Maximizing Uplift in Gas-Lifted Oil Production Systems

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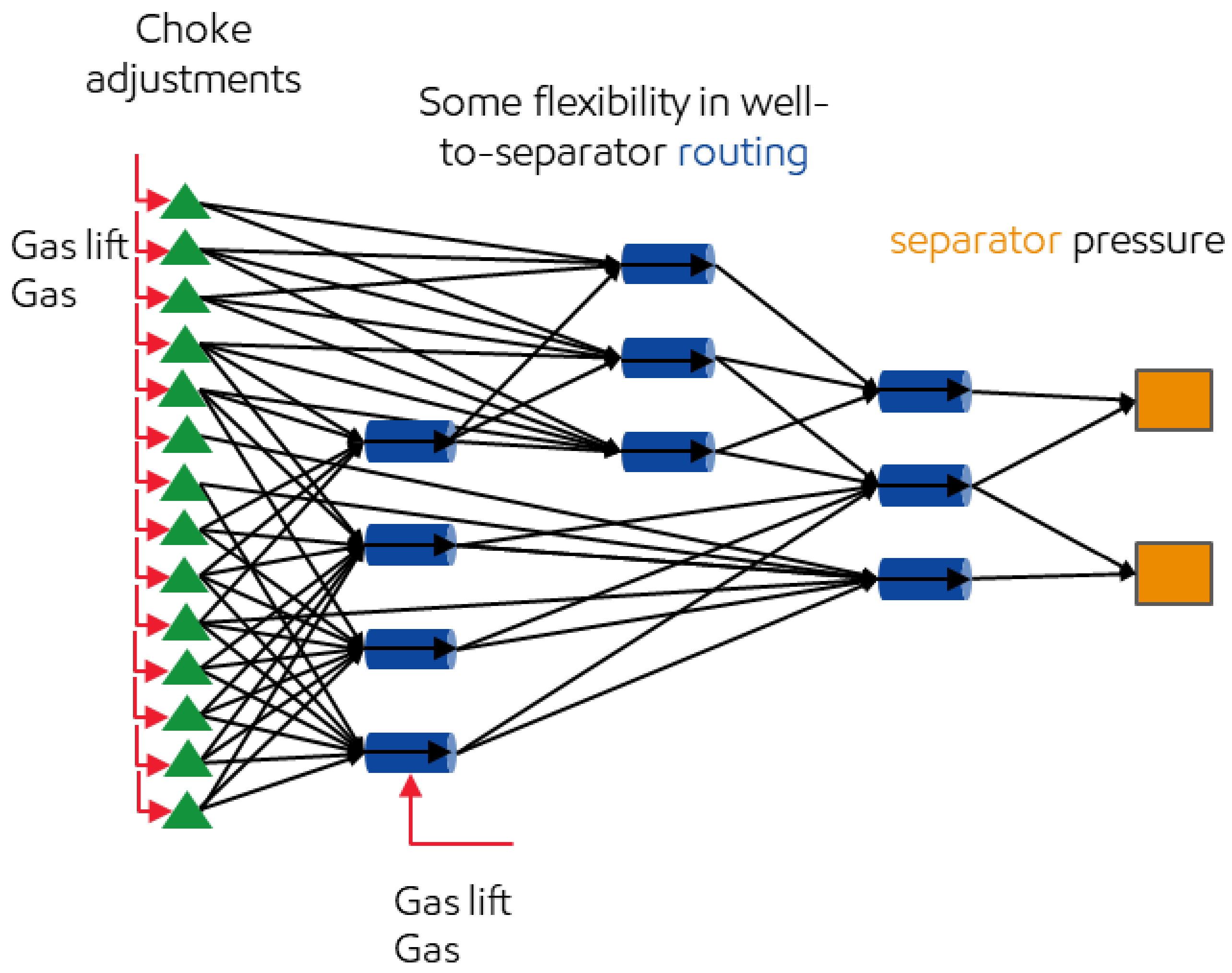
Presentation Outline

- Objective
- A new modeling framework for Optimization in Gas lifted System
- Application 1: Production network modeling and optimization
- Application 2; Well Cycling Optimization
- Conclusion and Future Direction

Objectives

- Develop a new generic modeling and optimization framework for improved decision making
- Highlight the value of the new approach- significant uplift improvement and reduced computational time required to optimize total field production
- Compare with the current/existing (in house) deployed modeling and optimization technology

Introduction to Production System Optimization



Schematic of a Production field

- **Production Optimization**
  - **Objective:** Maximize incremental oil production by adjusting well and network behavior (with little to no investment cost)
  - **Key decisions**
    - How much gas lift to inject? (continuous)
    - What are the choke positions? (continuous)
    - When to open/close the well and well-separator routing? (discrete)
  - Subject to field constraints
- **Model based Optimization**
  - Ex. Physics-based, well/flowline network; data driven models
  - Optimization algorithm to identify optimal operational changes that will max production
  - The algorithm is able to handle continuous, as well as discrete decisions
- **Users**
  - Reservoir/Production Engineers
  - Facility Engineers/Operators

Business Case for a Flexible Optimization Framework for Production Optimization

Challenges

- Optimization methods in third party tools (e.g. IPM suite, PIPESIM, etc) are not accessible to the user- i.e. black box
- Not flexible to add user specific settings (e.g. new variables, constraints, etc.)
- Inability to leverage the power of state of the art optimization solvers

