Optimizer as a CAPE-OPEN Unit Operation

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Authors:

Martin Gainville, Pascal Roux: IFP

Alain Vacher, Philippe Baudet: ProSim SA

Michel Pons: Michel Pons Technologie SA (for TOTAL)

Didier Paen: RSI - Dynamic Simulations Solutions

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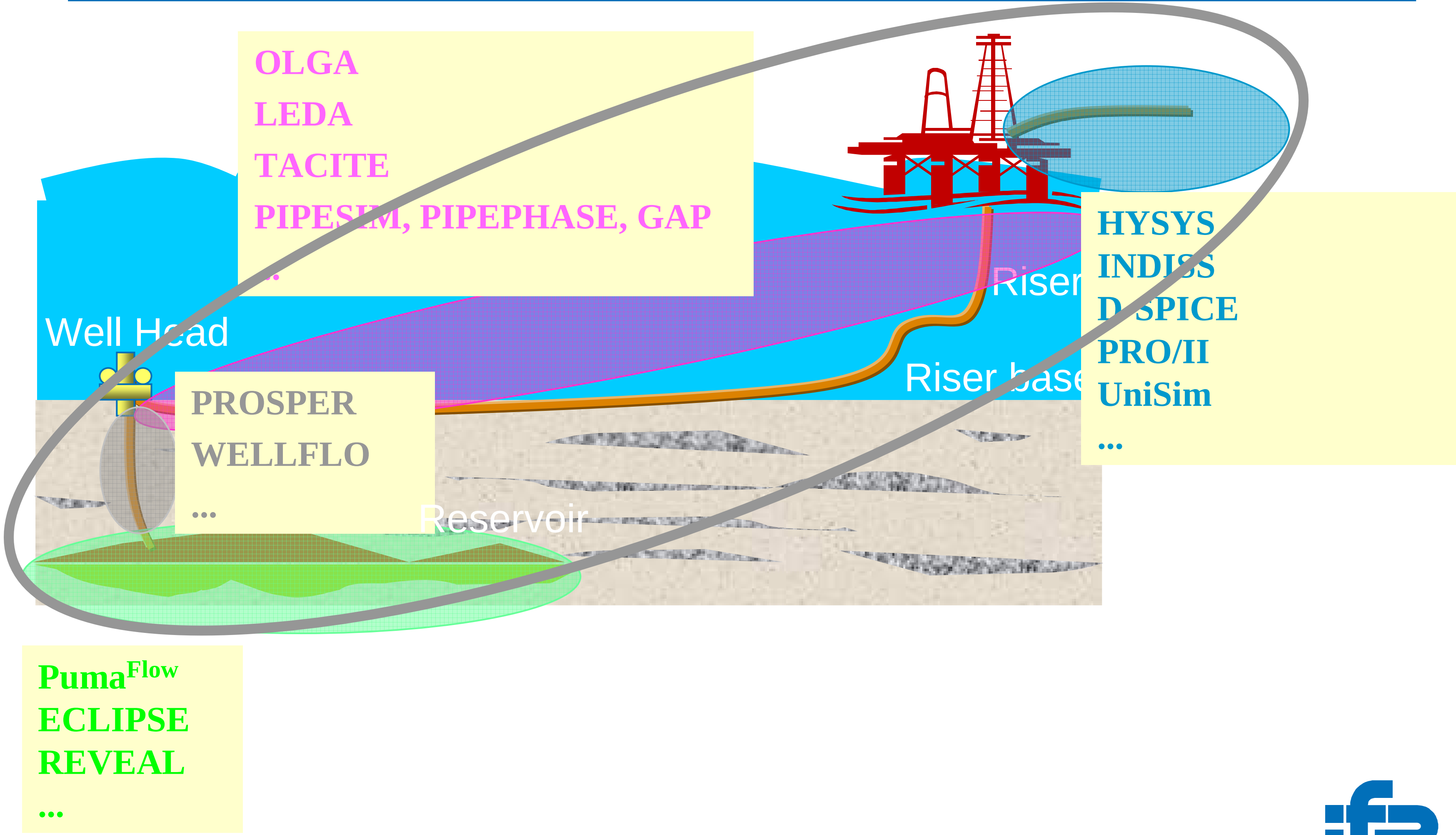
Introduction

