be pushed to the vendor cloud platform in a secure way (see Fig. 8). Vendor Machine to Machine (M2M) infrastructure is used to collect data from the onboard gateway/datalogger. Cybersecurity measures are implemented at various stages.

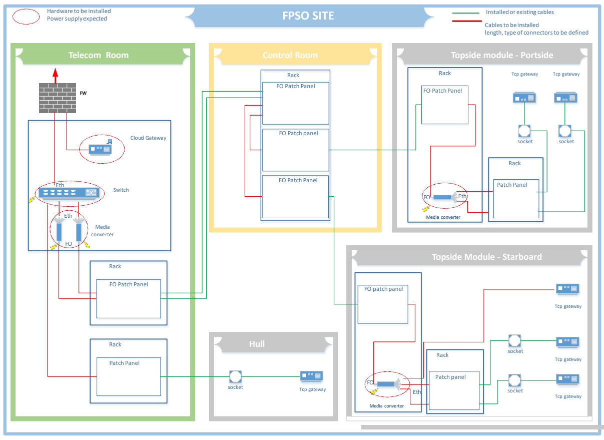

Fig. 8: LAN network implemented on board

Data are polled by the central gateway every 15 minutes, stored inside the gateway, and then pushed to the cloud platform every hour (see Fig. 9).

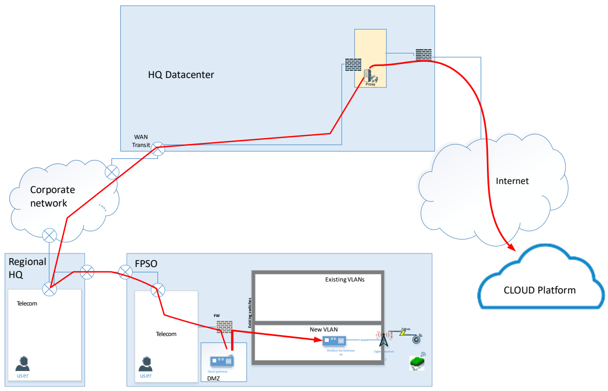

Fig. 9: Overview of the Thermal monitoring data flow

H. Protection relay data

Required data are polled by the PDCS PLC, and are collected by an OPC server before being available on the onboard historian. After two hops, the data are available on the historian at the company's headquarters in France. An extract transform load task is scheduled every 15 minutes on one server to extract relevant data from the historian and generate a CSV file with the measurements. This file is uploaded by the company to a vendor SFTP (Secure FTP) server from where it is ingested by the vendor cloud-based asset monitoring platform (see Fig. 10).

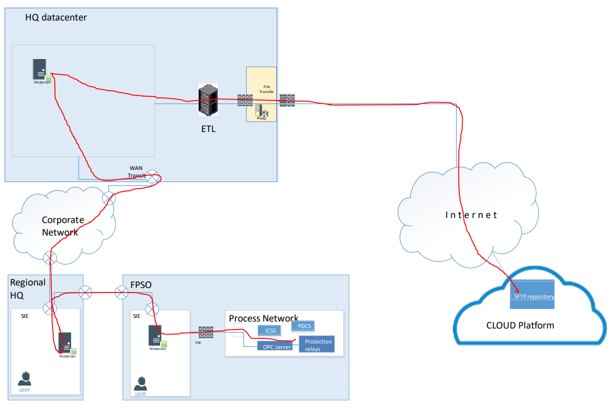

Fig. 10: Overview of the protection relays data flow

In reviewing the full scope of work from the engineering system design phase, the following high-level summary requirements was developed and communicated to the vendor.