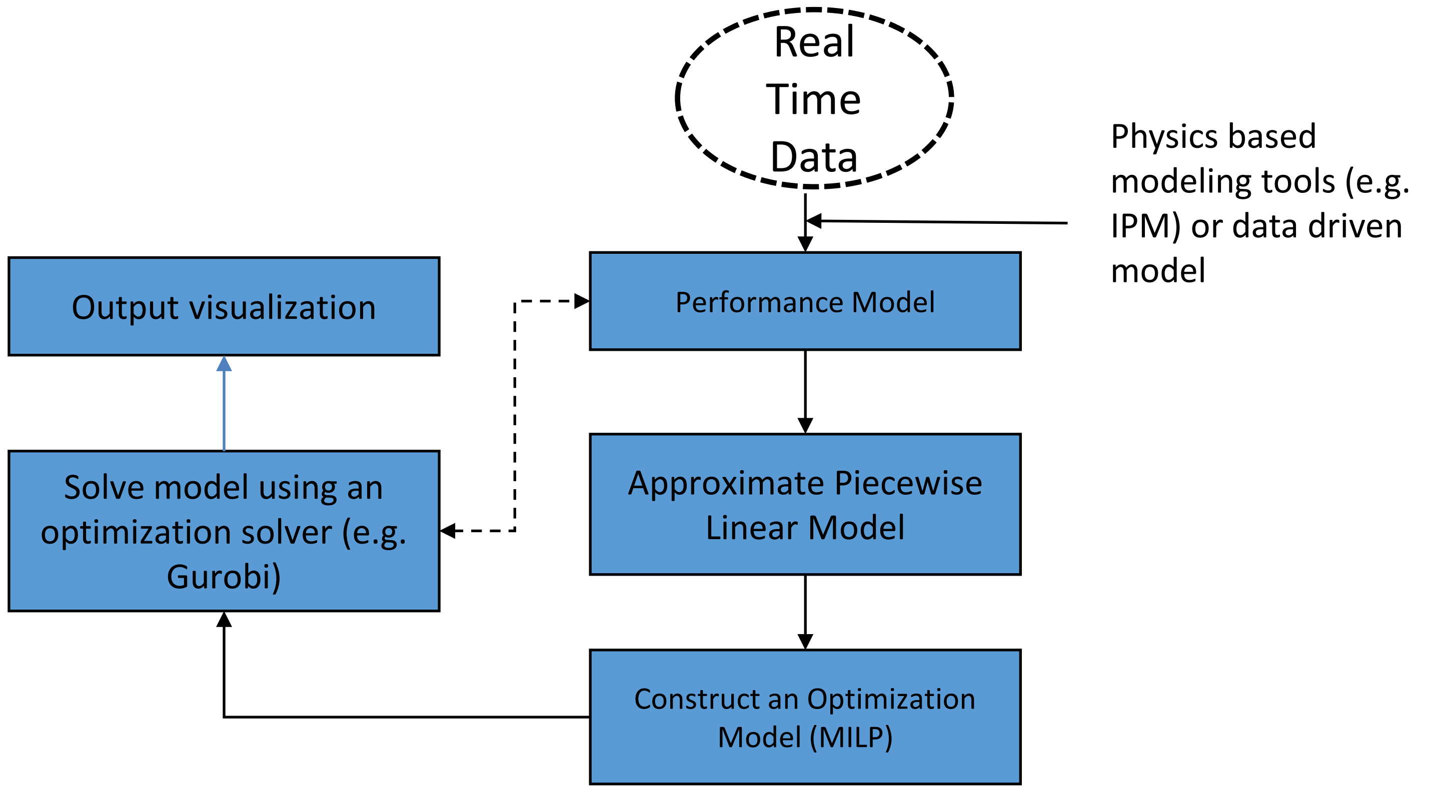
Demonstrated Value realized

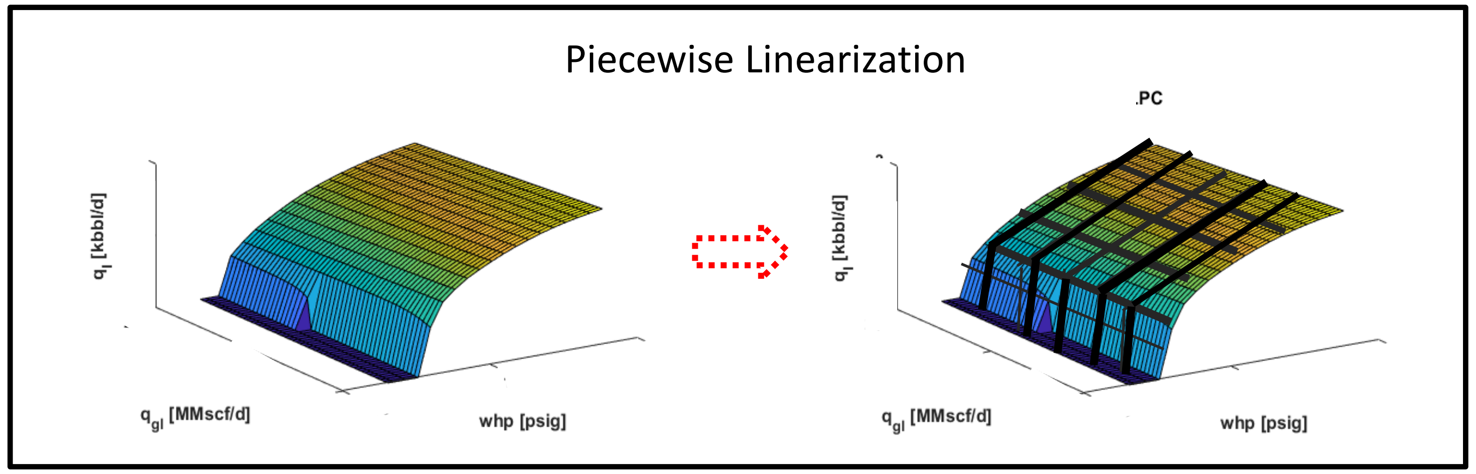
- Significant oil barrels can be recovered from field production optimization
  - Up to 9% (average of 2%) increase in production uplift from network optimization
  - Up to 10% increase in oil production from well cycling
- Computational time improvements
  - An order magnitude reduction in compute time

https://www.petex.com/products/ipm-suite/
https://www.software.slb.com/products/pipesim

