Available online at www.sciencedirect.com

ScienceDirect

IFAC Papers Online CONFERENCE PAPER ARCHIVE

IFAC-PapersOnLine 48-6 (2015) 083–088

Advanced Anti-slug Control for Offshore Production Plants

Campos, M. [1], **Takahashi, T.**[2], **Ashikawa, F.** [3], **Simões, S.** [4], **Stender, A.** [5], **Meien, O.** [6]

Petrobras, Research Center - CENPES, UO-RIO, UO-BS, Brazil, (e-mail: [1]*mariocampos@petrobras.com.br,* [2]*thiagotakahashi@ petrobras.com.br,* [3]*fabio_ashikawa@petrobras.com.br,* [4]*saulsimoes@petrobras.com.br,* [5]*alberto.santanna@petrobras.com.br* [6]*meienov@petrobras.com.br,)*

Abstract: The application of advanced control techniques in offshore oil production plants is a challenge. There are many changes in operational points in time, for example, the process is affected by the natural oil well's behavior dynamics. Besides that, limited instrumentation available has to be considered when thinking in oil optimization and control. In order to improve the scenario, taylor-made advanced control modules have been developed for those units. The present article will present development, implementation and results of anti-slug control for three platforms located at Campos and Santos basins. The controllers were designed to achieve improvement in operational stability and safety, decreasing in unscheduled compressor shutdown events, as well as increasing in operational efficiency.

Keywords: slug control, advanced control, offshore platform's automation, industrial control and results.

1 INTRODUCTION

Severe slugging is a common problem in many offshore platforms, because production facilities cannot handle the large flow and pressure variations due to slugging. As a consequence, unstable flow results in poor separation that may cause damage to critical equipment like heat exchangers, increases maintenance costs, and may also cause unscheduled shutdowns due to unstable multiphase flow. So, high pressure trips in compressors or high level trips in separators are able to generate substantial economic losses. There are many different mechanisms which cause unstable flow, or slugs, depending on flowline geometry, fluid distribution among phases and equipment. Slugging most common causes are due to irregularity in the sea bed terrain, vertical pipeline sections, instability in gas-lift flow, differences in gas/liquid velocities, etc. A description of slug mechanisms can be found in Pickering et al. (2001), Hu (2004), Sinegre (2006) and Kaasa et al. (2007).

The traditional method of minimizing slugs is manually choking flow at the expenses of production decreasing, increasing gas-lift flow, and subsea chemical injection, both leading to costs increasing. Another option is to use automatic control to reduce or even eliminate oscillations, without production loss, manipulating the choke valve (Storkaas, 2005) (Storkaas and Skogestad, 2007). Therefore, it is important to continue developing new control strategies which result in attenuation or protection against severe slugging.

In practice, there is some resistance by operators in using new automatic control, particularly anti-slug control, due to the belief of keeping choke valve fully open will result always in production improvement. Which is true for wells with no slug pattern, however may cause production losses in wells with slugging flow (Hu, 2004).

According to the American Petroleum Institute, advanced control is defined as any control strategy that has functions beyond those commonly associated with regulatory control. In this paper, it is discussed an advanced anti-slug control strategy, which can be thought as an expert system with three modules: slug diagnostic, anti-slug control algorithm, with auto-tuning capabilities, and severe slugging protection. This system was implemented on a process computer that communicates with the platform's automation system.

Although advanced control systems are reality in many industrial areas like refineries, petrochemicals and gas plants (Campos et al., 2009), they are not widely used for offshore production units (Campos et al., 2013). Many reasons can be pointed as causes for such behavior: no advanced control specialist onboard, more transients and disturbances due to oil well behavior, uncertainties and noise, non-linear and time-varying process, lack of instrumentation, etc.

Due to these problems, linear and multivariable predictive advanced controllers, common in other areas such as refineries and petrochemicals are difficult to apply in platforms' process. Thus, different advanced control strategies were proposed and applied to offshore platforms. The problem was divided in small and less complex problems. Each one has an expert system to deal with. One of the goals was to develop anti-slug control for wells, which will be the focus of this paper. This system has a control algorithm, with some degree of adaptation for each different operational condition, and also has some modules to diagnose and protect process equipment. The advanced controller was developed and implemented in three offshore platforms and

10.1016/j.ifacol.2015.08.014

the results will be shown in the following discussion. The implementations of anti-slugs advanced control strategies bring the following benefits:

- Reduction in production losses due to unplanned shutdowns.
- Increasing stability and profitability.
- Increasing safety and operating reliability.
- Increased sustainability by minimizing flaring.

