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Desenvolvimento de uma ferramenta de monitoramento da disponibilidade de sensores submarinos de poços

Development of a digitalized tool for monitoring the availability of subsea well sensors

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Resumo

Este trabalho descreve um sistema de informação que tem o objetivo de aumentar a disponibilidade das informações de pressão e temperatura dos sensores submarinos de poços. O sistema é alimentado por dados operacionais transmitidos em tempo real. Durante o desenvolvimento deste sistema, foram realizadas entrevistas com os principais usuários, mapeando os principais problemas enfrentados na disponibilidade das informações e as ações necessárias para a mitigação de tais problemas. Neste trabalho, apresentamos a descrição do sistema.

Palavras-chave: Sensores Submarinos de Poços. Disponibilidade. Confiabilidade. Dados Transmitidos em Tempo Real

Abstract

This work describes an information system to increase the availability of pressure and temperature data from subsea well sensors. The system is fed with operational data transmitted in real-time. Interviews with the main users were performed during the development of this system. In these interviews, we mapped the main issues faced regarding the availability of information and the necessary action to mitigate these problems. In this work, aside from the system description, we present the results of this mapping process.

Keywords: subsea well sensors. availability. reliability. data transmission in real-time

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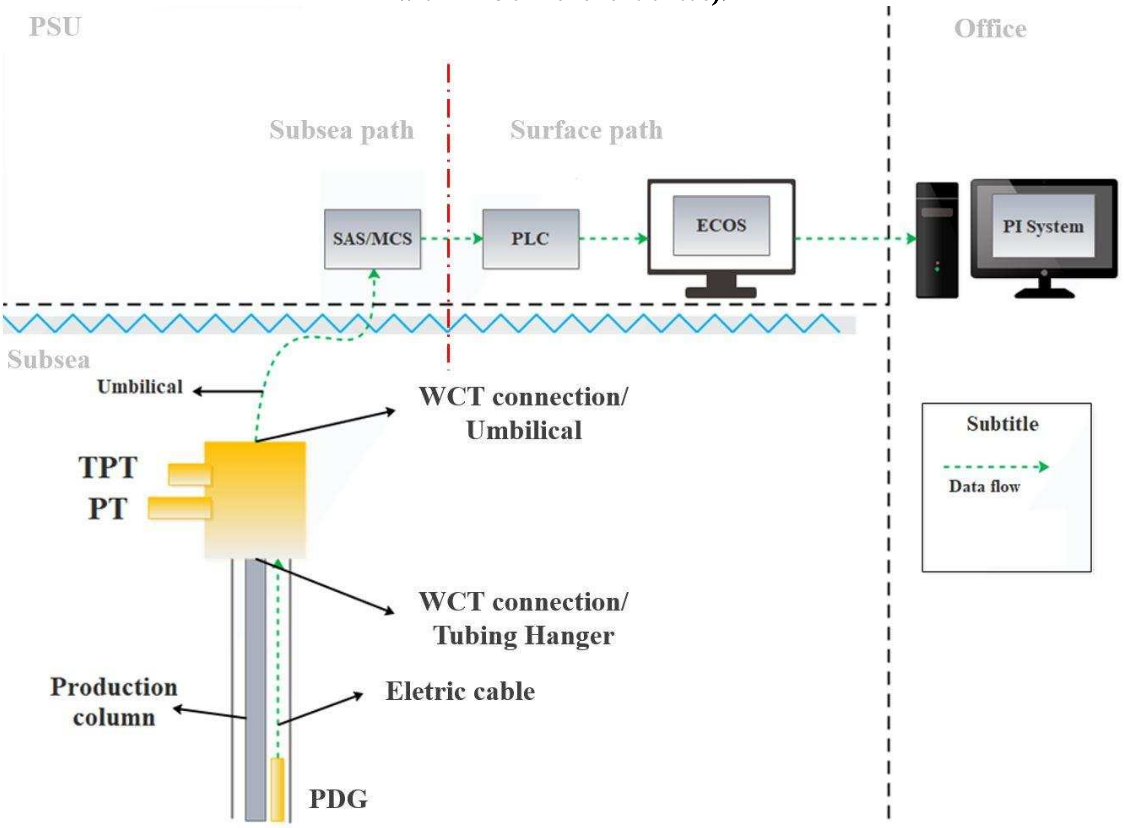
1. Introduction

Extracting and transporting hydrocarbons from marine reservoirs in deepwater locations require subsea production systems that must be reliable enough to keep the environment and people safe and avoid the need for interventions, for either operation or maintenance (Dash, 2012). A subsea production system includes subsea pressure and temperature sensors as important components. The operational availability of such sensors and the data emitted by them are fundamental for managing the well integrity, for managing the reservoir, for the lifting and flow activities and for the formation evaluation.

