Modeling and optimizing petroleum wells

Rannei Solbak Simonsen

Supervisor: Sigurd Skogestad
Co-Supervisor: Chriss Grimholt

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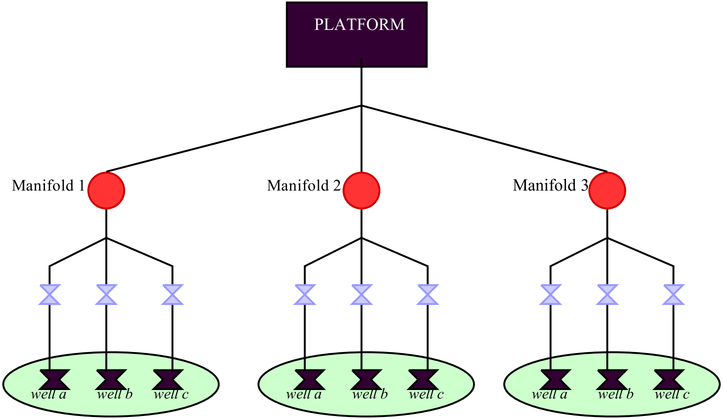
Petroleum production

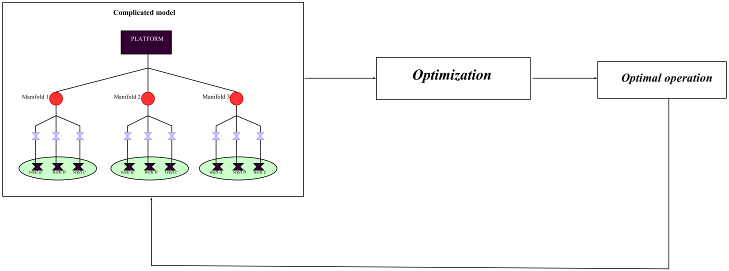
Important operational question: *How to maximize oil production?*



Optimizing the production

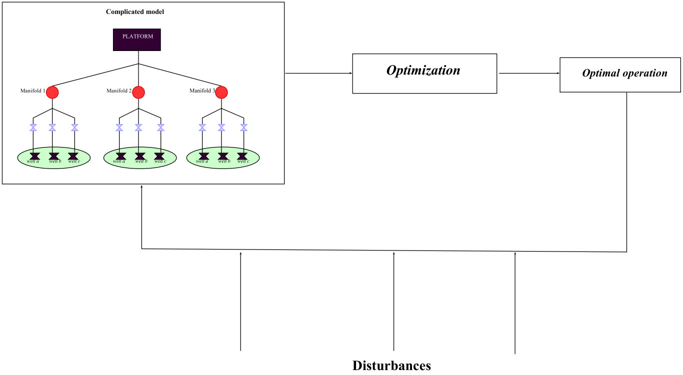
Today

- Large models of the system is optimized
- Very time consuming
- Often done only once or twice per day



Problem

- Disturbances are not accounted for until the next optimization



Leads to . . .

- Non-optimal operation of the wells in-between the optimizations

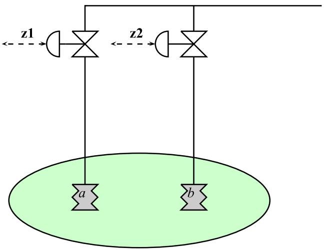
Possible solution

To ensure optimal operation:

- Design a control structure
- Avoid re-optimization
- Control variables
- Measurements

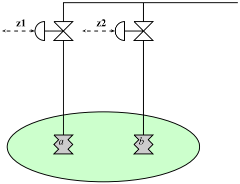
The system

Two-well manifold



- Oil, gas and water is produced
- Maximize oil production
- Maximum production → constraints become active
- Active gas constraint $m_g^{well\ a} + m_g^{well\ b} = m_g^{max}$

Optimal soltion



For a manifold operation under constrained conditions
We already know the optimal way to operate the wells:

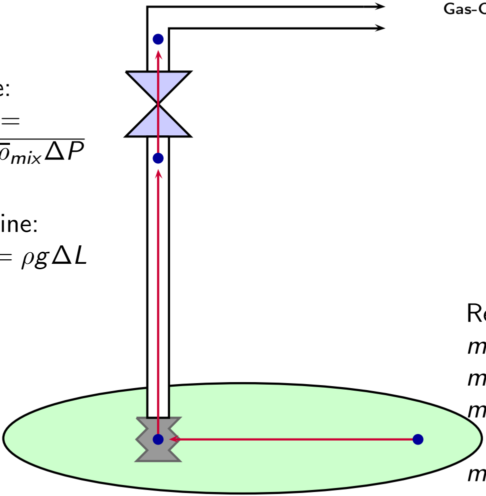
$$\left(\frac{\partial m_g}{\partial m_o}\right)_{well\ a} = \left(\frac{\partial m_g}{\partial m_o}\right)_{well\ b}$$

Problem: We have no way to measure this relation . . .