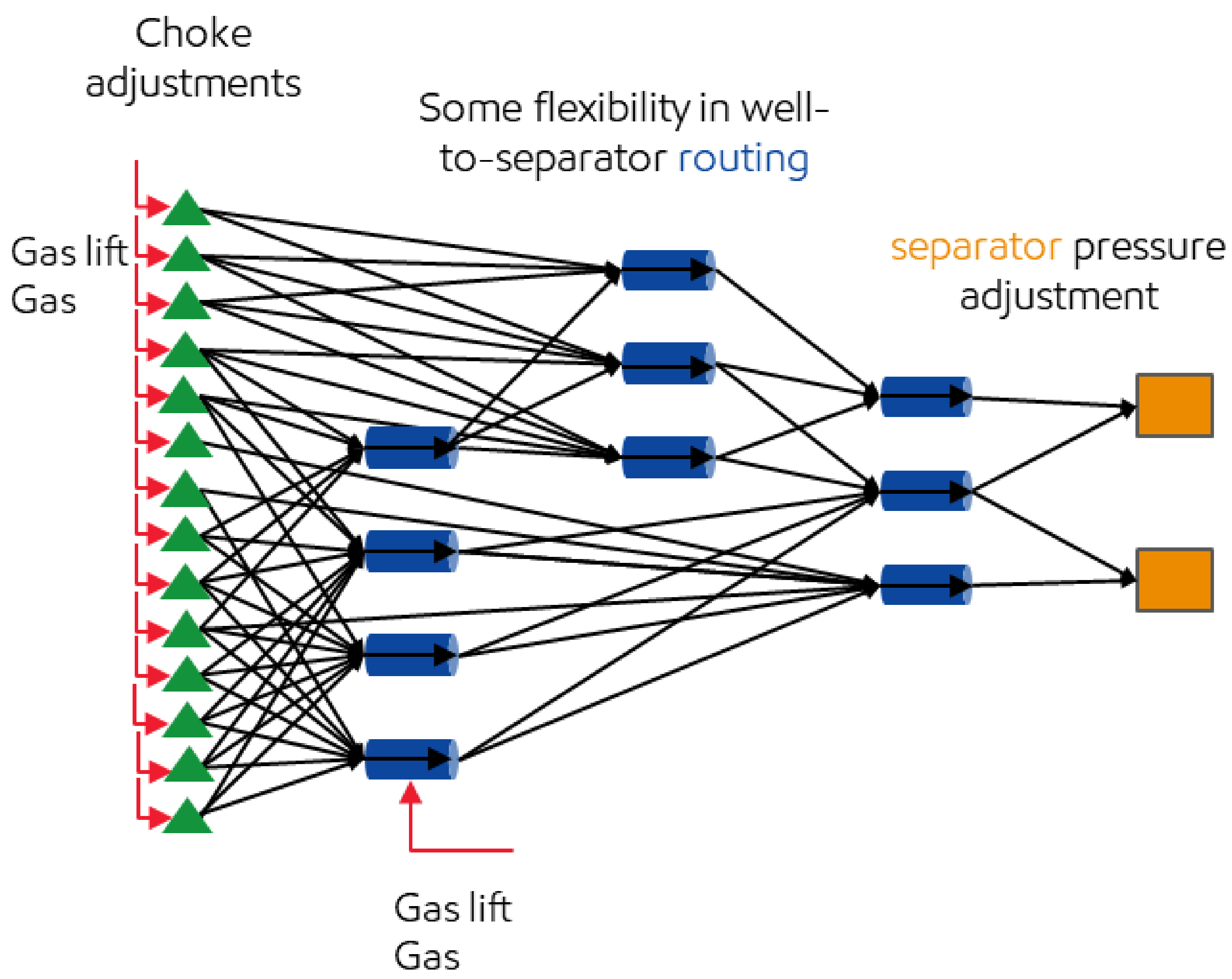
Generic Framework for the New Optimization Modeling

- Using real time data, build production models; Physics based models in Prosper/GAP or data driven model
- Develop the performance model for the system
- Use piecewise-linear models to approximate the performance models
- Insert the PWL into a optimization model and solve
- Mixed integer linear programming (MILP) is used to model the problem
- Compare optimal results with performance model and visualize the output



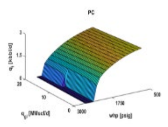


Application 1: Production Network Modeling/Optimization



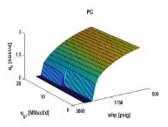
Network Model (MILP):

Objective: Max Oil rate



Well models; ql~f(qgl,whp)

+



Pipe models; dP~f(Pin,qg,ql)