This work describes an information system that aims to increase the availability of pressure and temperature information from subsea well sensors. We started its specification with a literature review to identify the state of the art in establishing reliability parameters of pressure and temperature sensors, considering, in addition to the installation and inspection data, the availability of sensor reading data in real time. We also verified the best way to store a large volume of real-time operational data to install the infrastructure in the operational area.

We then conducted interviews with the potential users of this information to map the main problems faced in the availability of information and the necessary actions to mitigate these problems. We concluded that the unavailability of data could cause production to stop in a well, highlighting its importance and justifying a system with the objective of maximizing its availability. With this objective in mind, we established that the measurement of the data by the sensor, its transmission, its use in the plant operation and its transmission to the storage facility (where the user uses the data) would be subdivided into two paths: the submerged path and the surface path (PSU – Production Stationary Unit + office onshore). Figure 1 shows a schematic of the two paths.

Figure 1: Schematic of the system – submerged (data flow within submerged areas) and surface paths (data flow within PSU + onshore areas).

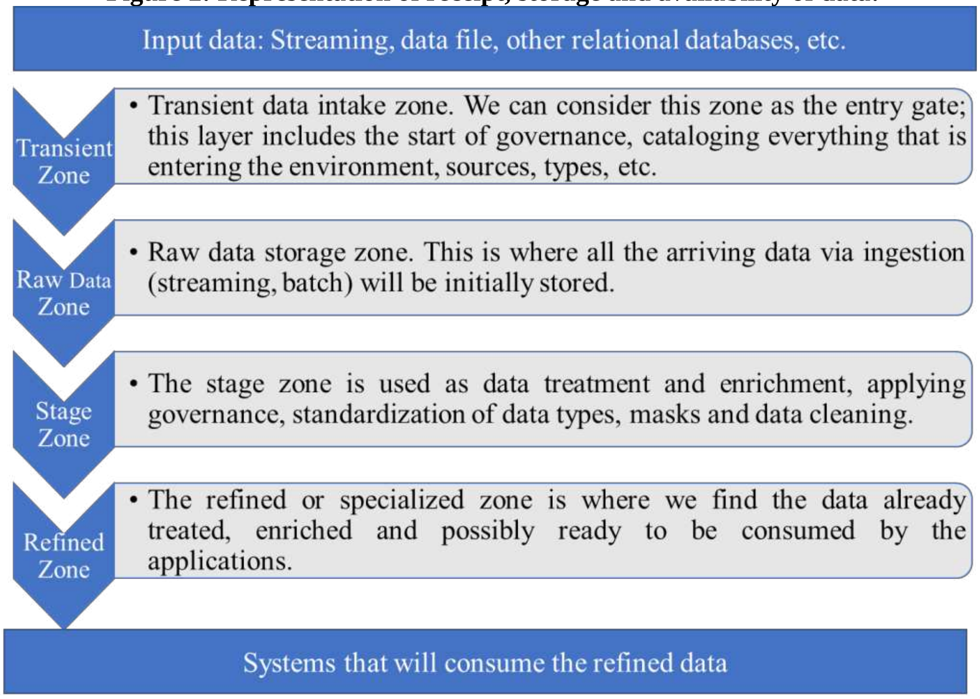


Source: elaborated by the authors.

The surface path has the greatest impact on the system unreliability (Silva, 2017) but repairs can be carried out relatively expeditiously. The system specification defines that, for the submerged path, the system registers and monitors the failures that occur, in addition to calculating the reliability to optimize the sensor life and maximize its availability. Meanwhile, for the surface path (PSU + onshore), the system immediately alerts the occurrence of abnormal behaviors in order to reduce the operational turnaround time (repair time). In these two paths, the system records and archives the failures using as a reference the methodology described in ISO 14224 (2006).

The way for storing the time series of operational data transmitted by the sensors is defined according to the literature review. The choice made is for a non-relational database based on Djamaluddin & Mohammed (2018) and for the creation of a data lake. Figure 2 shows the structure of this data storage system, which consists of a transient data intake zone, a raw data storage zone, a data processing and enrichment zone and a data consumption zone (Patel et. al, 2017). The system specification established the use of the data lake with a vision of the future – with the application of new technologies – to make the data available to enable developments for the optimization of operational performance and prediction of problems.

Figure 2: Representation of receipt, storage and availability of data.