Current situation



Introduction

- Design and operation of oil & gas production systems require more and more advanced process simulations
  - Multiple software solutions to address multiple knowledge domains
  - For integrated simulations from reservoir to process, seamless integration of different provider solutions is needed
  - Numerous issues to be resolved when coupling these solutions
    - Components interoperability
    - Data consistency
    - Numerical consistency

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Introduction

- To address these requirements, TOTAL and IFP have led a research collaborative project
  - TINA project based on INDISS Process Modelling Environment

- Purpose of the study
  - Extends modular strategy of INDISS for performing steady-state optimizations
    - Using a 3rd party optimization module within INDISS architecture
  - In a CAPE-OPEN interoperability framework
    - CAPE-OPEN PME: INDISS
    - TINA pipeline modules are CAPE-OPEN compliant
    - Optimizer wrapped as a CAPE-OPEN unit operation to be easily integrated within INDISS architecture

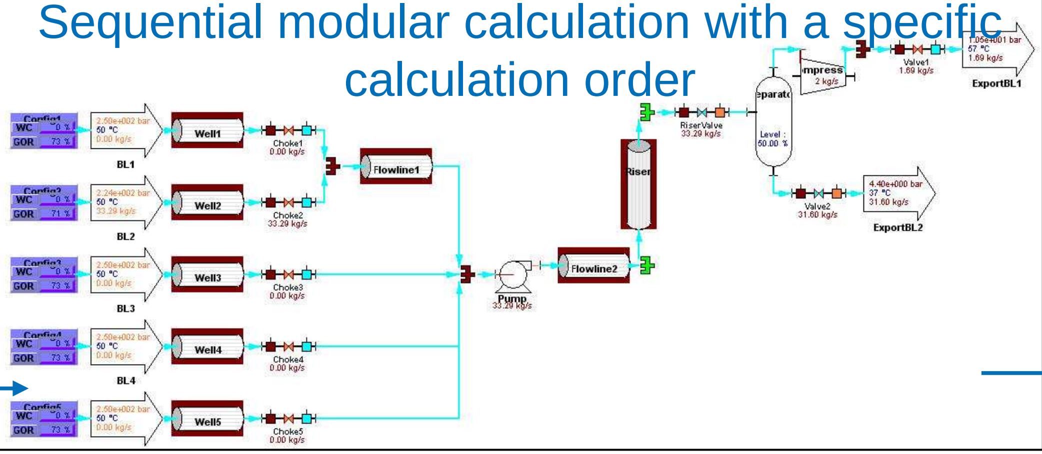
Problem statement

- Network variables: x
  - Unit operation parameters (ex: choke opening), pressure, flow rate, partial flow rate, ...
- Function to optimize: f(x)
  - Min of cost, max of Net Present Value, max of production, ...
- Equality constraints
  - $N(y) = 0$, $y \subset x$, network equations
    - Conservation equations, recycling equations, homogeneous pressure at nodes, ...
  - $Z(x) = 0$, other specifications
- Inequality constraints
  - $C(x) \leq 0$
  - Lower bound $\leq x \leq$ Upper bound

Problem statement

- Solving mechanism: a sequential modular approach and an "Unfeasible path" strategy

Sequential modular calculation with a specific calculation order



x for new estimate

or

x+dx for gradient estimate

C(x), Z(x), N(y), f(x)

Optimizer

C(x) ≤ 0 ? Z(x) = 0 ? N(y) = 0 ?

Lower bound ≤ x ≤ Upper Bound ?

min f(x) ?

Optimizer integration

- OPTI module: optimizer
  - Native optimizer of ProSimPlus PME (ProSim SA)
  - Applied to convergence of NLP optimization problems
    - Designed for a sequential modular approach
    - Unfeasible path strategy is recommended
  - Jacobian Matrix is estimated by numerical differentiation
    - Physical models are complex and implicit therefore analytical derivatives are not available

- OPTI wrapped as a CAPE-OPEN unit operation (CO-OPTI)
  - Specific parameter to check the optimizer convergence
  - Data transfer using CAPE-OPEN information streams