Developing a model

Overall mass balance:

$m_{tot} = m_g + m_o + m_w$



Valve:

$m_{tot} = C_v \sqrt{\bar{\rho}_{mix} \Delta P}$

Pipeline:

$\Delta P = \rho g \Delta L$

Gas-Oil-Ratios used in the models:

$$GOR_D = \frac{k_g}{k_o}(P_{wf} + P_R)$$

$$GOR_1 = \frac{k_g}{k_o}(P_{wf}^2 - P_R^2)$$

$$GOR_2 = \frac{k_g}{k_o}(P_{wf} - P_R)$$

$$GOR_3 = \frac{k_g}{k_o}(P_{wf} - P_R)^2$$

Reservoir:

$m_o = k_o(P_{wf} - P_R)$

$m_w = k_w(P_{wf} - P_R)$

$m_g = k_g(P_{wf}^2 - P_R^2)$

or

$m_g = GOR \times m_o$

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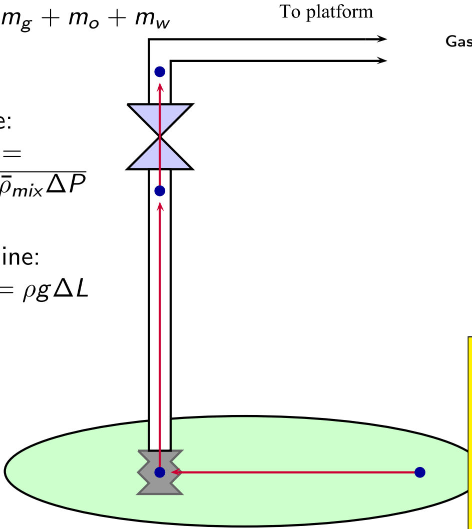

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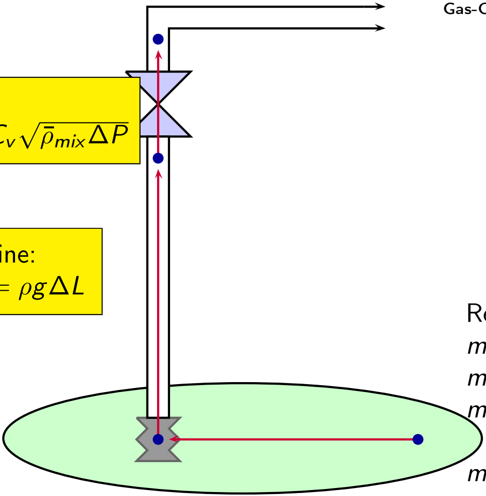

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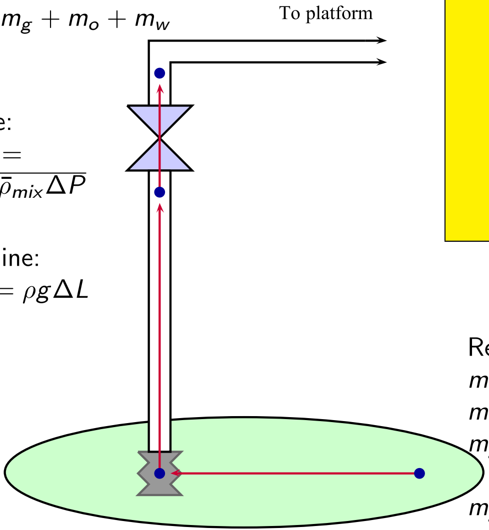

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Optimal solution for the the well models

The optimal solution is known to be:

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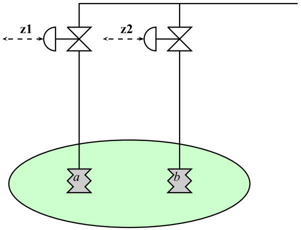


Optimal solution for the the well models

$$\left(\frac{\delta m_g}{\delta m_o}\right)_{GOR_D} = GOR_D + \frac{k_g}{k_o}(P_{wf} - P_R)$$

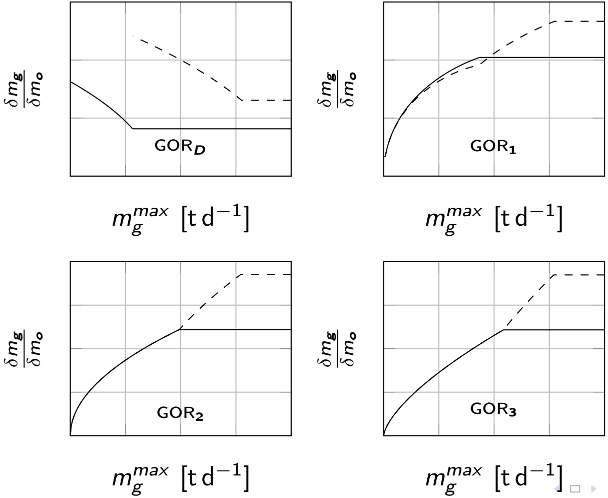
$$\left(\frac{\delta m_g}{\delta m_o}\right)_{GOR_1} = GOR_1 + 2\frac{k_g}{k_o}P_{wf}(P_{wf} - P_R)$$

$$\left(\frac{\delta m_g}{\delta m_o}\right)_{GOR_2} = 2GOR_2$$

$$\left(\frac{\delta m_g}{\delta m_o}\right)_{GOR_3} = 3GOR_3$$

Testing the optimal solution

The change in GOR with increasing production rate:



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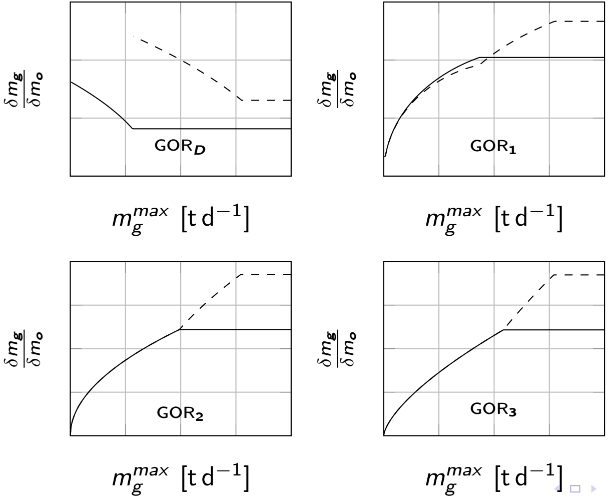

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A start...

Questions?