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THERMAL-HYDRAULIC SIMULATION AS AN EVALUATION TOOL FOR THE CONTINGENCY RESPONSE STRUCTURE

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Abstract

The Transpetro Gas Pipeline System, the largest of the country, with more than 7.3 thousand kilometers, 129 delivery stations, 414 SDVs and several compressing stations, moves over 77.3 million cubic meters of natural gas. Highly linked with Brazil's energy grid, during the dry period of the year a large part of the transported gas is used to generate around 6.4 gigawatts to power the country. It operates as an integrated mesh of pipelines running throughout the country, much like an energy grid system, but with the gas being stored in the pipelines. The gas pipeline operation is a continuous one, without interruption, and as such depends heavily on the maintenance of its contingency response structure, to solve any problem at the field so there are no deliveries impacts.

Due to the company's constant search for optimization, especially in regards to its operation and maintenance sector, a revision of the contingency response structure was studied to reduce costs linked to the activity. To this end, a study of the pipeline system requirement was commissioned. A part of this study was the evaluation of the system survival time (in regards to its deliveries commitment) in the case of incidental scenarios, focus mainly on inadequate Shut Down Valve (SDV) activation. This study was implemented simulating a normal system scenario and closing the system SDVs. The study evaluated the impact each valve had on the system and its deliveries, classifying each of them according to the system survival time, without human interference. The study result was used to determine in which region of the pipeline system a quicker intervention could be needed outside office hours.

1. Introduction

Operating a complex gas pipeline system, with its many intersections and mesh like condition can be tricky, demanding a high level of attention on the several segments at the same time, and being able to interpret and predict the network response to different scenarios. Every intervention must be evaluated to determine the impact on the system, requiring continuous study in regards to the day to day operation.

Transpetro operates Petrobras gas network, which includes 7.4 thousand kilometers of pipeline, 21 Compressing Stations, both owned and outsourced, 17 supplies and over 130 deliveries across the country. The Figure 1 shows the network and its placement country wise.

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Figure 1. Gas Pipeline operated by Transpetro

Operating a network with this configuration isn't easy by any means. While most of the operation is controlled by Transpetro National Operational Control Center (CNCO), a lot of secondary actions must be taken in the field. Besides the day to day operation, the maintenance team work tirelessly to insure an operation as smooth as possible. With constant predictive and preventive action, such as pig passing in all the pipelines, constant operation and change of compressing station, etc. But any system is bound to have unpredictable problems. When a system of this size is consider, the chances of occurrence gets higher and higher, especially as the installations grow older.

To protect the network from these events, several initiatives are taken to insure the safest operation possible. The use pressure safety valves at delivery points and stations, shut down valve along the pipelines, interlock systems on all the major equipment, allied with several teams of technicians and engineers on standby guarantees the safety of the network.

The use of SDVs as a pipeline safety feature is consistent worldwide. Due to its use, however, there has been several instance were the valve has close unexpectedly, be due to incorrect settings, problem with the actuator, an unpredicted transient or even human error. Because of the history of irregular closing on the Petrobras gas network, there is a constant concern of the consequence of such action on the deliveries.

The focus of the study is to evaluate, for each SDV on the system, what is the network survival time, considering the scenario for supply and delivery, without any human interaction. The results will be used to determine which region of the system a quicker intervention could be needed outside office hours.

2. Shut Down Valve (SDV)

The use of Shut Down Valves (SDV) to protect a pipeline system is widely use worldwide. On Gas Pipeline, there use is to isolate one part of the pipeline from another, reducing the impact a possible emergency can have. It can reduce the volume lost during a leakage or secure a part of the pipeline due to high pressure. While they may vary in type and direct application, they have three basic settings: PSL, PSH and ROPD.

The Pressure Switch, Low limit (PSL) is use in the case of leakage, to isolate the segment where the pressure has reach a dangerous limit. When activated, the volume of gas lost will be the one between two SDV, and not the entire pipeline. The Pressure Switch, High limit (PSH) is use in case of high pressure due to an outside element of the pipeline, either a compressing station or re-gas GNL station that, for whatever reason, didn't control its output pressure on a low pressure system. When activated, the SDV isolated the lower pressure pipeline from the high pressure system, be that a station or another pipeline.

