Dynamic Simulation of Filter Membrane Package for Produced Water Treatment

Produced Water Treatment Membrane System

- Produced water needs extra treatment before disposal
- Filter membrane package promises economic solution
  - Reduced use of expensive chemicals. Compact and light
- Membrane system is novel – no offshore experience
- Risk: pressure spikes cause membranes to 'clog up'
  - Requiring down-time and expensive cleaning procedures
- Objective: See how pressure spikes can be reduced through operational procedures and control.
  - Target: keep trans-membrane pressure (TMP) <= 0.8 bar

Membrane System Operation

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- Membranes let through ‘clean’ water
- Oil film build up on upstream side of membranes
  - Reduces throughput and needs to be removed periodically
- ‘Backflushing’ by reversing water flow through membrane
  - For short period at high flow rate
  - Needs to be fully automated
- Switching causes pressure transients
  - Changing order (operational procedures) and timing & speed (control tuning) of valve events can reduce pressure spikes

Model Boundaries

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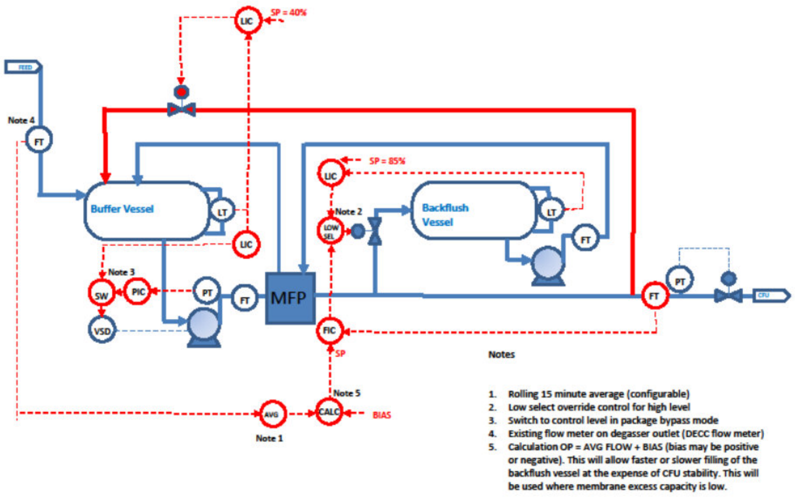
Membrane Package and CFU



Membrane System Variations

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- System configuration (“flow mode”) of produced water filtered through membrane groups is selected manually by operator
  - ❒ With water quality and feed flow
  - ❒ Resulting valve switching automated
- Can switch between single pass (parallel) and double pass (series) operation
  - ❒ Single pass allows higher throughput
  - ❒ But less filtering, so output water quality lower for same input quality

Flow Mode 6 – Series Flow

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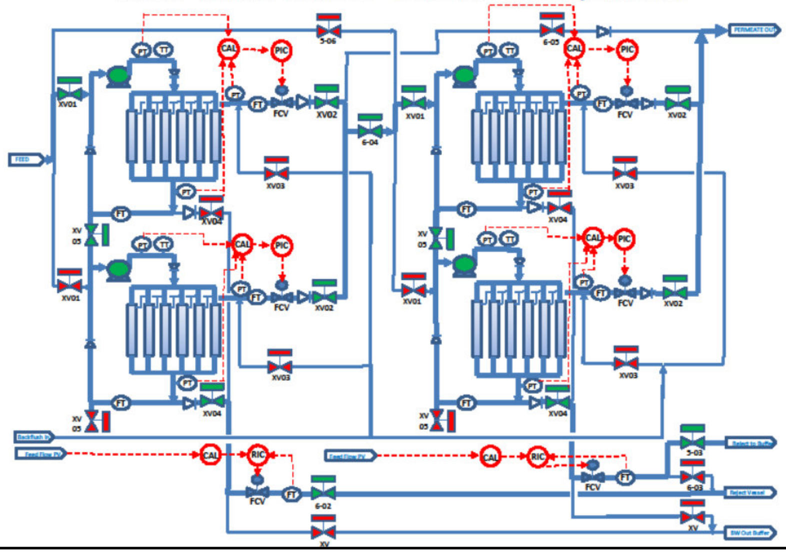
Mode 6 – Trains A + B and C + D – Double Pass Parallel Reject in Series



Motivation for Building Dynamic Simulation

- Objectives:
  - ❒ Increase confidence that system will work as intended – de-risking project
  - ❒ Resolve potential issues in factory
  - ❒ Reduce commissioning time and costs
  - ❒ Predict behaviour with produced water; FAT only with clean water
- Solution:
  - ❒ Build dynamic simulation to predict system behaviour, including pressure spikes, before system is built.
  - ❒ Investigate operations, control and design to prevent / limit spikes
  - ❒ Refine model as factory test data becomes available