In this article, we will present some details about advanced anti-slugging control strategy, results and economic gains obtained with its implementation in oil production platforms.

2 SLUGS PROBLEM DESCRIPTION

A scheme of unstable multiphase flow cyclic behavior is shown in Figure 1. This is an example of severe slugging caused by pipeline-riser systems with low points in front of the riser, where "slugs" of liquid accumulate before pushed upwards by gas. In the first sub-figure, liquid blocks the low point of the riser preventing gas flow. Liquid falls back from the riser by gravity and causes the slug to grow and fill the riser. The pressure in the pipeline steadily increases due to the inlet flow of gas until it is large enough to push the liquid slug out of the riser causing a great disturbance to downstream separators. When the tail of the liquid slug enters the riser, downhole pressure drops due to the reduced static head of the liquid column which causes the gas to expand. When gas leaves the riser, a large disturbance is generated to compressors pressure and anti-surge controllers. After that, velocities in the riser become too low to carry liquid up the riser and process starts again with liquid accumulation, fall-back, in lower points.

Slugs represent a major challenge to downstream processing facilities due to large variations in flow and pressure. As pointed before, the possible consequences are: unscheduled shutdowns, damage to topside equipment, production decreasing, resulting in substantial economic losses and increase in maintenance costs.

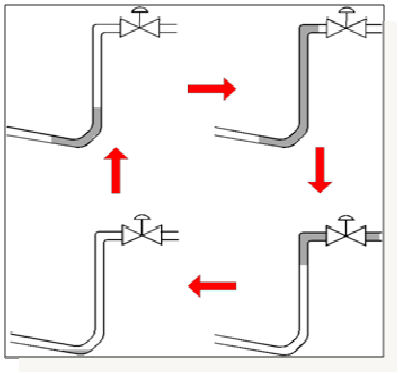

Fig. 1. Slug cycles.

One way to eliminate slugs is manually choking flow until reach stability; however this method has the drawback of production loss. Another option is the use of automatic control to reduce, or even eliminate, oscillations. In figure 2, it is shown the oscillating behavior of the downhole pressure (PDG - Permanent Downhole Gauge) of a slugging well. There is a maximum valve opening which enables stable operation when no control is applied. If we try to operate above bifurcation point unstable multiphase flow occurs characterized by the stable limit cycle where downhole pressure oscillates between high and low pressure values. The upper red line of the figure 2 shows the maximum pressure at a particular valve opening and the red lower line the minimum pressure. The dashed line in the middle shows the unstable steady-state solution, which is the desired operating point in closed-loop operation.

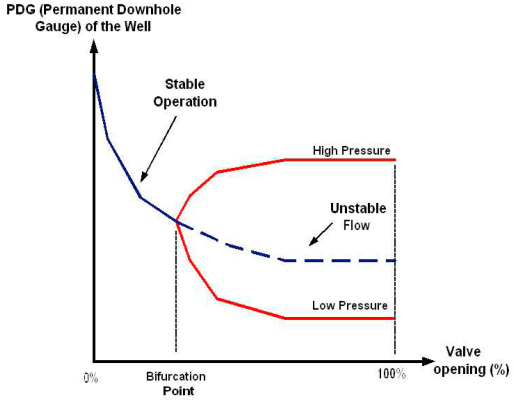

Fig. 2. Bifurcation plot (red line shows the limit cycle).

3 ANTI-SLUG ADVANCED CONTROL

The proposed advanced anti-slug control has three main modules, as shown if figure 3:

- Diagnostic Module – responsible for detecting severe slugs based on pressure measurements.
- Anti-slug Protection Module – responsible for preventing propagation of severe slugs to topside equipment (separators and compressor).
- Anti-slug Control Module – responsible for minimizing or even eliminating slugs. If possible, keeping choke valve at the desired position.

Following these modules will be described.

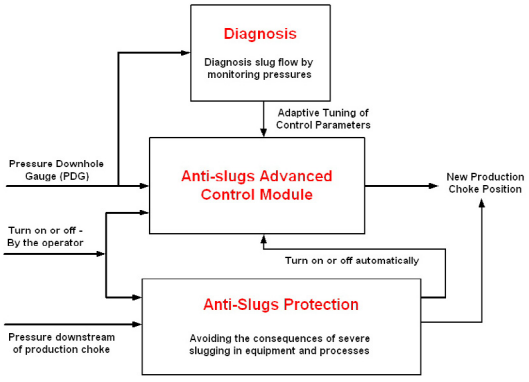

Fig. 3. Block diagram of the Anti-slug Advanced Control.