- A system of multiple wireless temperature sensors that could be reliably installed
- A collection of sensors that could reliably measure temperature differences within the switchgear cubicles
- The ability to perform predictive maintenance recommendations to assure high availability of electrical equipment
- Improved safety through advanced notice of potential equipment failure
- Assured connectivity and linkages between sensor and data concentrator/aggregator and control system in the harsh industrial environment of an FPSO vessel
- Reliable and secure communication between the offshore site and the vendor's data analysis server
- Absolute compliance with the company's cybersecurity rules and requirements

VIII. IMPLEMENTATION SEQUENCE OF EVENTS

Since the environment on board meant working around the constraints of an existing brownfield installation, a number of preliminary steps needed to be taken prior to launching the pilot project:

- Testing of sensor and technology on a company site in France.
- Preliminary engineering studies that were required to examine the as-built documentation.
- Site survey performed by the company team onboard the FPSO using pictures to identify installation requirements and suitable location to finalize engineering.
- Ordering of equipment.
- Off-site equipment configuration including sensors pairing.
- Shipment of hardware to site.
- Modification of the PLC configuration off site
- Full field shutdown with three main activities, PLC configuration, OPC server configuration and sensor / hardware installation. Installation of sensors on the switchboard/switchgear requires a shutdown and a close coordination with the operation.
- Two data paths to be implemented end-to-end.

A. Installation of sensors during full field shutdown

In November of 2018, a window of opportunity presented itself for the installation of sensors. In order to perform general maintenance, operations on the FPSO are shut down once every five years. The platform stops production for an entire month. A critical milestone for the pilot project pilot was to install new state-of-the-art temperature sensors during this full field shutdown.

The sensors were installed on three types of equipment based on the risk analysis performed by the vendor:

- Within the MV cubicle containing circuit breakers, nine sensors were installed in each cubicle: three on the cable connections, three on the upper arms of the circuit breakers and three on the lower arms of the circuit breakers. Sensors were not installed at the busbar connection as busbar shutdown was highly improbable even during the full field shutdown.
- Within the MV contactor cubicle, three sensors were installed on the field shaper of the upper fuse holder and three sensors on the cable connections (see Fig. 11).
- Within the LV air circuit breaker main incomers, three sensors were installed at each rear connection of the circuit breaker chassis in order to monitor the circuit breaker connection and the circuit breaker cluster.

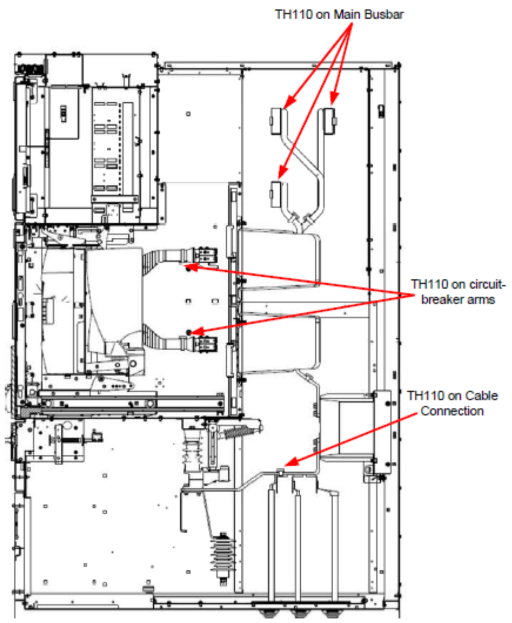

Fig. 11: Location of sensors within the MV circuit breaker cubicle

Two vendor field service representatives were sent on site, for two weeks, to install a total of 383 sensors during the intervention (see Figs 12 and 13).

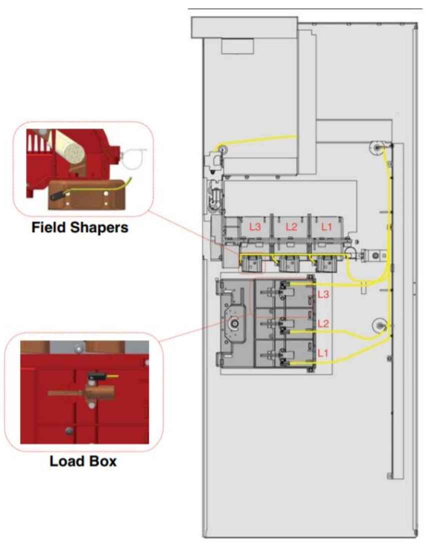

Fig. 12: Location of sensors within the MV contactor cubicle

The emergency switchboard which was identified as an LV switchboard inside the hull electrical room could not be made available for sensor installations, therefore, sensors were relocated to another switchboard.