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2. Survey with system users

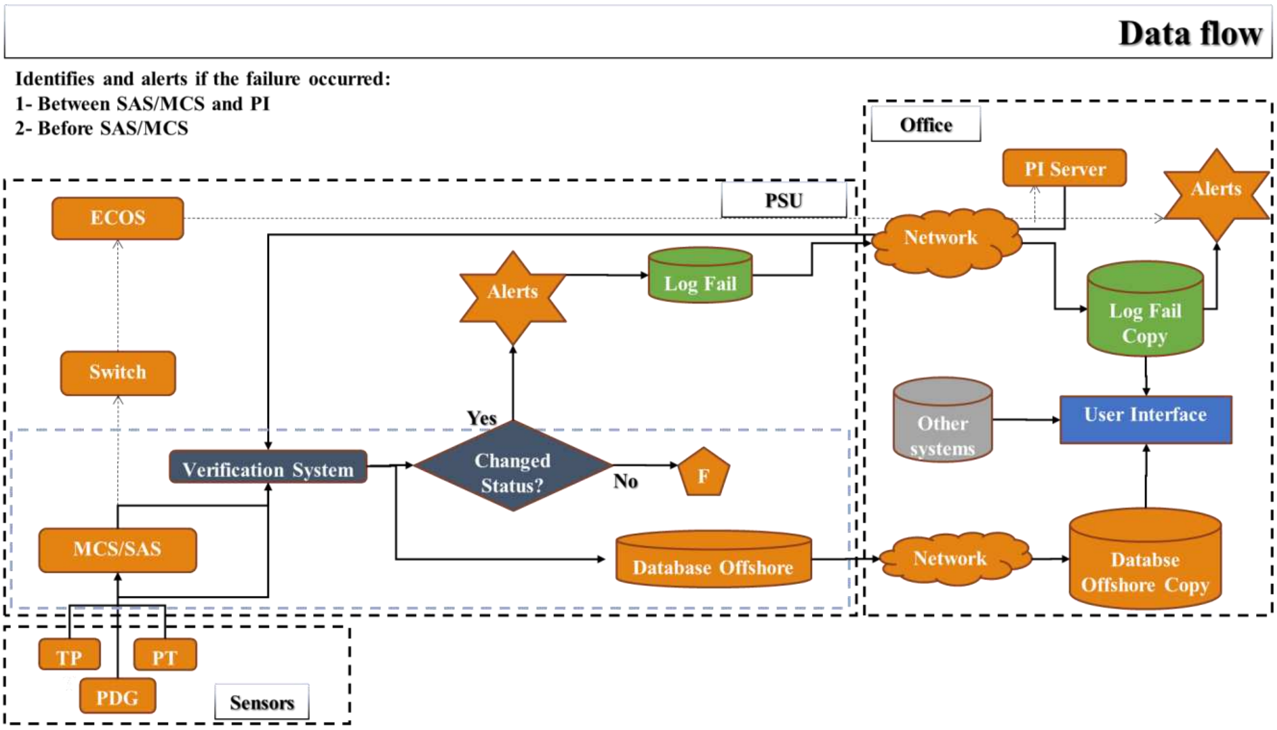
During the survey of the necessary information for the development of the system, interviews were carried out with the users of the information provided by the sensors, with these users being from different operational areas. The main data inconsistencies reported by users were negative values, zeroed or frozen, lack of information on the unit of measurement used, signals coming from disconnected wells, and sudden changes in values for no apparent reason.

During the interviews, it was also concluded that when the failure occurs in the surface path the onboard personnel performs actions to solve it. There is no record that the maintenance was carried out when the problem is solved, which causes a loss of the maintenance record and no disclosure that the data is available once more. When the fault occurs in the submerged path or when the onboard personnel does not solve the fault in the surface path, the maintenance team is called upon and the need for boarding a specialized team or for an intervention with a rig is evaluated. In these cases, maintenance reports are recorded in an unstructured manner, which makes it difficult to consult previous solutions and prevents good practices from being properly disseminated.

3. System scope definition

The scope of this work is to increase the availability of data from subsea sensors. As aforementioned, the data flow was divided into two paths. The first path contains the bottomhole well components up to the SAS/MCS[1], while the second path contains the interface components with the SAS/MCS up to the onshore storage facility (PI System). Figure 3 illustrates this flow of data, considering the scope and architecture of the system.

Figure 3: Flow of the data obtained from the sensors until they arrive onshore.



Source: elaborated by the authors.