+

Other equipment models e.g. chokes

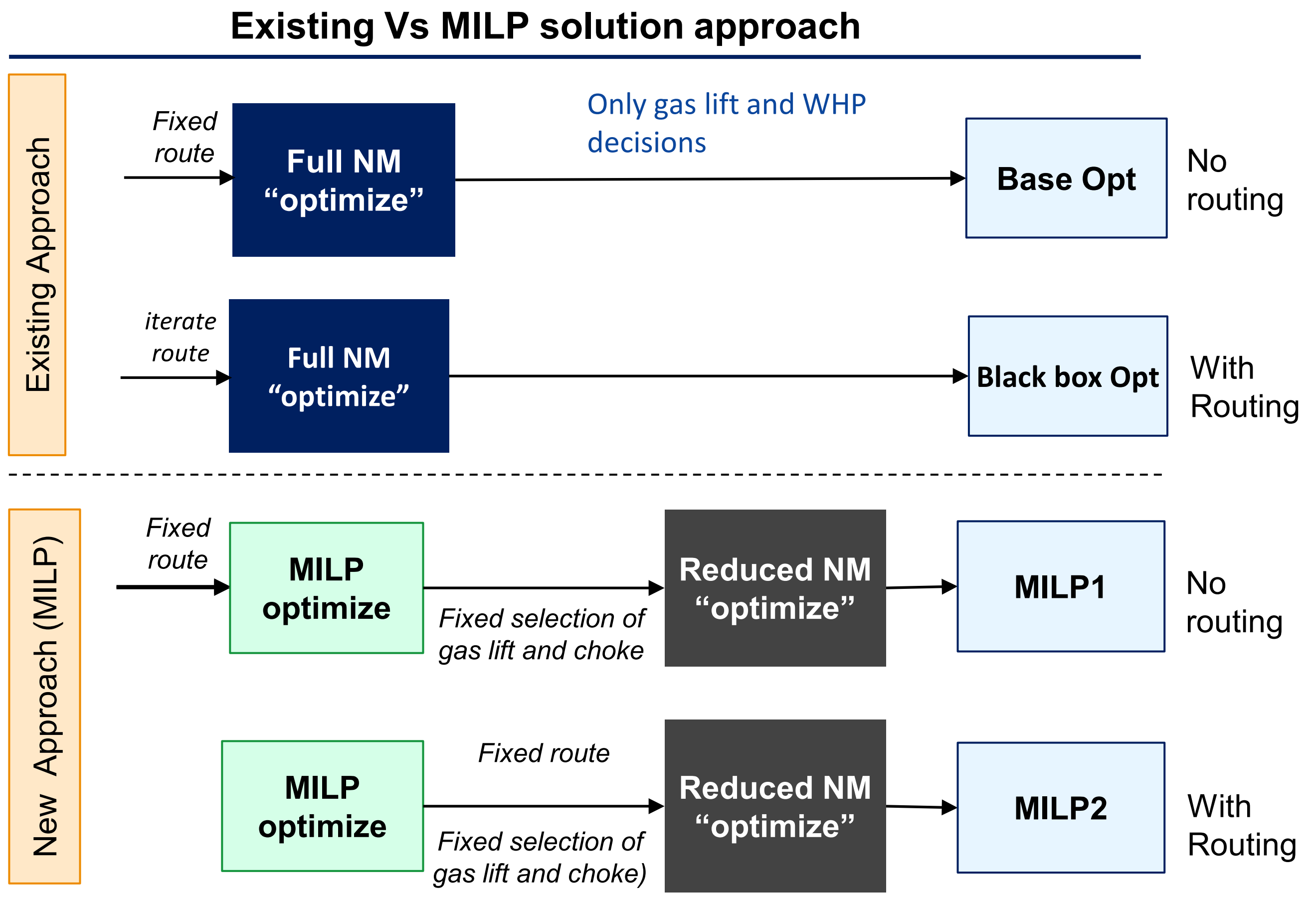
+

Additional considerations

- Network mass balance
- Capacity limits
- Reservoir management
- Flow assurance
- Etc.

Existing Vs New Optimization (MILP) Strategy

- Current existing approach optimize the full Network Model using 3P tools
  - GL and WHP is optimized over fixed route
  - Routing optimization is done separately
- The new approach (MILP) implements an integrated approach for optimizing gas lift, WHP and routing
  - Uses a robust optimization engine
  - Optimizing over a reduced Network Model (RNM)

