Abstract
Phillips and ABB have completed a project on active control—or, feedback control—of the pipeline between the Tor platform and the EkoJ processing platform at the Ekofisk field center. Ekofisk is the largest oil producer in the Norwegian sector of the North Sea.

At the Tor platform water is separated from the well streams and treated locally, some gas is used for gas lift, while the oil and the surplus gas are exported through a 13 km 14” pipeline to EkoJ for further processing. Due to low production rates at Tor, terrain induced slugging is experienced in the pipeline. The resulting large variations in EkoJ oil- and gas inflow disturb the processing at EkoJ, while the resulting oscillating backpressure experienced at Tor leads to gas-lift processing problems as well as reduced oil production. The goal for the project was to eliminate the terrain induced slugging in the flowline.

To solve the problem, it was decided to actively control the already existing control valve at the pipeline outlet. This approach is, compared to installing a slug catcher or a multi-phase pump or other mechanical means for handling the problem, extremely cheap (one to two orders of magnitude cheaper). In addition, it enables control of the pressure at the pipeline inlet and hence the Tor production. This would not be the case if one were to use a slug catcher to resolve the problem.

The control algorithm utilizes pressure measurements at the pipeline inlet, upstream the control valve, and downstream the control valve to continuously change the opening of the control valve at the pipeline outlet. The result is stabilization of the pipeline—stable and continuous oil and gas flow through the pipeline is established—under normal upstream (Tor) and downstream (EkoJ) conditions. By normal conditions it is meant that neither shut downs nor pipeline pigging are occurring. The controller will after such occurrences take control over the imposed instabilities, and return the pipeline to a stable state. By this, the control strategy allows a 10% oil production- and 5% gas production increase at Tor, it removes disturbances at EkoJ from the pipeline—enabling a production increase at EkoJ—and it removes disturbances to the suction pressure of the gas-lift compressor at Tor.

Introduction
- Problems due to slugging in general (Up- and downstream)
- Slugging types (hydro dynamic, terrain induced, riser induced)
- Importance of solving the problem (pre- and post plateau production problem, long risers...)
- Approaches to slug handling (mechanical vs. software, cost vs. performance) This approach is, compared to installing a slug catcher or a multi-phase pump or other mechanical means for handling the problem, extremely cheap (one to two orders of magnitude cheaper). Fixed choking....

Production System Description
At the Tor platform water is separated from the well streams and treated locally, some gas is used for gas lift, while the oil and the surplus gas are exported through a 13 km 14” pipeline to EkoJ for further processing.

Operational Challenge Description
Due to low production rates at Tor, terrain induced slugging is experienced in the pipeline. The resulting large variations in EkoJ oil- and gas inflow disturb the processing at EkoJ, while the resulting oscillating backpressure experienced at Tor leads to gas-lift processing problems as well as reduced oil production. The goal for the project was to eliminate the terrain induced slugging in the flowline. To solve the problem, it was decided to actively control the already existing control valve at the pipeline outlet.
**Feedback Control Fundamentals**

By feedback control it is meant that the setting of one or more controls in a system—e.g. valve openings or set points for pressures-, temperatures-, levels- or flows—is based on readings of one or more measurements in the same system. Feedback control can be automatic or manual. By manual it is meant that the decision on the setting of the controls is done by a human, while by automatic it is meant that the decision is made by some device. The device could be mechanically based, electrically based, electronically based, hydraulically based, etc. or a combination thereof. Of course, there is an abundance of examples of both manual and automatic feedback control related to oil production. Wellhead- and pipeline choke settings are typically controlled by manual feedback, where the feedback is in the form of Examples on manual control related to off-shore oil production include:

**Feasibility study: OLGA/MATLAB simulations**

The control algorithm utilizes pressure measurements at the pipeline inlet, upstream the control valve, and downstream the control valve to continuously change the opening of the control valve at the pipeline outlet.

**Pipeline Control System Description**

**Field Results and Gained Experiences**

The result is stabilization of the pipeline—stable and continuous oil and gas flow through the pipeline is established—under normal upstream (Tor) and downstream (EkoJ) conditions. By normal conditions it is meant that neither shut downs nor pipeline pigging are occurring. The controller will after such occurrences take control over the imposed instabilities, and return the pipeline to a stable state. By this, the control strategy allows a 10% oil production- and 5% gas production increase at Tor, it removes disturbances at EkoJ from the pipeline—enabling a production increase at EkoJ—and it removes disturbances to the suction pressure of the gas-lift compressor at Tor.

**Conclusions**