In the submerged path, the system checks the sensor data arriving at the SAS/MCS. In this step, the system checks whether the data is zeroed, frozen, negative, unavailable and/or if it is within a previously established interval. These checks ensure the correct functioning and configuration of the equipment. If the verification finds any inconsistency in the data, the system sends an alert and stores this failure event to be included later in the reliability calculations. In addition, the event is recorded in a maintenance history, which is filled during the diagnosis, planning and fault correction phases.

In the surface path, the system compares the data leaving the SAS/MCS in real time, respecting the latency of its flow, with the same information presented in the onshore storage facility. In the event of an inconsistency, the system sends an alert to the responsible sector to verify the cause of the failure. Unlike faults that occur in the submerged path, most faults in the surface path can be

1 The term SAS/MCS, in this work, requires a definition. The signal leaves the sensor through an electrical transmission system, arrives in a junction box aboard the PSU and goes to a signal acquisition system, which receives the “SAS” nomenclature for wells equipped with wet Christmas trees with hydraulic drive and “MCS” for wells equipped with multiplexed wet Christmas trees. In this work, we adopted the SAS/MCS nomenclature for both cases.

solved without the need of boarding a crew or performing an intervention in the well. The onboard maintenance team solves the problem and records this event in a system maintenance history.

The system includes industrial hardware physically installed near the SAS/MCS with a verification system and a data lake recording pressure and temperature information in real time. A mirror of the offshore database is installed onshore to receive this data from all platforms that have the hardware. Through an interface, users have access to the data transmitted by the sensors, structured records of fault information, reliability information and fault statistics, as well as an overview of the situation of the sensors.

4. Methodology to calculate the reliability of the submerged path

The reliability calculation methodology was developed using a database containing information from the PDG, TPT and PT sensors with installation date between January 1st, 2008 and January 9th, 2014, totalizing 285 wells. The system is modeled as a series system and a failure is defined when there is the total interruption or any abnormal behavior of signal reception in the SAS/MCS due to an abnormality in any point contained in the submerged path. Depending on the technology available at PSU, it is possible to categorize the failures in 1) sensor failure and failure in the electrical data transmission system or 2) failure in the set comprised of sensor + electrical data transmission system. Censored samples from PDG sensors were evaluated to define the probability distribution, being divided by family and generation. This was performed for a 2-parameter Weibull distribution and an exponential distribution. The best fit was found to be the Weibull distribution.

The following steps were used to calculate the reliability:

1. Stratification of failure data in censored segmented samples by sensor type, family, and generation;
2. Estimation of Kaplan-Meier non-parametric reliability from the failure samples;
3. Estimation of parameters η and β of the 2-parameter Weibull distribution, using regression through the maximum likelihood estimation (MLE) to obtain:
    a. Functions $R(t)$, $f(t)$, $F(t)$, $\lambda(t)$, and the confidence intervals;
    b. Calculation of the MTTF[2] and MTBF[3] statistics;
    c. The parameter β that defines the position in the bathtub curve. $\beta < 1$ represents infant mortality, $\beta = 1$ represents constant failure rate, and $\beta > 1$ represents senility (Ebelling, 2003);
    d. The parameter η, which represents the time in years to cause failure of 63.2% of the sample data (Ebelling, 2003).

5. Results and discussion

A reliability graph was generated for each PDG sensor family and generation as shown in Figure 4. This graph provides an estimate of the reliability curve, for up to 30 years, with 95% confidence intervals; the non-parametric Kaplan-Meier curve; the MTTF and MTBF statistics; and the η and β parameters, based on data from sensors failure and the parameters adjustment using the Weibull distribution.

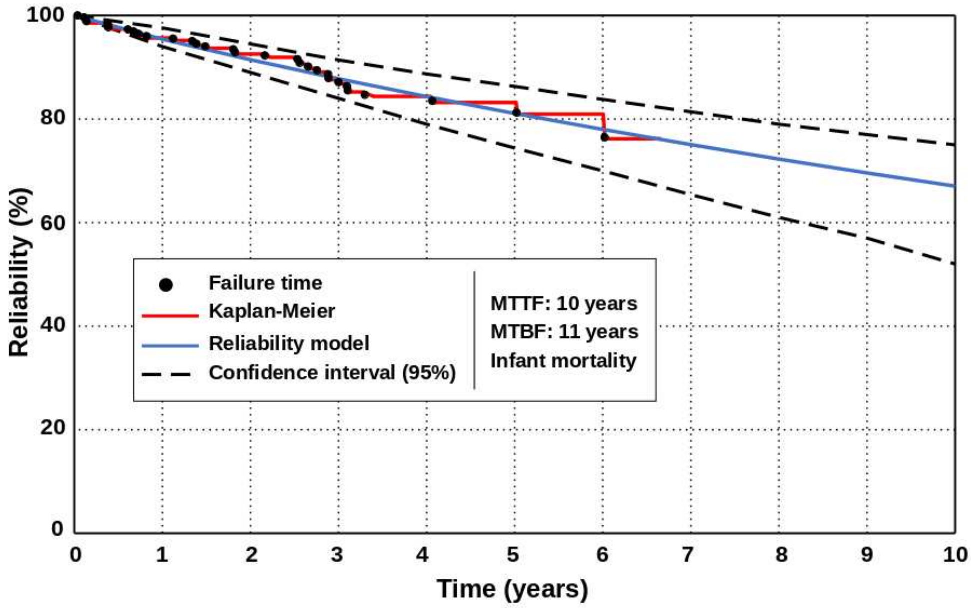
The comparison between the reliability curve and the Kaplan-Meier curve in Figure 4 allows analyzing the quality of the parameter adjustment. A good fit is given when the Weibull estimate curve presents reliability values close to the ones from the Kaplan-Meier curve. The confidence