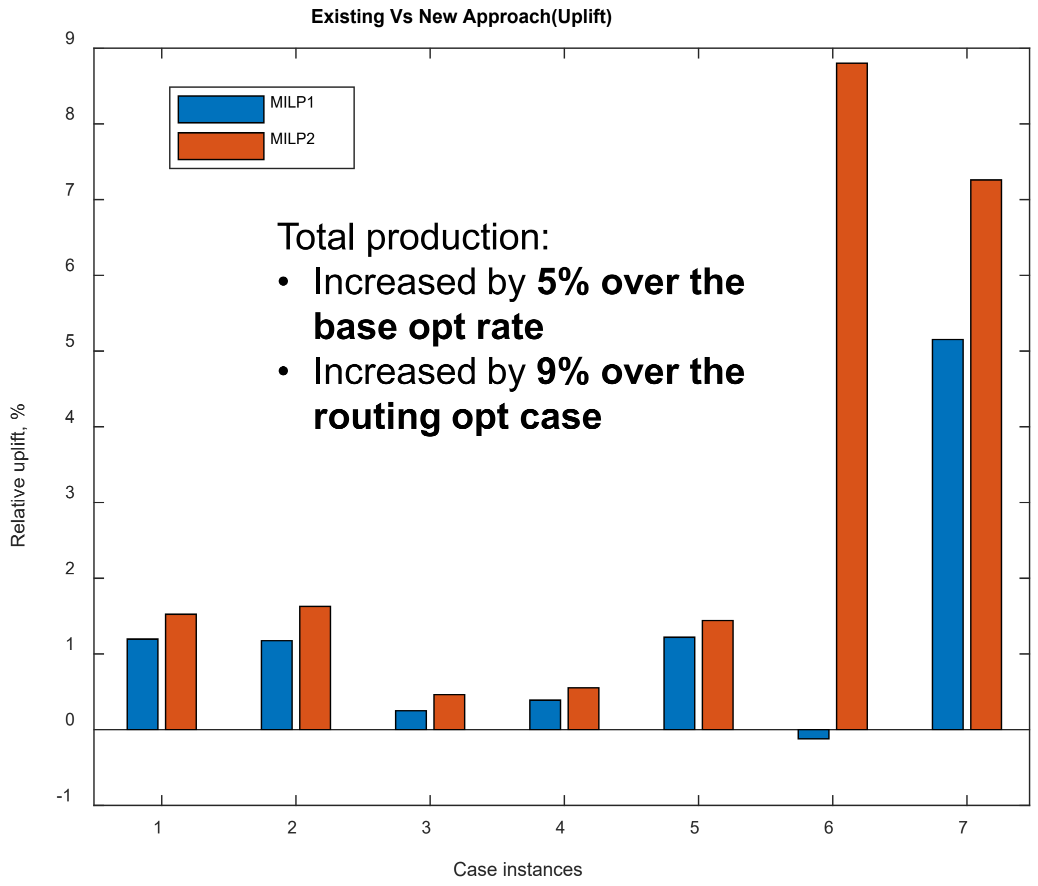


NM= Network Model

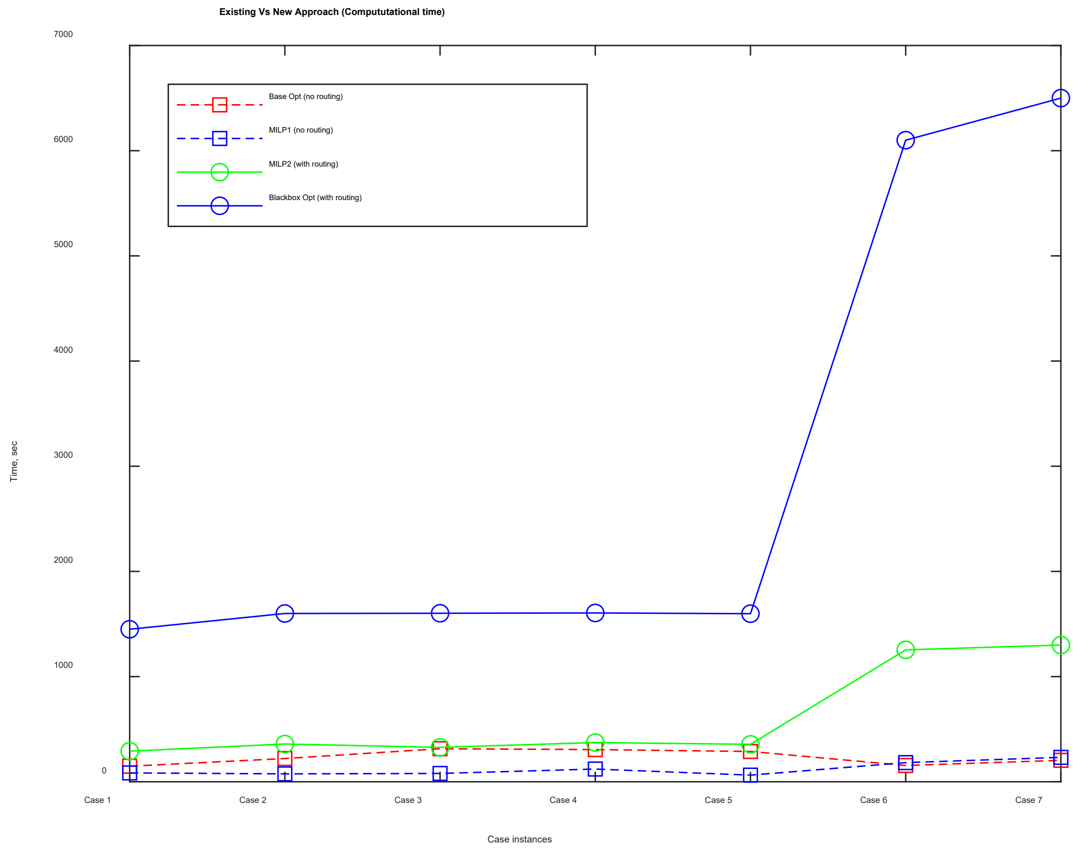
RNM= Reduced Network Model

MILP= Mixed Integer Linear Program

Production Network: Uplift/Computation time Reduction



Continuous variable optimization (with fixed GL and WHP in GAP) is feasible and increases production



Simultaneous optimization of route, gas lift, and choke (discrete optimization) provides significant benefits

Application 2: Well Cycling Optimization

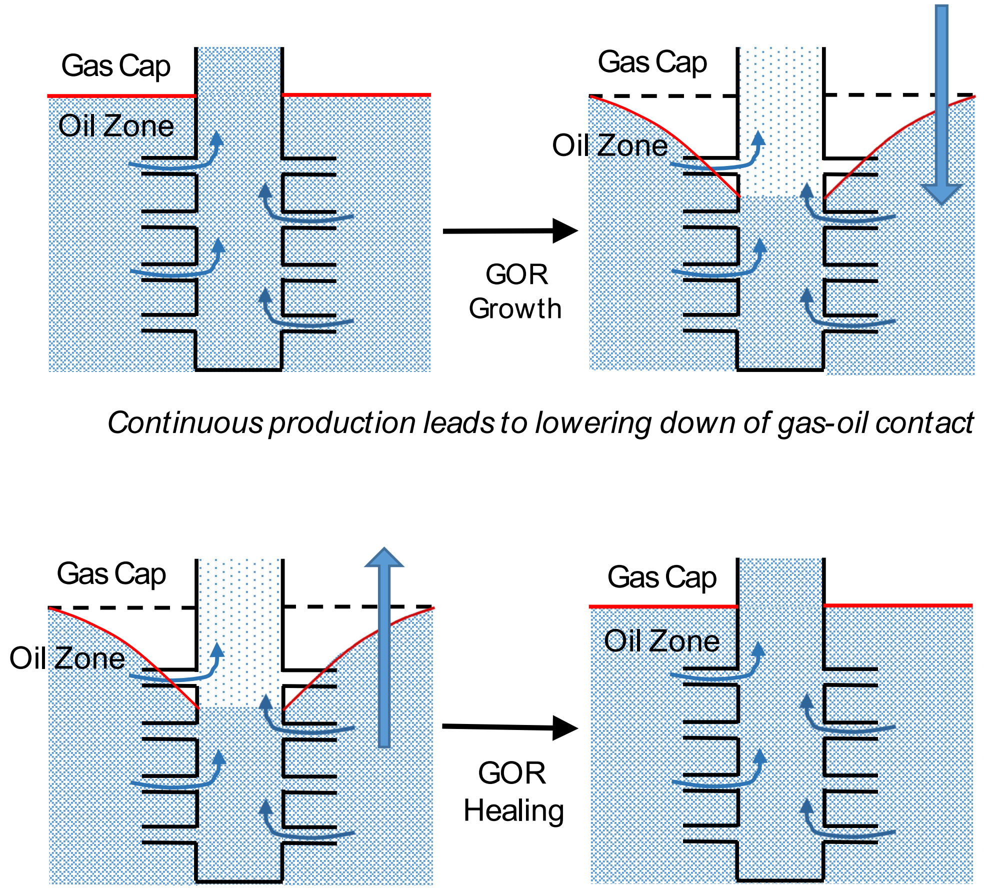
- The presence of gas coning in production wells reduces oil production. Leads to GOR growth

- Wells are shut-in for couple of days to raise back the gas-oil contact. Shut-in time heals the well and when brought online, it has lower GOR

Objective: Maximize cumulative oil production under gas limit constraints.

