Virtual Flow Metering
P11b - De Ruyter Platform
DEVEX 2013

Quirinius van Dorp
Setting
- P11b
- First Oil: September 2006
- Oil and gas production
- Gravity Base Structure
- 3 platform wells
- 2 subsea tie-ins (Medway) (1 oil well, 1 gas well)
- 1 platform well being drilled

Challenge
- Reliable energy, oil, gas and water production allocation
- Addition of new wells to production allocation procedure
De Ruyter: Simplified process schematic
Data Validation and Reconciliation (DVR)

What

is Belsim’s “Vali DVR model”?

Why

do we need a software solution for oil/gas/energy allocation on P11b - De Ruyter?

How

is the DVR model performing on De Ruyter?

Benefits

Limitations

Benefits

Limitations
1) Sensor precision

2) Installation problems, induced biases

3) Fluctuation of the physical phenomenon itself

4) Drift or accuracy bias of the sensor itself

5) Compensation (e.g. flow meters)

6) Accuracy of the acquisition system
DVR Principles: Penalty

- $y_i$ the measured value
- $y_i^*$ the corrected value or the reconciled value
- $\sigma$ accuracy

Individual penalty of measurement $y_i$ is equal to the correction weighted by its uncertainty

$$Penalty_i = \left(\frac{y_i - y_i^*}{\sigma(y_i)}\right)^2$$
DVR Principles: Redundancy

Redundancy generates contradictions, a necessary source of information.

Redundancy is actively used to correct all wrong measurements simultaneously.

Volumetric oil flowrate estimation per manifold (BPD)
Data Validation and Reconciliation Concepts

Redundancy Number = \( \text{No of available measurements} - \text{No of variables} + \text{No of Equations} \)
\[ = 4 - 4 + 2 \]
\[ = 2 \]

\( = \text{No of equations} - \text{No of unmeasured variables} \)
\[ = 2 - 0 \]
\[ = 2 \]

Objective Function
\[ = \sum \text{(Penalties)} = 481,983,1735 \]

Mass Balance Equation
\[ = A - B - C = 0 \]
\[ = 0 \]

\[ \text{Penalty}_i = \left( \frac{y_i - y_i^*}{\sigma(y_i)} \right)^2 \]

\( y_i \) is the measured value
\( y_i^* \) is the corrected value or the reconciled value
\( \sigma \) is the accuracy of the measurement

Redundant Sensors read the same value
What is Data Validation and Reconciliation?

Acquires *dynamic* data from PI database
- performs *static* validation and reconciliation
- produces hourly results

Uses redundancies
- increases accuracy

Accuracies
- reconciliation of data outside its accuracy range increases total penalty
- solution with lowest total penalty is presented

Modeling
- thermodynamic behaviour and mass/energy balance
- PFD’s, P&ID’s, well schematics, VLP’s, choke equations, etc.

Virtual meters
- at any point in the process

Back allocation of Oil – Gas – Water – Energy
- concise and validatable interface
ESP well A2 enters the oil separation train. Some reconciliation was necessary. Right clicking the blue box allows stepping back into the wellbore model.

MP separator gas out flows to 2nd stage flash gas compressor or to HP flare KO drum.
Why a software solution for oil/gas/energy allocation?

Managing uncertainties
- No test separator
- Muliphase flow meters unreliable

Different partner equities with introduction of new wells
- Need for accountable allocation

Managing engineering resource requirements
- Rate by difference increasingly time consuming and ambiguous

Optimisation of individual well production
- Accurate production data essential for nodal analysis

Improving reservoir management
- Different fields producing comingled to GBS
### Why a software solution for oil/gas/energy allocation?

<table>
<thead>
<tr>
<th>Without Vali DVR</th>
<th>With Vali DVR</th>
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<tbody>
<tr>
<td>Multi Phase Flow Meters</td>
<td>Temperature measurements</td>
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<tr>
<td>Daily BS&amp;W measurements</td>
<td>Choke equations</td>
</tr>
<tr>
<td>Static and flowing THP &amp; BHP</td>
<td>Mass &amp; Energy balance</td>
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<tr>
<td>GOR assumptions per well based on original oil sample analyses</td>
<td>Pressure drop calculations</td>
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<tr>
<td>Producing status of each well (rate by difference checks)</td>
<td>Accuracy specification of individual meters</td>
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<tr>
<td>Process flow meters</td>
<td>Thermodynamic phase behaviour of hydrocarbons along the entire flow path</td>
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<td>• Oil to GBS</td>
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<tr>
<td>• Process water from IGF</td>
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<tr>
<td>• HP/MP/LP hydrocyclones</td>
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<tr>
<td>• Gas export and import</td>
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<td>• Flare gas</td>
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<td>• Fuel gas consumption</td>
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**Real time data**
Oil allocation – Valimodel vs MPFM

Vali vs. Multi Phase Flow Meters

A01 - A02 - A03 Oil standard flow rate (m³/h)
A-03 Oil vs Water production – MPFM error

MPFM re-configuration

A-03 MPFM reports one liquid phase. All liquid = oil. Requires resetting.
What other benefits do we get from Belsim and Vali?

**Real time data validation and reconciliation**
- As opposed to bi-weekly update

**Consistency**
- Less prone to hidden errors
- Errors flagged
- Corrective measures easily communicated

**Advice**
- Benefit of increased redundancy
- Which meters to purchase and where to place them

**Detection of failing sensors**
- Feedback to maintenance program

**Support**
- Ensuring consistent results
- Investigation into suspicious data

**Vali output**
- Tags exported to PI Processbook
What are the limitations of the DVR model?

**Static model**
- Transient periods lead to poor convergence rates
- Slugging behaviour is difficult to model

**Requires dedicated maintenance**
- Belsim expertise is essential
- Commitment Dana ↔ Belsim

**Process modifications**
- Must be reported to Belsim and integrated into the model

**Resources**
- Reduces but does not eliminate engineering resources
Thank you for your attention!

With recognition to Belsim for their contribution to this presentation.