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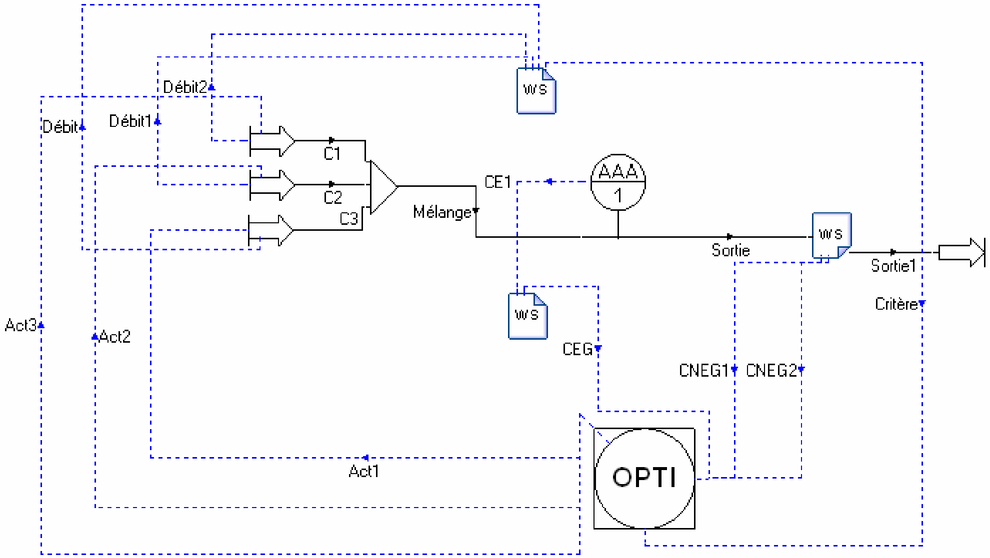
Optimizer integration

- INDISS PME has been adapted: INDISS-TINA
  - To check the convergence of the optimizer
  - To manage tear streams solved by CO-OPTI
  - To establish convenient calculation order
    - CO-OPTI made last UO in the maximum recycle sequence

- CO-OPTI *ICapeUnit.Calculate( )* method
  - Retrieves values of constraints and objective function through information streams
  - Transfers data to OPTI that gives new iterative values in return
  - Updates CO-OPTI outputs variables with the new iterative values
    - Including recycle material streams which are flashed
  - Updates the convergence status (flag parameter)

Validation on a simple linear problem

- Within ProSimPlus PME
  - ProSimPlus is a CAPE-OPEN compliant PME
  - Native OPTI module in ProSimPlus and CO-OPTI used as CAPE-OPEN UO in ProSimPlus give identical results
- Within ProSimPlus and INDISS using CO-OPTI as a CO UO
  - Convergence path and final results are identical in both PMEs



Case study

- Cost optimization of a sub-sea production system
  - Target function: minimize the design cost of the system
  - Cost of pipe installation + cost of multiphase pump

$$C_{Line} = L\left(\alpha D^{2} + \beta D + \gamma\right)$$

$$C_{Pump} = A + B\, W_{Pump}^{C}$$

$$W_{Pump} = Q\ \Delta P$$

  - Optimization parameters
    - Line diameter
    - Pump useful power (or differential pressure)
  - Equality constraint (operational constraint)
    - Topside arrival pressure equal to 15 bars
  - Inequality constraints
    - Maximum Pump useful power: 1.2 MW
    - Line diameter: from 8 to 12 inches