Technical Challenges

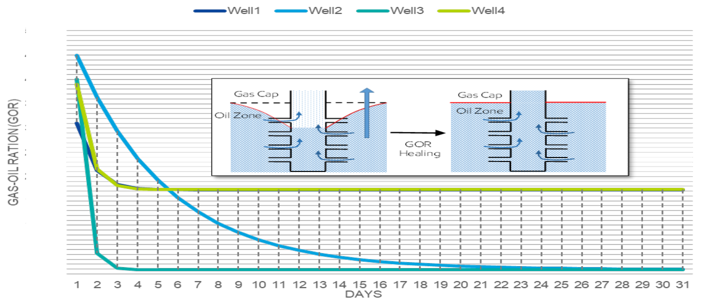
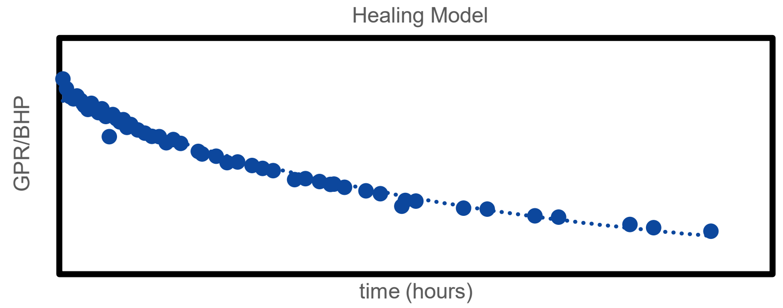
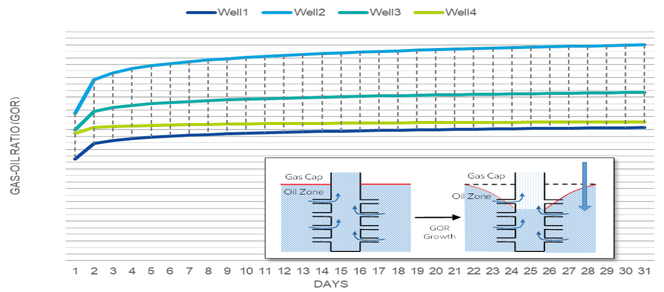
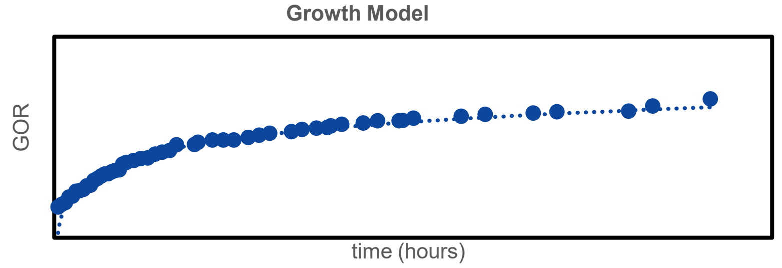
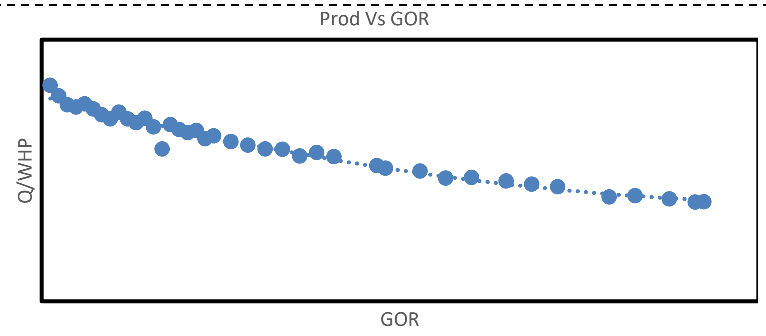
- Model GOR Vs time under growth and healing, as well as relation between production and GOR
- Optimization of complex (nonlinear) scheduling model for a multi-well system



Continuous production leads to lowering down of gas-oil contact

Well shut-in heals the reservoir and raises back the gas-oil contact

Challenge 1: Modeling Complex Relations

Process	Model	Data driven model
	$$\left(\frac{GOR}{BHP}\right)_{ASI} = \left(\frac{GOR}{BHP}\right)_{BSI} e^{-bt} + R(1 - e^{-bt})$$	
	$$GOR = A \times ln(t+1) + B$$	
Production vs. GOR (Gilbert-like Oil Model)	$$Q = a\frac{P_u \phi^b}{GOR^c}$$	

W.E. Gilbert. Rigorous modeling of solution gasoil ratios for a wide ranges of reservoir fluid properties. Drilling and Production Practice, 13:126–157, 1954.

Challenge 2: Optimal Scheduling

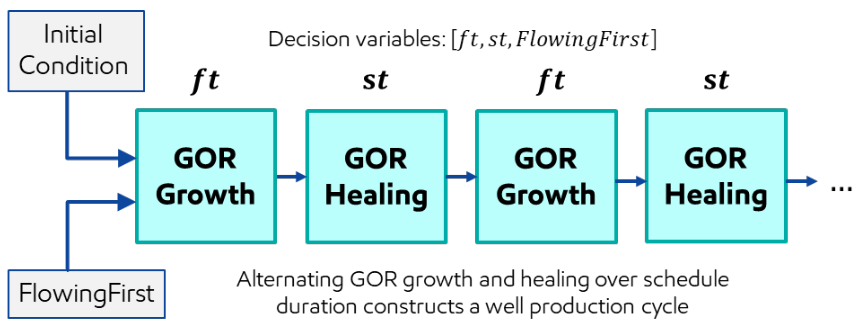
- Scheduling with nonlinear production curves
- Good GOR measurements; impacts on the GOR predictions at a given mode
- How to operate the field; mode of operation (heal or growth) determine oil and gas rate calculations

Optimizer Decisions

- What mode of operation (flowing or shut in) to start the schedule?
- How long to stay on a given mode?