Fig. 13: Sensors installed on a cable connection of an MV cubicle with circuit breaker

IX. OPERATION

Although some data began to flow to the platform early in February, the pilot project officially went live in May 2019. At that time, the two data streams were up and running after fine tuning actions between vendor and company were performed.

A. Data analysis methodology

Once the data became available on the vendor cloud platform, it was processed by analytics in background mode. A variety of analytics, ranging from basic to advanced analytics, were run. The analytical models that recognize anomalies are sometimes created using machine learning (ML) techniques. Benefits of ML include more accurate diagnosis and predictions and improved operational precision. Results are made available for the vendor Service Bureau experts. The parameters being monitored by the Service Bureau are used to provide the following key performance indicators:

- Usage (load factors, profiles calculated to obtain references and assess the use of the equipment).
- Wear and tear (electrical and mechanical wear of equipment). Circuit breaker mechanical wear, for example, is linked to the number of operations whereas electrical wear is associated to the contact wear.
- Aging (events causing accelerated aging of equipment). Thermal aging is a good example.
- Operating condition (environment and equipment condition).
- Thermal monitoring of bolted connections status (tracking temperatures of components inside of the switchgear). Analytics are tracking any anomalies or inconsistencies not only on a phase basis, but across the three phases. Correlation with current is also performed to verify that heating of the connection is in line with the current.

Gaps between the operating conditions and the design conditions are one of the main reasons for equipment failure.

The reason for analyzing the data is to identify any anomalies that could lead to an issue. Service Bureau experts are tasked with validating the asset health data being gathered from the FPSO.

When an issue is validated, the Service Bureau not only informs the company that an issue exists, but there is also an explanation of the probable cause of the issue. Recommendations are then made for how to best resolve that issue and the next steps to take.

All Service Bureau recommendations are shared with the company contact in the country and the team responsible for managing the on-board pilot project. There is a first-response team available on board the vessel should an issue need to be immediately addressed.

B. Report generation

Once the data is analyzed, insights and reports regarding the status of the on-board electrical equipment are provided to the company through web-based dashboards, where stakeholders within both regional and headquarters locations can view the asset health data. The dashboard reflects the overall health of all of the critical electrical distribution assets through an asset health matrix. This matrix is automatically generated and illustrates, on a continuous basis, the high-level health status of all assets being monitored, using yellow, green and red color-coded indicators (see Fig. 14). In this way, potential risks within their electrical distribution processes are identified.

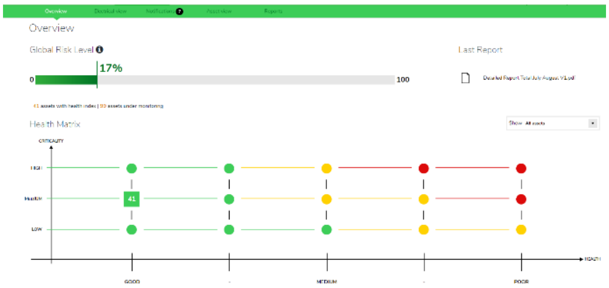

Fig. 14: Graphical interface demonstrating color-coded indicators

The web-based dashboard provides interested parties with the following types of information:

- Secure login screen
- A multi-site view
- A criticality matrix
- A one-line diagram of the installation
- Notifications
- Reports
- Asset view

X. PRELIMINARY FINDINGS AND CURRENT STATUS

Part of the purpose of the pilot project was to determine whether the system could identify and catch potential issues before they manifested themselves into electrical system downtime.