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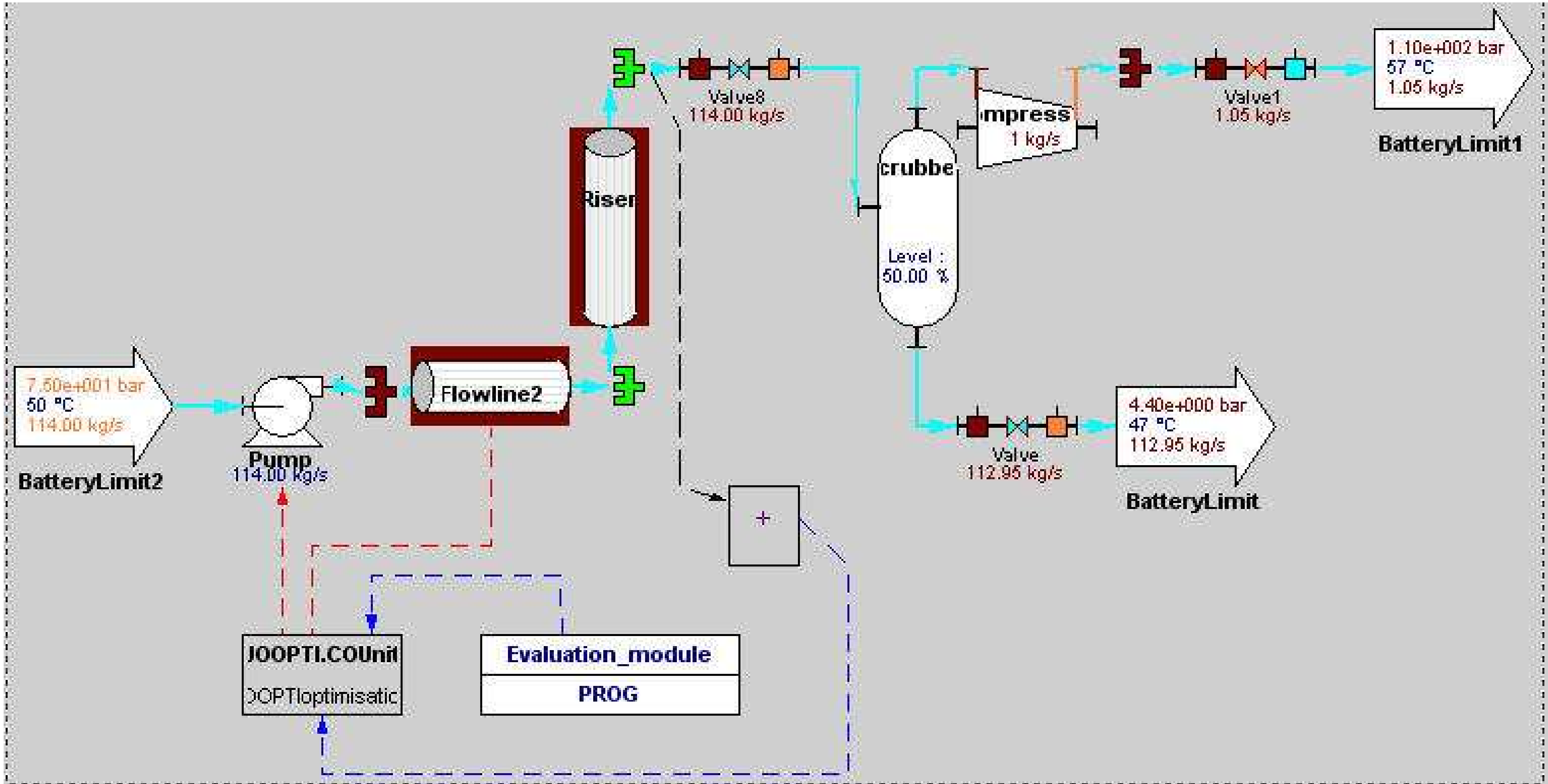
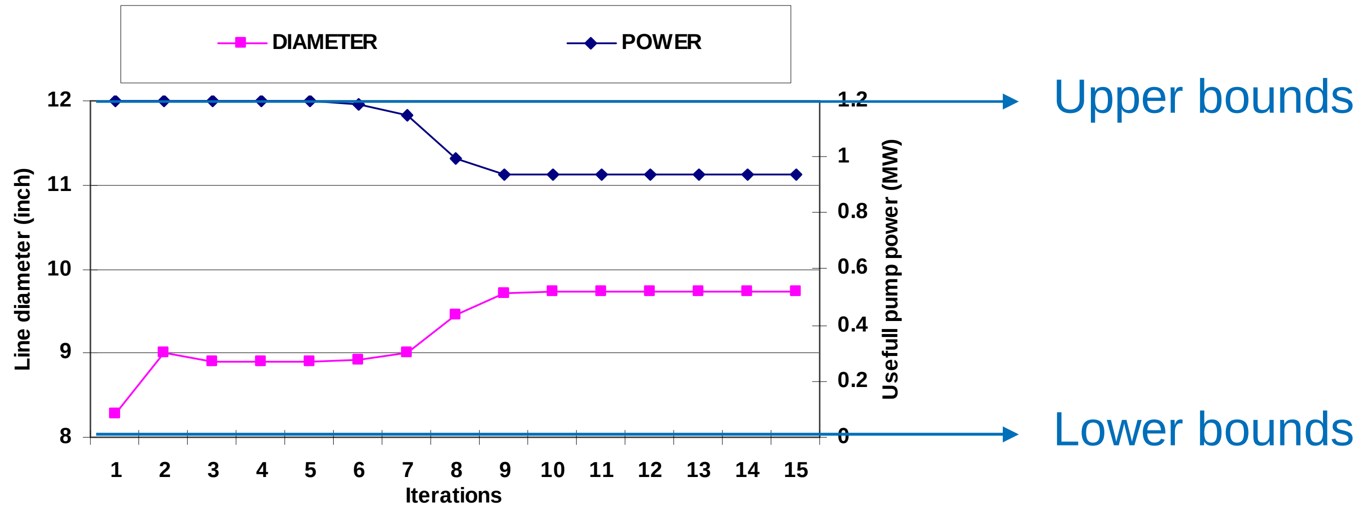
Case study

