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Well Start-up Assistant

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Abstract

The *Partidário de Poços* (from Portuguese, Well Start-up Assistant) is a tool developed to assist in monitoring the start-up operation of a well. The tool provides quick decision-making by real-time comparison between the main variables of the actual start-up (such as gas-lift pressure, gas-lift flow rate, pressure and temperature of the production line at the platform, gas-lift, and production choke opening) and a database of previous recorded successful start-ups. Therefore, this tool allows faster identification of several problems during a well startup procedure (such as subsea valve malfunction, insufficient gas-lift flow rate, insufficient demulsifier flow rate, high flowing pressure or low flowing temperature, and in worst scenarios, hydrates in the production line or gas-lift line). Early identification of abnormalities during a start-up is crucial to support the decision to abort the operation or adjust some parameters. Especially for wells with high water cut, if the anomaly during start-up is not detected or detected too late, the fluid on the production line may reach the hydrate, increasing the blockage risk. The Well Start-up Assistant tool is currently running to monitor critical wells through the Petrobras Decision Support Center. This paper aims to discuss the tool development, how it works, its use, and future work.

Keywords

Field Operations; Digital Solutions; Hydrates; Data Analysis; Start-up; Surveillance; Real-Time Monitoring

Introduction

The motivation to develop the Well Start-up Assistant tool came from production loss events caused by hydrate blockages during well start-up operations. The analysis of how some hydrate blockages occurred suggested the necessity to improve the monitoring of well start-up procedures. The well start-up history indicates that there is an acceptable operating range for the main variables (gas-lift flow rate, wellhead pressure etc.). If a measured parameter exceeds the operation range, it is suggested that there is some abnormality in development or that the well is in a more vulnerable condition.

It was registered a hydrate blockage event during an unmonitored start-up procedure in which three well parameters were not within the proper range from the beginning of the start-up: temperature in the production line was negative; pressure in the production line indicated no flow rate; gas-lift injection pressure inconsistent with the gas-lift injection flow rate.

On further analysis of the event, the team was convinced that if there was an expert tool to assist the start-up in real-time, this hydrate blockage event would be avoided as there was enough time for decision making.

Due to the wide spectrum of possibilities of the transient behavior of the well start-up, it is very difficult to establish an adequate range for the well parameters – this range varies over time for each parameter. Furthermore, even when monitored by an engineer, the task of detecting an anomaly and taking the decision to abort the operation is not trivial. The expected variables pattern during start-up is not available a priori, nor in an adequate tool that allows the comparison with what is happening in the current operation.

In this context, the Well Start-up Assistant is designed to fill this gap in well monitoring process. The well surveillance team at Petrobras Decision Support Center can use the tool to give them insight to decide if the start-up operation is acceptable, must be adapted or needs to be aborted.

Methodology

The development of the Well Start-up Assistant consists of two main stages. The first one is an algorithm that helps determine the acceptable range of each variable according to previous successful well start-ups (data were collected from 111 operations of seven wells in the last two years). The second stage consists of a web application that automatically identifies a start-up operation, collects data for each variable in real-time during the operation, and compares it with the ranges.

Stage 1: Algorithm to determine ranges of variables

1) Scan the PI System to identify the time of each start-up operation of a specific well;
2) Collect data for the pre-defined variables during the start-up;
3) Display all previous start-ups synchronized in a single graph to facilitate the visualization and classification of those considered successful;
4) Filter the successful operations that will be used to determine the ranges – the flow assurance specialists analyze and select the successful operations.