In June of 2019, only one month after having turned on the system, an abnormal temperature issue was identified in one of the MV contactor cubicles responsible for powering one of the sea water pumps. The rise in temperature of the cable connection might be the indicator of a possible current increase but this was not the case at that time. The higher temperature rise was observed on phase C only (see Fig. 15). The temperature discrepancy between the three phases was limited to 5°C which was deemed acceptable but not normal.

However, five hours later, as the current was stabilized, a second temperature increase appeared on phase C only, leading to a temperature discrepancy of up to 10°C. This second increase was not correlated with any current increase. However, the maximum temperature reached (50°C) was far from the absolute temperature limits of the connections (85°C). Thus, the situation was not deemed urgent. Investigations were communicated using an on-event report.

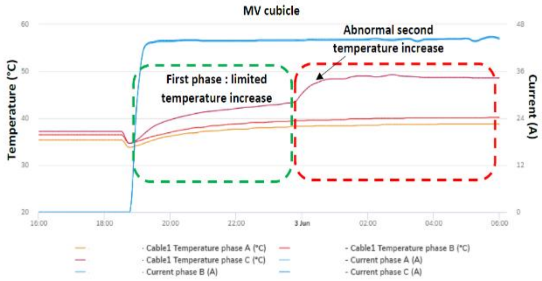

Fig. 15: Abnormal heating of one connection on a MV contactor cable connection

An action plan has been defined which consists mainly of an inspection of the connection. However, the intervention had not been performed yet as of the writing of this paper.

As the asset condition-based monitoring pilot project has progressed, new information has helped to raise awareness regarding the steps required for deploying a successful implementation.

XI. LESSONS LEARNED

Implementation of such technologies onboard an existing installation was a significant challenge for multiple reasons.

The FPSO was engineered more than 10 years ago. Changes are quite difficult to implement while an existing facility is under operation. Due to the "siloed" nature of the layered systems available on the FPSO, the pilot project might have been abandoned for budgetary reasons. However, a new, disruptive approach, which was fully aligned with company standards, has enabled the pilot project to move forward.

Adding even a single box to a low voltage compartment is sometimes not feasible. All assumptions regarding hardware implementation had to be confirmed through pictures.

The objective of the pilot project is to leverage the data to identify the condition of the equipment. For MV circuit breakers, the parameters of interest should be provided by the IED, but the availability depends on how it was configured and wired at construction stage. For example, one key parameter for a circuit breaker is the charging time (i.e., the time it takes for the spring to arm), in order to evaluate the condition of the mechanism. It was observed when the process was completed that all charging times were reported as null because the end of charging position was not wired to the logic input of the IED as not part of the specification.

The same situation occurred for the LV incomer circuit breaker fitted with an MV IED. It is not common on such installations for condition monitoring data—like contact wear or health state built into the vendor Electronic Trip Unit (ETU)—to be available. Implementing condition solutions which are leveraging the data available requires dedicated engineering practices and the implementation of smart equipment. This requirement has to be included in the project specification as EPC (Engineering Procurement and Construction) contracts are mainly cost driven and will only provide the minimum compliant equipment.

Implementing such a pilot project requires multiple teams to be involved: electricians, instrumentation, cybersecurity, IoT, telecom, with teams belonging to different companies and departments (i.e., on site, affiliate, headquarter, subcontractor). The role of the project manager is also key. It took less than 3 months to make the data available inside of the cloud platform.

The only true success factor in such a pilot project is the business benefit accrued. Sending data outside the facility / company is accepted only if there is a business value, and cybersecurity should not be considered a roadblock. However, cybersecurity has to be carefully negotiated and implemented.

Regarding thermal monitoring of bolted connections, it was confirmed that the absolute temperature of the connection, even taking the current into account, does not allow for the proper checking of connection quality [6]. Phase discrepancy enables a more precise and smarter insight.

XII. LOOKING FORWARD

The pilot project was still underway as this paper was written, but preliminary findings confirm that the wireless and battery-less technology is working. In parallel to the pilot project, several initiatives between the company and vendor were agreed upon to identify how the pilot project can be extended to increase the value provided.