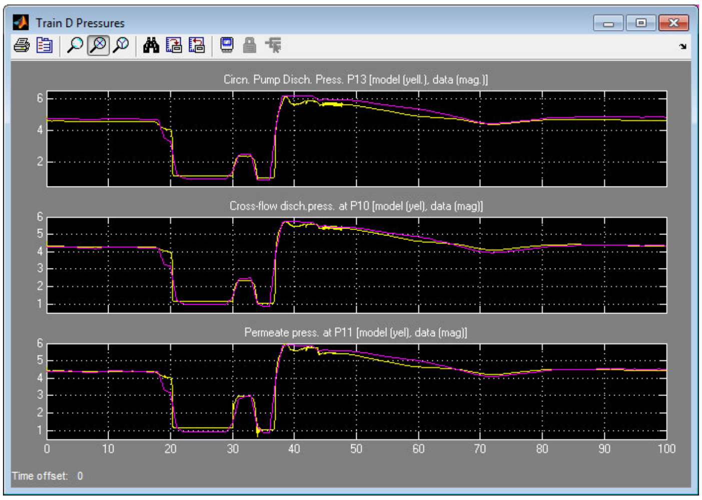
Modelling, Simulation and Data

- Developed simulation in MATLAB/Simulink
  - ❒ Easier to include non-standard elements than standard simulation tools like Hysys, etc. – Examples:
    - ➢ Model of membrane flow vs. pressure drop relationship
    - ➢ Backflush valve and pump switching logic
- Mathematical model of process
  - ❒ Based on physical first-principles physical relationships
- Model parameters obtained from:
  - ❒ Data sheets
  - ❒ Estimated from factory acceptance test (FAT) data – “grey box”

Model Validation – Typical Result: Train D Backflush

Train D Pressures:

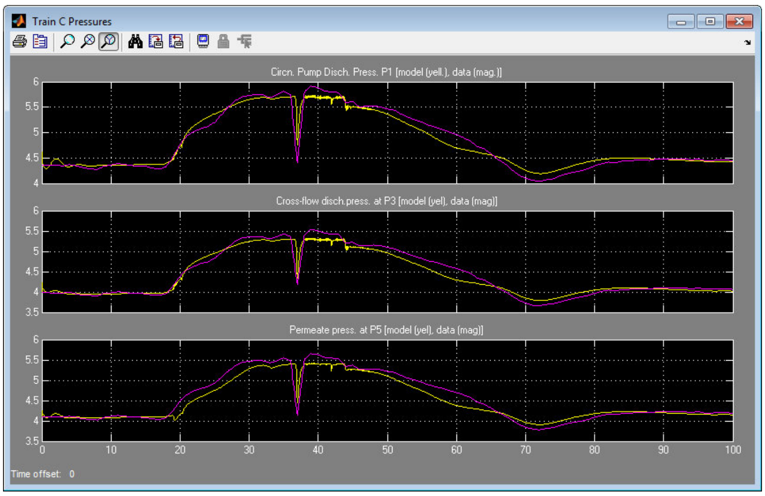
Yellow – Model
Magenta – FAT Plant Data



Model Validation: Train D Backflush - Effect on Train C

Train C Pressures:

Yellow – Model
Magenta – FAT Plant Data



Control Tuning of TMP on Train A: Train B Backflush

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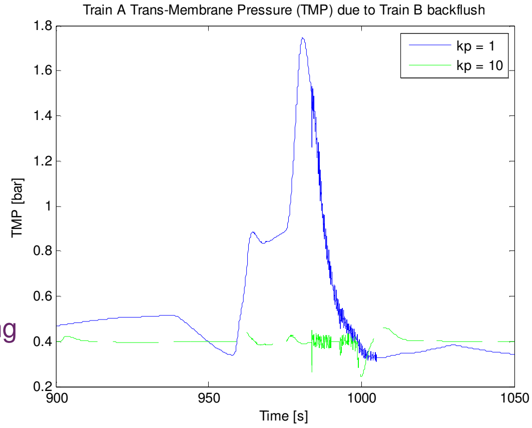
- TMP control setpoint is 0.4 bar. Target keep TMP <= 0.8 bar
  - TMP (SP) determines flow rate in steady-state conditions
- Example: PI controller proportional gain (kp) changed from default setting 1 to 10
- Result: TMP spike/max reduced from 1.74 to 0.46 bar
- Model and manual tuning used to tune all control parameters



Conclusions

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- Customer very satisfied:
  - Model validation against FAT data
  - Model showed operation in expected conditions of produced water quality and flow rates – gave confidence in design
    - Indicated min and max water flow rates for normal operation
  - Recommendations on operational procedures, control and tuning
    - Pressure spikes constrained within limits
  - Customer able to try adjustments to procedures and tuning before and during installation
- To date, system still awaiting commissioning