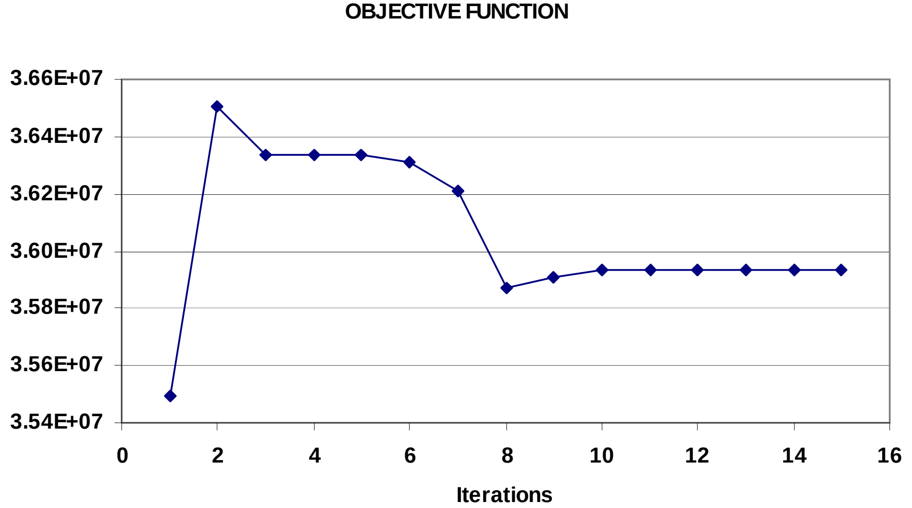
- Demo: CO-OPTI within INDISS-TINA

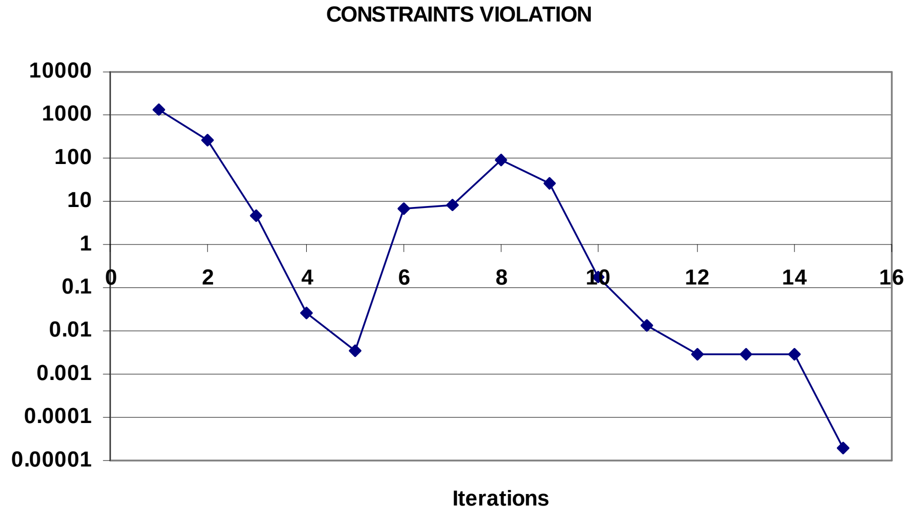


Case study

- Results







Conclusion

- CO-OPTI integrated and used successfully in INDISS as a CAPE-OPEN Unit Operation
  - Use of CAPE-OPEN specifications has reduced development time for integrating CO-OPTI into INDISS-TINA
    - CO-OPTI easily plugged into INDISS-TINA PME
    - Recycle material streams easily handled
    - CAPE-OPEN information streams useful for data transfer

- CAPE-OPEN enables optimizer integration in sequential modular PMEs

Thank you for your attention

- Acknowledgements to TOTAL, RSI, ProSim SA for their contribution to this work

- Questions?

- Additional explanations will be provided tomorrow morning during the CAPE-OPEN Interoperability Workshop session

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Case study

- Sensitivity study to the transportation distance
  - Optimizations are performed for several distances
    - 5, 10, 15, 20 and 25 km
  - Three design options
    - <u>Option 1</u>: system designed with the maximum specified pipe diameter (Pipe diameter of 12 inches),
    - <u>Option 2</u>: system designed with the maximum pump unit capacity (Pump unit of 1.2 MW),
    - <u>Option 3</u>: optimum solution calculated by CO-OPTI