Common pain points reported to vendor by the offshore industries are :

- Cable termination / Cable head monitoring - Issues are occurring with more frequency mainly due to quality issues when the connections are made at the construction yard.
- Subsea cable monitoring - This allows detection of impending failure on a subsea cable in order for it to be repaired before an extended period of unanticipated downtime occurs.
- Big Variable Speed Drive failures
- An issue of partial electrical discharge surrounding motors needed to be analyzed and addressed.
- A faulty single cell within a string of UPS batteries can jeopardize the capacity of the whole battery.

Within the context of the pilot project the following topics are currently under discussion:

- Increase the analytic coverage (for example by using big data techniques vis-à-vis the installed base to allow further correlation and a more intense statistical approach).
- Extend the equipment range hosting thermal sensors (for example 13.6kV switchgear or on the gas turbine generator connection.
- Involve other vendor equipment like 13.6 kV switchgear.

- Include additional equipment like electrical motors using Motor Electrical Signature Analysis for monitoring rotating equipment or batteries used inside of AC or DC UPS (Uninterruptible Power Supply).
- Incorporate soon-to-be-available new sensors from the vendor like ozone sensors to detect corona effect or heat detection sensors leveraging the volatile organic components that are emitted when an insulation material like PVC sheath is heating.
- Modify the data exchange mechanism between the company and the cloud platform for live streaming.

XIII. CONCLUSIONS

The oil company had experienced issues regarding electrical infrastructure and regular testing is challenging due to lack of suitable technologies. Any loss of production due to failure within their electrical systems network represents a huge loss of production and can have safety and environmental potential implication. That's why the decision was made to explore a data-driven solution that would enable the company to remotely monitor the health of their electrical infrastructure.

As believers in the overall vision that the old ways of monitoring and maintaining electrical can be optimized, the pilot project was streamlined to encompass a very narrow focus that introduced minimal disruption while radically altering the way electrical equipment data was captured, analyzed and acted upon.

Cybersecurity emerged as the most important issue to address. Rather than adopting a cookie-cutter, one-size-fits-all approach, the team decided to analyze the importance of the data being gathered, and the possible exposure of electrical assets and related data to outside control or view. As a result, two different systems of data gathering and consolidation were implemented in order to comply with the company requirement

The company also was willing to overcome the traditional practice of keeping all facility-generated data on site. Instead, the project team pursued the idea of testing the potential for IoT, data driven techniques, and cloud-based solutions to identify and address electrical system availability issues.

The oil & gas industry is undergoing a transformation that relies heavily on the ability to implement data-driven solutions. Industry observers have estimated that digitalization and related initiatives will create up to $1.6 trillion of value for the oil & gas industry, its customers and wider society [7].

Deployment of digitization technologies such as smart sensors and advanced analytics will modernize operations, drive efficiencies and improve breakeven cost of production. These newer technologies lower overall capital expenditures while increasing process efficiency and reducing maintenance costs.

But this is an evolution and not a revolution. Much is to be learned from pilot project exercises such as the work being conducted on Floating Production Storage and Offloading (FPSO) vessels.

XIV. NOMENCLATURE

AC Alternative Current.
CB Circuit Breaker.
DC Direct Current.
ENMCS Electrical Network Monitoring & Control System.
EPC Engineering Procurement & Construction.
ESD Emergency Shutdown.
ETU Electronic Trip Unit.
FFSD Full d Shutdown.
FPSO Floating Production Storage Offloading.
HSE Health Safety & Environment
ICSS Instrumentation Control and Safety System.
IIoT Industrial Internet of Things.
IR Infra Red.
IED Intelligent Electronic Device.
LV Voltages less than 1kV.
M2M Machine to Machine.
MV Voltages between 1kV and 40kV.
OPC OLE for Process Control.
PDCS: Power Distribution Control System.
PLC Programmable Logic Controller.
RF Radio Frequency
SFTP Secure File Transfer Protocol.
UPS Uninterruptible Power Supply.

XV. REFERENCES

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XVI. VITA

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