2 MTTF: Mean Time to Failure (ISO 14224, 2006).
3 MTBF: Mean Time Between Failures (ISO 14224, 2006).

interval informs the probable values for the reliability estimate, with a 95% confidence that the true value is between the upper limit and the lower limit.

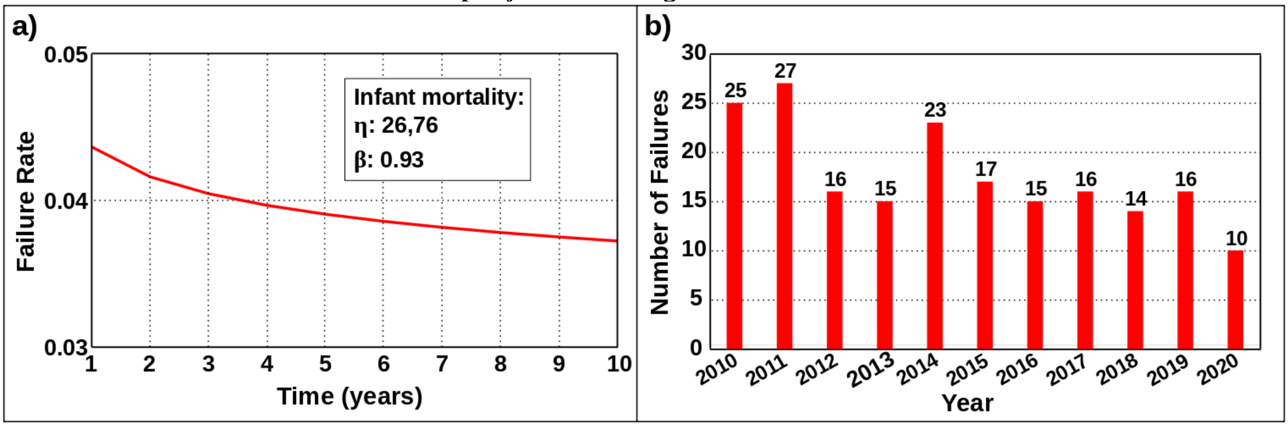
The system statistics module presents, in addition to the reliability data, the graphs shown in Figure 5. These graphs allow to complement the proposed reliability knowledge through the analysis of the number of failures occurred per year for a type of sensor and the failure rate function. This curve indicates how much a component is exposed to risk over time. It can be decreasing, constant or increasing, indicating the position on the bathtub curve of the sample, according to the estimated value of β.

Figure 4: Reliability of the sensors over time, with the respective statistics.



Source: elaborated by the authors.

Figure 5: (a) Failure rate as a function of time using the 2-parameter Weibull distribution and (b) Number of failures per year according to the collected data.



Source: elaborated by the authors.

6. Final remarks

The unavailability of information from subsea well sensors makes it difficult to identify abnormalities that can lead to production stoppage. By increasing the availability of pressure and temperature information, this system allows for an increase in production efficiency, which is particularly important for wells with high flow rate in the Brazilian pre-salt.

The expectation is that the system will increase, in the short term, the availability of information in the event of failures in the surface path compared to what occurs today, since it alerts immediately after the fault occurs and allows immediate repairs on the surface. In the medium and long term, it is expected that the system will increase the availability of information in the submerged path through the continuous improvement of the technical specification of sensor acquisition, guided by the reliability parameters generated by the system.

As further steps in the future, data from the PDG, PT and TPT sensors aboard the platform, together with the emergence of new technologies, will serve as inputs that allow developing different processes to continuously improve the efficiency of well production, as well as for predictive maintenance respective sensors.

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