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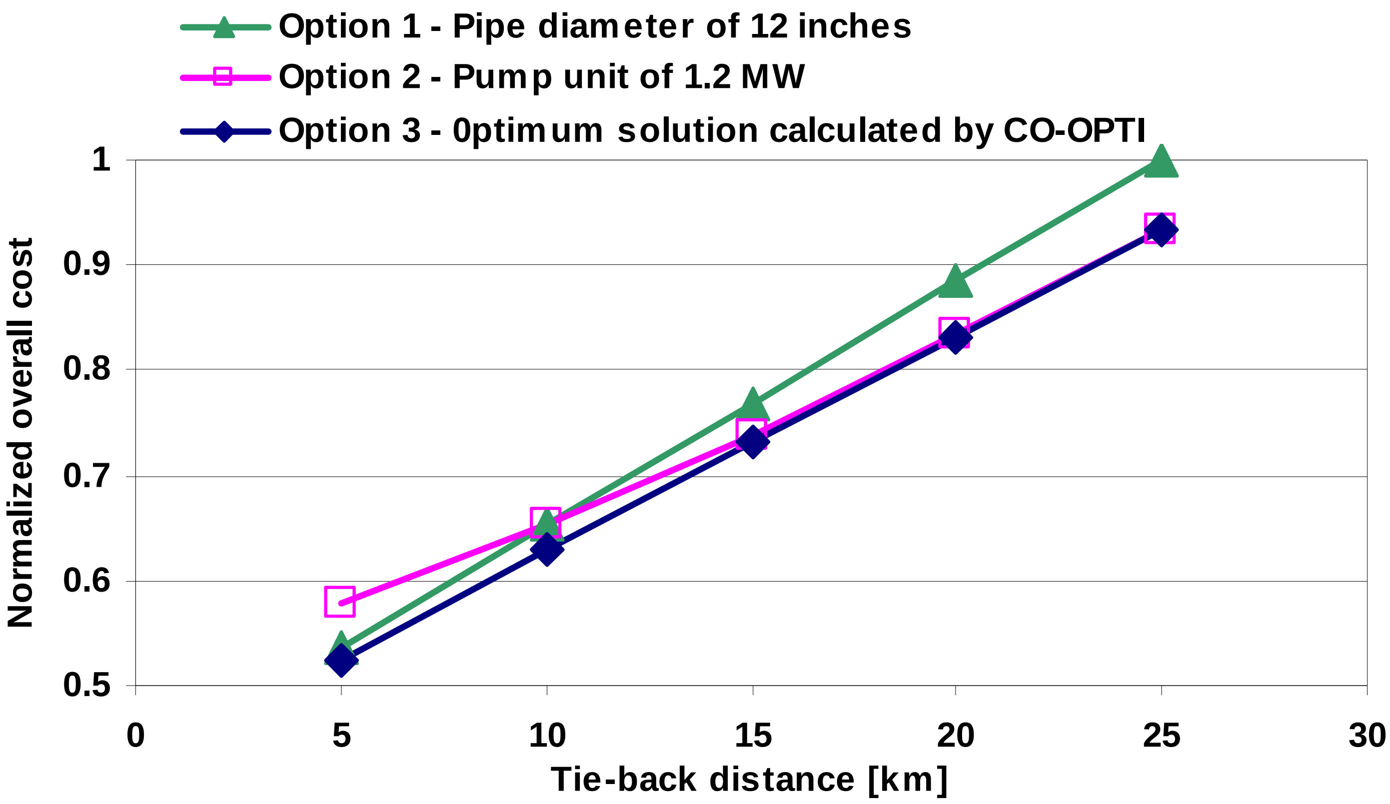
