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Technology Transfer as

NTNU – Trondheim
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A new Solution for Riser Slugging Control

This recently patent filed method from NTNU enables autonomous operation of existing anti-slug control systems. The topside choke valve is controlled in a way that automatically maximizes production while being stable for varying well conditions.

The method was published on the 2nd IFAC Workshop on Automatic Control in Offshore Oil and Gas Production in Brazil:
V. de Oliveira, J. Jäschke, S. Skogestad. (2015) An autonomous approach for driving systems towards their limit: an intelligent adaptive anti-slug control system for production maximization.

Challenges with existing systems

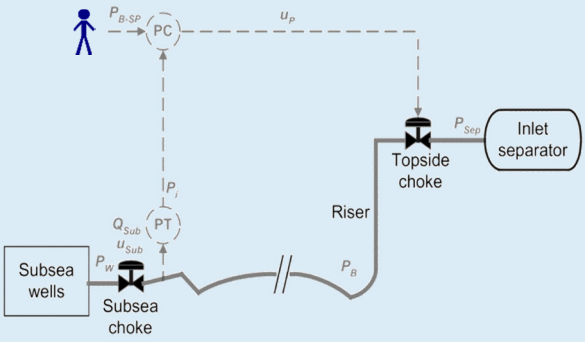
Anti-slug control in multiphase risers involves stabilizing an open-loop unstable operating point. Existing anti-slug control systems are not robust and tend to become unstable after some time, because of inflow disturbances or plant changes, thus, requiring constant supervision and retuning. A second problem is the fact that the ideal set point is unknown and a suboptimal or infeasible operating point may easily been chosen.

New NTNU solution

Our control solution is composed of an autonomous supervisor that seeks to maximize production by manipulating a pressure set point, and a robust adaptive controller that is able to quickly identify and adapt to changes in the system. The autonomous supervisor automatically detects instability problems in the control loop and moves the system to a safer and stable operating point. The autonomous supervisor and the adaptive controller can be added easily on-top of any existing controller. Our proposed solution has been tested in an experimental rig with very good results.

Standard solution

- Setpoint updated *manually*
- Controller parameters adjusted *manually*



New NTNU solution

- Setpoint updated *automatically* to avoid slugging and maximize production
- Controller parameters adjusted *automatically*

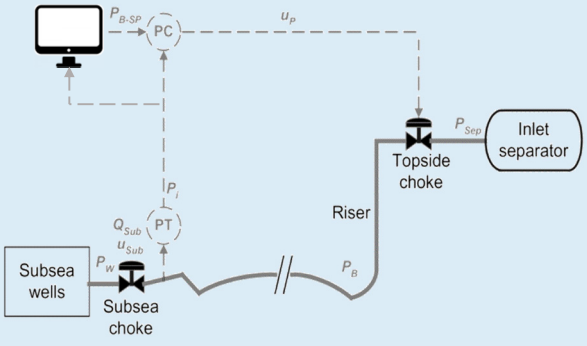


Fig. 1: Comparison of state-of-the-art and new NTNU anti-slug control solution

Experimental results

Our results show that the supervisor and the adaptive control scheme are able to deliver very good performance, especially when they are added on-top of a poorly tuned PI controller.
Table 1 summarizes the results of three experiments where we compare the set point tracking performance based on the integrated square error (ISE) and the 'economic' performance based on the mean valve opening and pressure. Experiment 1 is based on a poorly tuned PI controller, without our adaptation and automatic supervisor. Note the improvement from Experiment 1 to 2, in which we use our new method on-top of a poorly tuned PI controller. We observe a substantial increase of 31% of the average valve opening. On the other hand, by using our method on-top of a well tuned controller (LTR), the improvement from Experiment 2 to 3 is minor. Nevertheless, for this case it was shown that the autonomous supervisor and adaptive controller allowed stabilizing and production maximization even during serious disturbances. This is impossible with a standard system.

Table 1. Comparison of different controllers with same experimantal conditions

Experiment	Controller	ISE	Mean valve opening (%)	Mean pressure(kpa)
1	Bad PI - adaptation OFF	6.2	38.45	23.58
2	Bad PI - adaptation ON	0.76	50.42	22.33
3	LTR - adaptation ON	0.64	53.23	22.29

Economic potential

In a recent publication, Campos et al. studied the results of existing anti-slug control systems for three platforms located at Campos and Santos basins, and compared them to no slug control. The controllers were designed to improve operational stability and safety, reduce unscheduled compressor shutdowns, and increase efficiency.
In their study, Campos et al. found:

- "The economic gain, avoiding gas flaring was estimated **around US$ 300.000,00 per year**."
- "Anti-slug control **improved operational efficiency around 1.5%** in one particular platform. Such improvement represents **economic gains of approximately five millions of dollars per year**."
- "**A major challenge** after implementation of anti-slug advanced controls **is to keep applications in use and with good performance**. Therefore, it is very important to keep continuous monitoring in order to tune parameters when necessary to adapt with changes in wells behaviors and process plants."

(M. Campos, Takahashi, T., Ashikawa, F., Simões, S., Stender, A., Meien, O. (2015) Advanced Anti-slug Control for Offshore Production Plants In 2nd IFAC Workshop on Automatic Control in Offshore Oil and Gas Production. Florianópolis, Brazil)

Conclusion

- Our solution is composed of an autonomous supervisor that manipulates the pressure setpoint and a robust adaptive controller that quickly identifies and adapts to changes in the plant.
- The supervisor automatically detects instability problems in the control loop and moves the system to a safer operating point when necessary. The method demonstrated great resilience and good performance in a variety of operating conditions.
- Our solution addresses the major challenges of operating existing anti-slug control systems. It reduces the manual supervision and need for frequent retuning of the controller parameters while maximizing oil production.

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