Figure 1 shows the process of acquisition of the successful start-ups:

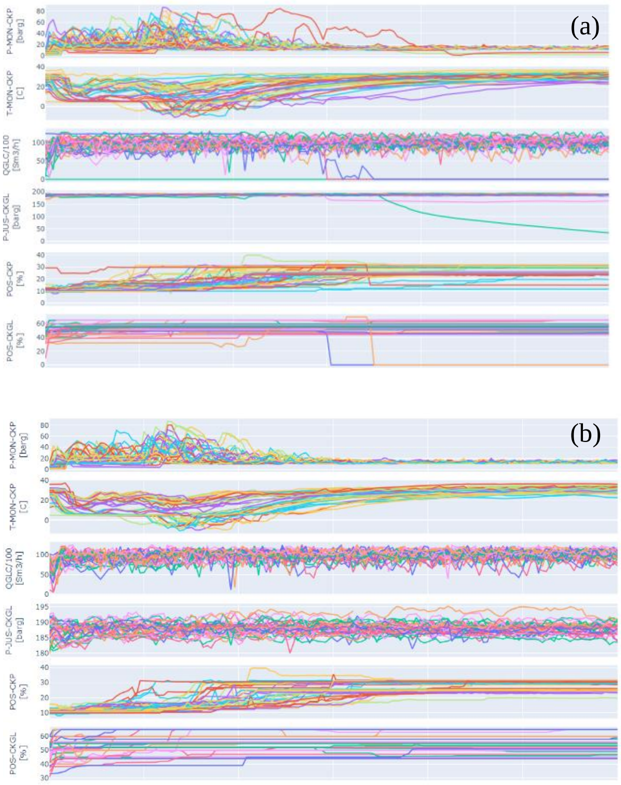

Figure 1. Successful Start-ups acquisition process. (a) Start-ups of a well before filtering; (b) Valid successful start-ups after flow assurance expert filtering

5) Calculate the acceptable ranges for the following variables: production choke valve upstream pressure and temperature (P-MON-CKP and T-MON-CKP), gas-lift flow rate (QGLC), gas-lift injection pressure (P-JUS-CKGL), production choke valve opening (POS-CKP) and gas-lift choke valve opening (POS-CKGL). The minimum, maximum and average values of the variables listed above are calculated, thus defining the adequate range.

Stage 2: Web application - Real-time monitoring of Start-up operation

An interface was developed and hosted on a web server that can be accessed from any computer connected to the company internal network. The server-hosted algorithm scans data from the PI System and automatically detects if a start-up has begun, starting the application.

A dashboard shows the trends of each variable with its respective envelope (region between maximum and minimum values, in addition to the average value) and current value. The main goal is to simplify the comparison between current values and the historical data of successful well start-ups. Additionally, a real-time score of the startup is calculated by counting how many variables are within acceptable ranges.

Results and Discussion

Figure 2 shows an example of the graphic interface of the web application during a well start-up.

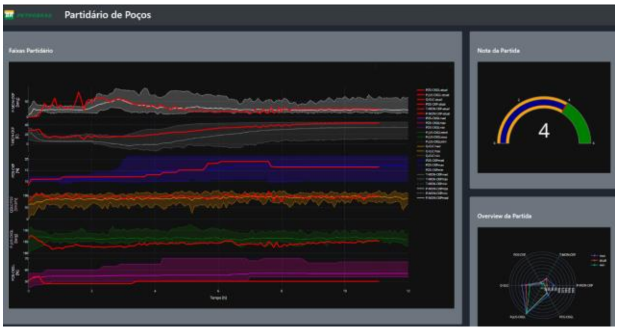

Figure 2. Single view graphic Interface of Well Start-up Assistant

The red lines represent the real-time data for the current start-up operation. The successful start-ups envelopes are shown in transparent colors behind red lines.

The score is assigned to this start-up in the upper right corner of the screen. Flow assurance team can adopt an individual criterion for each well to determine when to abort the start-up operation. For example, it can be assumed for a particular well that, after 4 hours, if the score is less than 5, the well must be closed, so that a new attempt to start-up can be made.

Several problems can occur during a well start-up, such as spurious closing of valves, interruption of the gas compression system or shutdown on the platform. The Well Start-up Assistant tool allows the detection of those issues at an early stage, as they will inevitably cause some monitored variables to fall outside the range of successful startups.