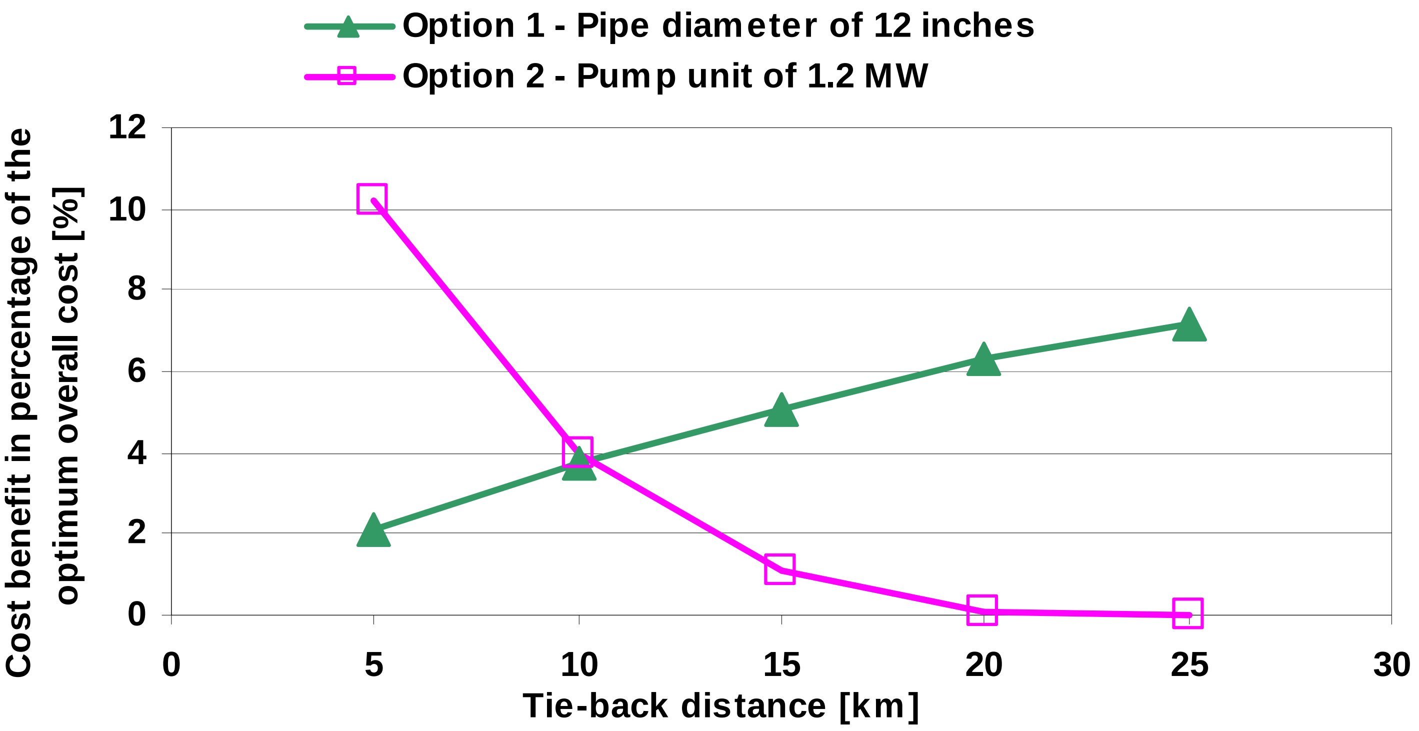
Case study

