Robust implementation of optimal operation of LNG refrigeration cycles

Alexander Leguizamon
Supervisor: Sigurd Skogestad
Co-Supervisor: Adriana Reyes Lua

Norwegian University of Science and Technology, NTNU
Specialization Project

16.12.2015
Figure: Mini LNG Configuration  [Neksået al., 2010]
Process Description

Figure: Simplified mini LNG PFD
Objective: Propose a model for optimization

Criteria for the model

- Reliable
- Robust

Approach

- Software: Aspen Hysys® or Matlab
- Modular Sequential or Equations Oriented

The models (except for the thermodynamics) are made from scratch
The units used simplified models
Figure: MiniLNG PFD showing the operation degrees of freedom for the model
Figure: MiniLNG PFD showing the main assumptions for the model
The properties of the refrigerant and the gas are modelled using Soave’s modification of the Redlich-Kwong equation of state [Soave, 1972].

Flash calculations algorithms, based on [Skogestad, 2014]:

**Implicit compressibility calculation**

- Input: \( h_f, P, z \) and estimates of \( x, y, v_f, T \)
- Extract input data
- Solve SRK
- Simultaneous solution
- Fmincon
- Output: \( x, y, v_f, T \)

**Explicit compressibility calculation**

- Input: \( T, P, z, (h) \) and estimates of \( x, y, v_f, Z_v, Z_l, (T) \)
- Extract input data
- Solve: VLE, CEOS (Energy Balance)
- Simultaneous solution
- Fmincon
- Output: \( x, y, v_f, (T) \)
Simulation results: The model in Matlab was consistent with the results from Aspen Hysys®

P-H Diagram for the Refrigerant

Dew Point $z_1$
Bubble Point $z_1$
Dew Point $z_2$
Bubble Point $z_2$

$z_1$
$z_2$
Conclusions

- It was possible to proposed a model reliable enough for the conditions described by [Nekså et al., 2010]
- The model is robust enough for points that are far enough from the two phase boundaries. However, for points in which there can be one or two phases, the model requires a more careful initialization.
- An initial framework using the degrees of freedom analysis towards the optimization was done.
Further work

- Improve the robustness of the model towards optimization
  - Implement the model as a fully equations oriented model
  - Further improve the flash calculations for points close to the change phase boundaries
- Further define the optimization problem
  - Maximum capacity or optimal energy consumption. This can lead to modifications in the degrees of freedom analysis
- Optimize the plant


Thanks for you attention!