Existing Vs New Optimization: Approach

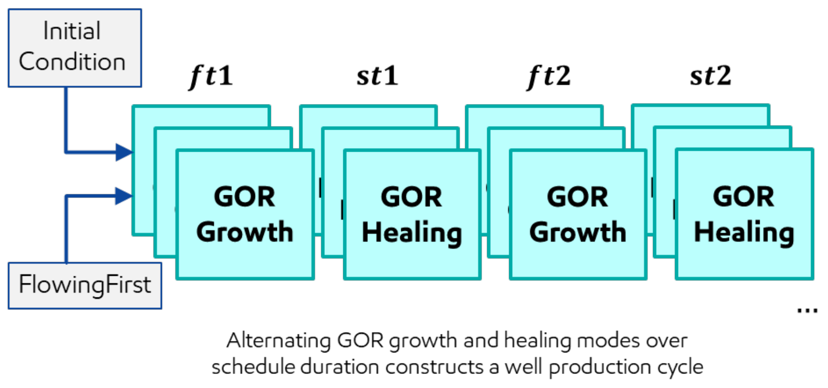
Basic optimization
(fixed cycle duration)



- Black box optimization (using genetic algorithm)
- Cumulative oil rate over the schedule is obtained by numerically integrating the oil rate curve

- Main assumptions
  - All cycles (flowing/shut in) have the same duration
  - No choke/WHP change while generating schedule
  - Difficult to customize for additional business constraints

New (Advanced) Optimization
("flexible cycles")

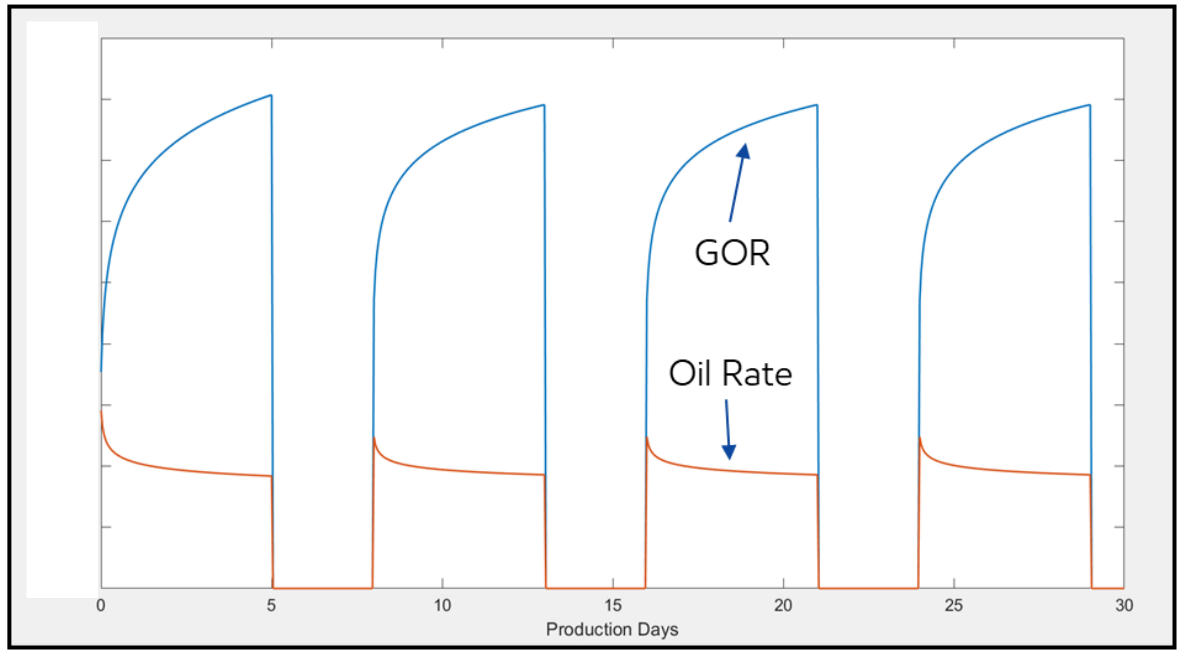


- Piecewise linear models are used to approximate nonlinear growth/healing models and implemented as an optimization model

- Extends capabilities to consider:
  - Constant and variable length cycle durations
  - Multiple growth and healing modes (e.g. different choke sizes)
  - Enforce different field constraints

Existing Vs New Optimization: Results

Basic optimization
(fixed cycle duration)



New (Advanced) optimization
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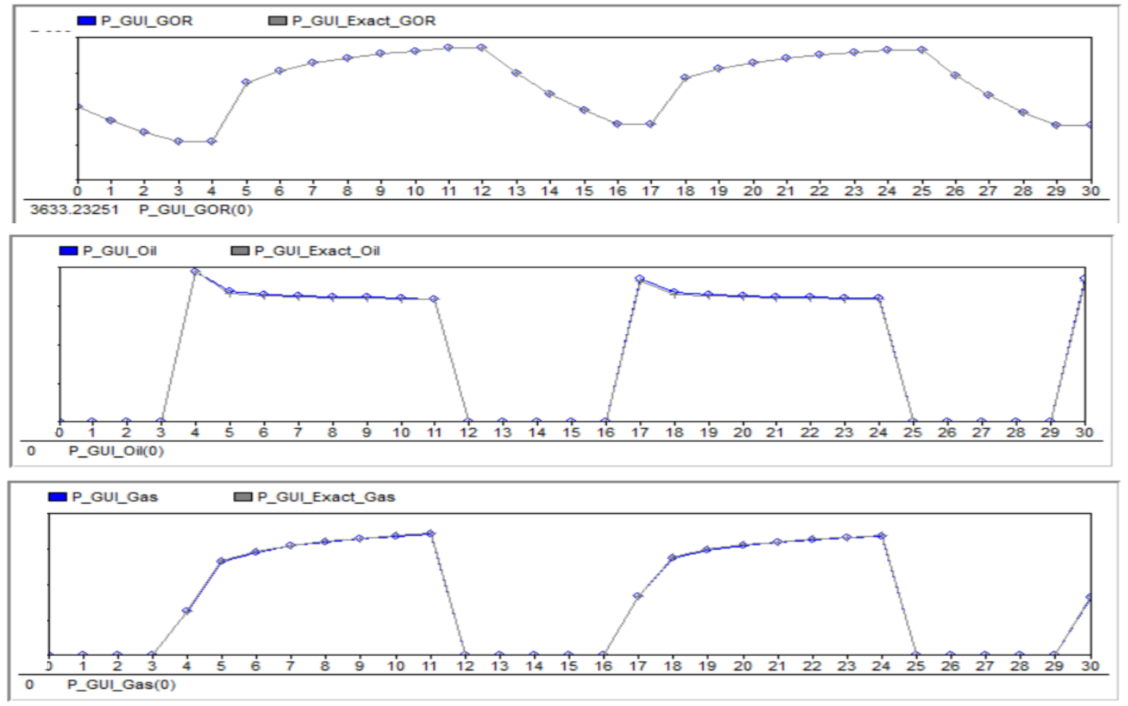

