Real-time multiphase modeling: Mitigating the challenge of slugging by proactive flow assurance decisions

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Problem Statement / Objectives

- Challenge Description
- Status Real-time Flow Assurance Systems per 2010
- R&D Project Repsol – FMC Technologies
- Key Differentiating elements in developed model
- Pilot Selection
- Pilot Results
- Demo
The Challenge

Longer / Hilly Terrains  
Deeper  
Colder

Challenge: Increased Flow Assurance Risks  
Lost barrels

Development of real-time monitoring slugging models. 
Proactive Decisions

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Real-time Flow Assurance Models

- Operation Modes:
  - Real-time Mode (RT)
  - What-if Mode (WI)
  - Look-ahead Mode (LAH)

- Typical Advisory Modules:
  - Pipeline Monitoring (P,T, holdup)
  - Slug-catcher/Separator Monitoring
  - Virtual Metering
  - Production Ramp-up

- Optional Modules:
  - Solids-handling related: Wax, Hydrate, Sand
  - Integrity-related: Corrosion, Erosion, Leakage, Condition Monitoring
  - Mitigation-related: Choke control, Pigging
Real-time Flow Assurance Models, Status 2010

SPT Group

- 17 implementations

Expensive, difficult to tune and maintain systems

Strategy: Increased computation power

FMC Technologies

In 2 of the 17 (most advanced)
Largest experience in virtual metering: 60% of Norway’s prod., over 400 wells

Strategy: Tailor-made dynamic model for online applications

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R&D Collaboration Repsol – FMC Technologies

- Expected Benefits:
  - New model / tool 30% cheaper in CAPEX and OPEX
  - New model just in time for most Repsol’s Key Projects in Strategic Plan
  - Knowhow transfer from FMC to Repsol on real-time FA systems
  - Pilot test with real data from a Repsol field
  - If pilot successful and final implementation in the piloted field, cost of project discounted

[Diagram showing 2-phase model, 3-phase model, Tuning, Pilot Testing milestones: Mar-11, Sept-11, Mar-12, Ongoing]
Model Development

- 1-D drift-flux model with algebraic slip and friction relations for all flow regimes
  - Separate mass equations for each phase (gas, oil, water/MEG)
  - One total (drift-flux) momentum equation
  - One pressure evolution equation that is coupled implicitly to the momentum equation
  - One energy equation for the total energy
  - Volume fraction constraint

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FlowManager™ multivariable optimization solver

For every time step:

1. Initiate @ \( P, T \)
2. 'Guess' phase rates
3. Simulate Well or System Performance
4. Search for new rates
5. Calculate objective function
6. Store values
7. Accept? Yes
8. Store values
9. Accept? No
10. Search for new rates

Optimization Object Function:

\[
F(x) = \sum_{j=1}^{N} W_j \left( X_{m,j} - X_{c,j} \right)^2
\]

where

- \( W_j \): weight on sensor \( j \)
- \( X_{m,j} \): measured value sensor \( j \)
- \( X_{c,j} \): calculated value sensor \( j \)
Key Differentiating Elements of New Model

- Reliable flow regime models
- Widely tested in virtual metering applications
- Possible to use gradient-based methods
- Fast and efficient computation
- Better prediction of surge waves (slugging fronts)
- Fast and efficient computation
- Well (SS) and pipeline (Dynamic)
Pilot Testing: Margarita (Bolivia BU)

- Key project in Strategic Plan, starting production in 2012 (Data availability)
- Gas condensate field with pipelines in hilly terrain (Slugging Potential)
- Margarita is well instrumented and has production historian PI (Real-time data)
- Support from BU Production and Reservoir Engineering Departments
- Interest in virtual metering and pipeline and slug-catcher monitoring
Pilot Testing: Margarita (Bolivia BU)

Margarita FAS model scope

- 4 wells
- 4 infield pipelines
- Infield header
- Plano pipeline
- Slug catcher

Optimization Object Function:

\[ F(x) = \sum_{j=1}^{n} W_j \left( x_{m,j} - x_{e,j} \right)^2 \]
Pilot Testing: Margarita (Bolivia BU)
Pilot Testing: Virtual Metering results
Pilot: What-if scenarios Demos
Shut-in 2 wells and Ramp-up

Pressure Profile

Liquid Holdup

Pipeline Elevation

Condensate Level
Slugcatcher

Liquid Accumulated in pipeline

Flowrate Outlet Slugcatcher

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Pilot Conclusions

- Slugging potential can be minimized by the use of real-time flow assurance systems for operational planning
- A few years back such RT-FA systems were too expensive and difficult to implement
- Repsol engaged in an R&D collaboration with FMC to develop and pilot test a transient multiphase flow model tailor-made for RT-FA systems
- Margarita was chosen as best candidate for piloting
- Virtual Metering results and ramp-up and what-if scenarios demonstrate potential value
- Data gathering to build these systems can be challenging
Status 2014

- In the Piloted Field a complete FAS system is being evaluated for final implementation.

- This type of tool has been presented to other 3 fields from the company’s Strategic Plan, and a preliminary evaluation is under way:
  - An Offshore Deepwater Oil field for Virtual Metering to back up subsea multiphase meters.
  - An Offshore Gas Condensate field for FAS application (slugging).
  - An Onshore Gas Condensate field for allocation in a gas pipeline shared by different fields.

- FMC Technologies is currently using the FlowManager dynamic model in 4 online FAS systems:
  - Shell Ormen Lange FAS: FlowManager replaced Olga in 2011 giving improved prediction on surge waves.
  - Statoil Åsgard B FAS: FlowManager will replace Olga in 2014. Includes subsea gas compression.
  - BG Knarr FAS and Lundin Brynhild FAS delivered and installed in 2014.
Thank you / Questions