The problem with both settings is that they require to work around the normal pressure variation that occurs on gas pipeline. This means that PSH must be set higher than the highest pressure possible on the system, and PSL lower then lowest working pressure of the system. This means that, during a high pressure operation, in the case of leakage, the SDV will only shut down after it reaches the minimal operating pressure.

For occasions such as this, the Rate Of Pressure Drop (ROPD or RPD) is a valid alternative. It calculates pressure drop during a time frame, closes if the pressure drop reaches its settings. The downsize is how to determine such setting. All normal operational scenarios must be considered (i.e. sudden star or stopping of a compressor, accidental closure of a supply or delivery, etc.). This setting is the most common to be activated without an actual emergency, usually due either to changes in the previous operation or a critical scenario not considered during the simulations to determine the setting. Figure 2 shows an example of a SDV valve.

Figure 2. Example of a Shut Down Valve

2. Transpetro Gas Pipeline Network

The Transpetro Gas Network can be divided in 3 separated regions, depending where in the country they are located. Each region has its own characteristics and peculiarities, both physically and operation wise. The three regions are the North, the Northeast and the southeast network.

The North network is the simplest pipeline wise, with only one supply and two compressing stations. It's composed by two pipelines and crosses the Amazon forest and two of its main rivers. Besides being completely disconnected from the rest of Brazilian pipeline system, it also has the most inhospitable environment, since almost its entire pipe way is located deep within the Amazon jungle, and at least half of it can be submerged half of the year. These facts make it extremely important to keep its operation as hazard free as possible. The Figure 3 shows the details of the network.

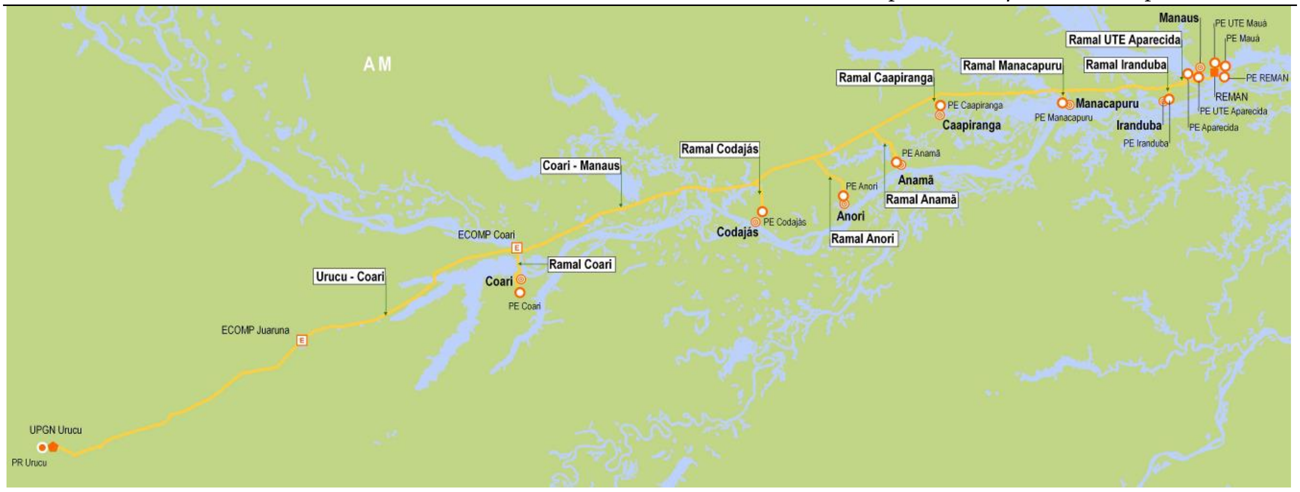

Figure 3. North network

The Northeast network can be divided in two separated segment, both geographic and complex wise. The first part is mostly consistent of several pipelines in line, with loops and branches along its course. With three compressing stations, three supplies e several deliveries, it has a more complex operation the North network, due to changes the gas flow has depending on the supply condition, specially due to the LNG re-gas plant. The first part of the network can be seen on Figure 4.

Figure 4. First part of Northeast network

The second part of the Northeast network is the link to the Southeast network. It also has a complex system at Bahia state, where there are several supplies and deliveries with different pressure limit pipelines, linked right in the middle of the main network. This part of the network can be seen on Figure 5.