- Four cycles over 30 days schedule
- It takes five days to flow and 3 days to shut in

- Two cycles with high 'sustained' peaks in this case
- Uplift of 10% in production
- An order magnitude reduction in compute time for fixed cycle problem

Conclusion and Future Direction

Conclusions

- New modeling and optimization framework provided significant value to applications in network optimization and well cycling
- Case study results show up to 9% (average of 2%) increase in uplift from production network optimization and 10% (month on month) for well cycling, compared to existing approach

Future direction

- Extend to full field optimization; adding more equipment model and control decisions to the optimization, e.g. compressor optimization; injection optimization
- Optimization under uncertainty

Thank You

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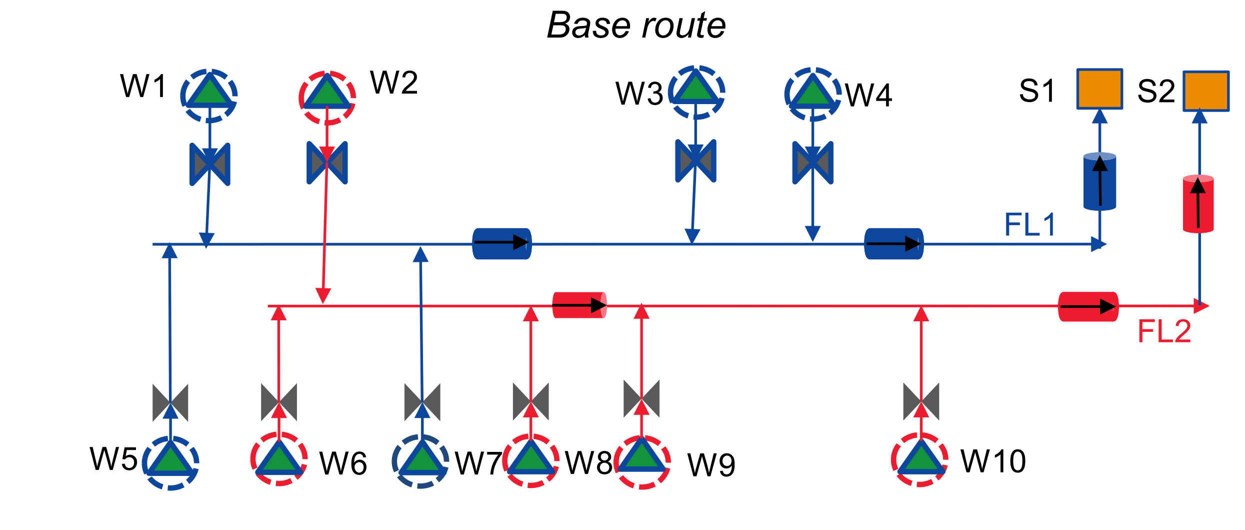
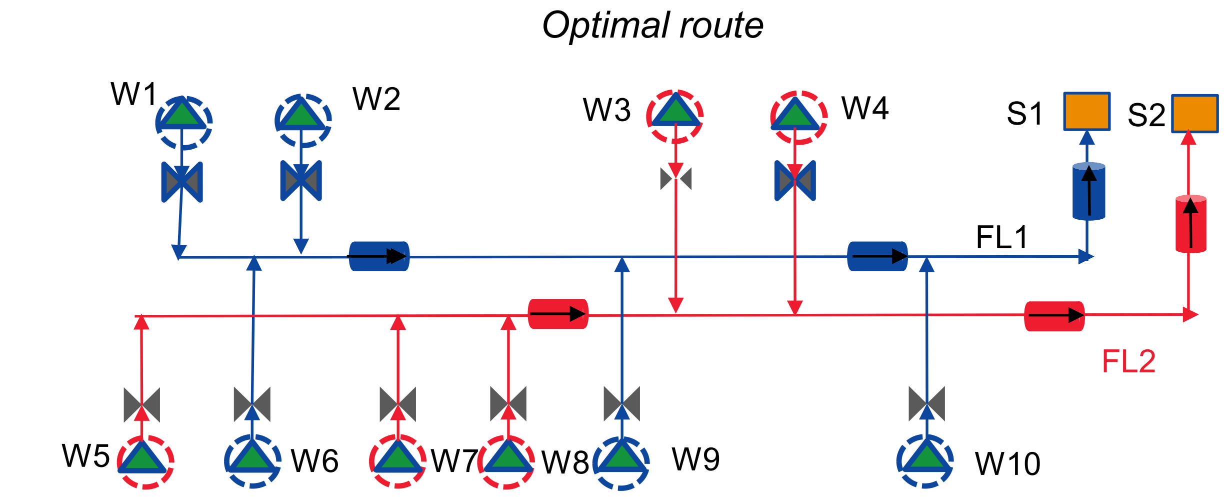
Production Network: Optimal Routing



- W1, W3, W4, W5, W7 are routed to FL1 (Blue)
- W2, W6, W7, W8, W9, W10 are routed to FL2 (Red)



- W1, W2, W6, W9, W10 are routed to FL1 (Blue)
- W3, W4, W5, W7, W8 are routed to FL2 (Red); Decrease in oil rate
- Oil rate increased by 9%