One of the main problems in a well start-up is the possibility of hydrate blockage. In this case, an abnormal increase in the gas-lift injection pressure and a considerable drop in the gas-lift flow rate is expected. Under these circumstances, the tool should indicate, through its graphic interface, that from the beginning of the event these two variables

were outside the envelope, providing enough time to avoid the blockage.
Figure 3 illustrates an example of an unsuccessful start-up operation.

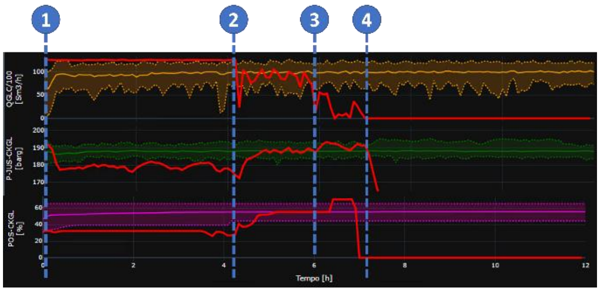

Figure 3. Well Start-up Assistant during Well X unsuccessful operation.

Well X start-up analysis is described in the points below.

1) Well start-up initiated.
2) Gas-lift flow rate (QGLC) adjusted. Between points 1 and 2, despite the gas flow rate being slightly above the range, the flowmeter was faulty, and the gas-lift flow rate was below minimum adequate. This is confirmed by noting that the gas-lift injection pressure (P-JUS-CKGL) was below minimum range.
3) The gas-lift flow rate drops below minimum and injection pressure increases.
4) Well start-up interrupted.
Further analysis indicated that there was hydrate blockage in the production line. Tests showed that there was an unexpected closure of the SSSV (subsurface safety valve). Therefore, it was concluded that the combination of gas-lift flow below the minimum for 4 hours (point 1 to 2) and unexpected SSSV closure led the production line to stay inside the hydrate envelope, culminating in hydrate blockage. Early detection of the event using the Well Start-up Assistant would prevent production losses.
Figure 4 illustrates another example of an unsuccessful start-up operation.

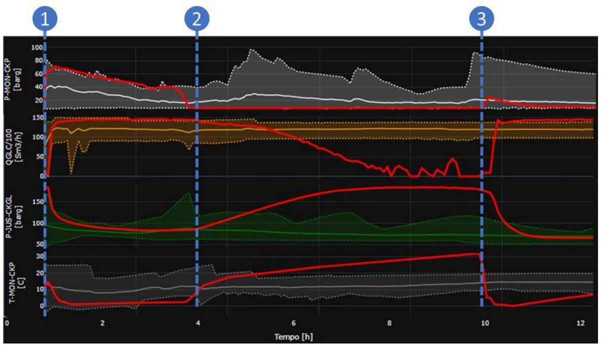

Figure 4: Well Start-up Assistant during Well Y unsuccessful operation.

Well Y start-up analysis is described in the points below.

1) Well start-up initiated.
2) Beginning of production line hydrate blockage. The production choke valve upstream pressure drops to separator pressure (P-MON-CKP) and the production choke valve upstream temperature (T-MON-CKP) approaches the ambient temperature, indicating that there is no flow. In addition, the gas-lift flow rate decreases (QGLC) while the gas-lift injection pressure increases (P-JUS-CKGL), indicating that there was a blockage.
3) Well start-up was aborted, and hydrate prevention procedure was performed.
In this case, the behavior of variables was different from the previous operations, and the well start-up assistant helped to identify the hydrate blockage early.

Conclusions

Field testing indicated that the Well Start-up Assistant tool shall be able to consistently identify anomalies during start-up operations and decrease production losses. Due to the significant number of oil-producing wells, each one with its particularities and constantly changing parameters, the Well Surveillance Team can be overwhelmed during start-ups. In this context, the developed solution should improve well monitoring and the decision-making process, resulting in production increase, by preventing losses, and cost reduction, by avoiding the need of hydrate dissociation operations.

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