Figure 5. Second part of Northeast network

The Southeast network is the most complex of the pipeline systems operated by Transpetro. With over eight supplies distributed along the network, two of which are connected to another pipeline network (the Brazil-Bolivia Pipeline), several compressing stations and deliveries spread out along its length. The network has different pressure limits, and different flow direction depend on the scenario. This network can be seen on Figure 6.

Figure 6. Southeast network

Across all the pipeline system presented here, there were over 414 SDVs installed and operating at the time the original study occurred. Since then, some SDVs have been installed and some removed due to operational and network change. To determine the number of simulations involved, and the premises used, the following methodology was implemented.

3. Methodology

To assist in the analysis, a software for pipeline simulation, Energy Solution's PipelineStudio was used the study the thermal hydraulic of the pipelines. Using a model for each of the three separates network, a scenario was established for each of them, to try and determine to most stressful case in which the SDVs can cause the worst consequence to the day to day operation.

To determine worst case scenarios, some premises were established using both the history of the relation between supply and delivery, the usual flow programming for each and the use of compressing stations. The experience of the operation was also taken in consideration, since each network has in own peculiarity. This was used to determine a single permanent state for all the simulations.

While the use of a single permanent state doesn't cover all alternatives necessary to determine the worst case scenario for each SDVs, the high number of SDV and the complexity of the system invalidates the use of permanent state for each SDV. The permanent state used in each network was the one considered most critical for the network itself. After determining the permanent state, transient state simulations consisting on closing each SDV on the system were made and the time it took to affect a delivery was measured.

4. Results Analysis

To try and reduce the number of simulations needed and have a simple way of analyzing the results, some premises where made. The result where divided according to the survival time of the network study. The SDVs where divided in four categories:

- Category 1 - Survival time of less than one hour
- Category 2 - Survival time between one and two hours
- Category 3 - Survival time between two and four hours
- Category 4 - Survival time higher the four hours or no impact in over 12 hours

These premises allowed for a reduction of the simulations needed. Using the North network as an example, if an SDV closer to the deliveries reaches Category 4, then all other before it (closer to the supply) would have the same category. This method was used in all the networks, although on to the Northeast and especially on the Southeast network, due to the large number of Supplies and the more distributed deliveries, wasn't as effective, requiring a higher number of transient state simulations.

Some considerations where made in the cases of compressing station, when sometimes the dropping pressure reached a low pressure limit, the compressors where automatically turned off. All the minimum pressure at the deliveries where considered.

The results were exposed in the form of a table, with the SDVs for each pipeline in all the networks. If the simulations results had no impact in over 12 hours, no comment where made. However, in the other cases, for all 4 categories, a note for each SDV was made exposing the consequences and especially which delivery was first affect by the SDV closing.

Figure 7 shows an example of the result obtained during this study, in reference to one of the pipelines. As can be seen, for this pipeline the Delivery J (name redacted) was the critical delivery point. As such, after simulating SDV-07, SDV-06, SDV-05 and SDV-04, there was no need to simulate the closing of SDV-01, SDV-02 and SDV-03. No other deliveries were affected by the closing of the SDVs from this pipeline.

Valve	Impact Time			
	< 1 hour	< 2 hours	< 4 hours	< 12 hours
SDV-01				X
SDV-02				X
SDV-03				X
SDV-04				X
SDV-05				X
SDV-06			X	
SDV-07	X			

- SDV-05 – The impact occurs in 8 hours and 12 minutes. The minimum pressure setting of 41 kgf/cm² was reached at Delivery J.
- SDV-06 - The impact occurs in 3 hours and 54 minutes. The minimum pressure setting of 41 kgf/cm² was reached at Delivery J.
- SDV-07 - The impact occurs immediately. The minimum pressure setting of 41 kgf/cm² was reached at Delivery J.

Figure 7. Result Example

5. Conclusion

While the original study of the effect of closing was part of a much larger initiate to improve and optimize the company´s contingency response structure, the results was of extreme importance to the operation of the pipeline. The knowledge, even if based on a single permanent state of the pipeline system, gave the operation a better understanding of the networks itself and what consequences to expect with the closing of such important security element on the pipeline system.

For the maintenance team, it also provided a better time frame to work with during those incidental closures, allowing the teams to better prepare themselves for those eventualities.