- Normalized overall cost



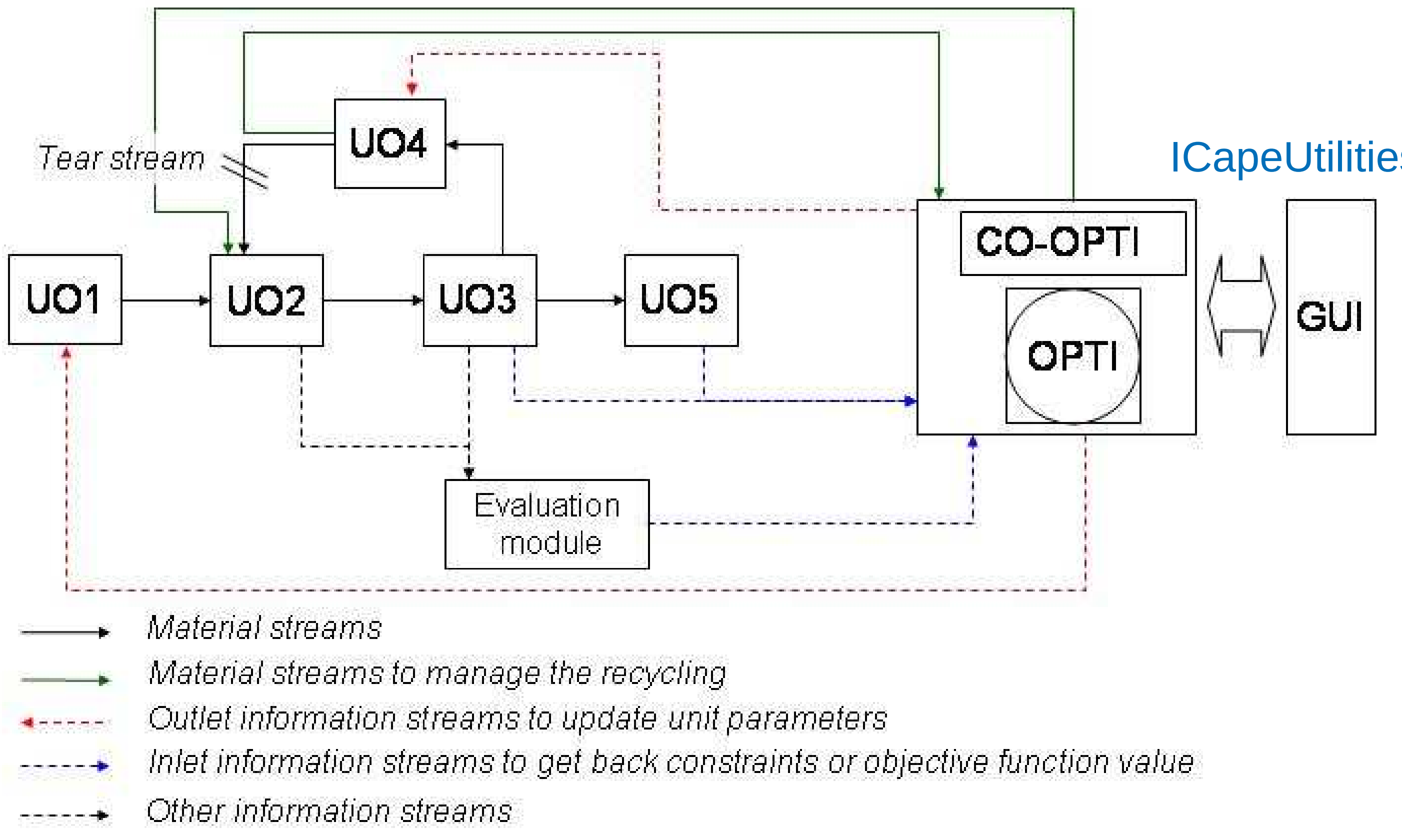
Case study

- Over cost in percentage of the optimum cost



Optimizer integration

- Schematic view



ICapeUtilities.Edit

- Calculation order
  - {UO1, UO2, UO3, Evaluation module, UO5, UO4, CO-OPTI}