The impact of process design decisions on operability and control of an LNG process

Finn Are Michelsen
Berit Floor Lund
Ivar J. Halvorsen

SINTEF ICT
Department of applied cybernetics

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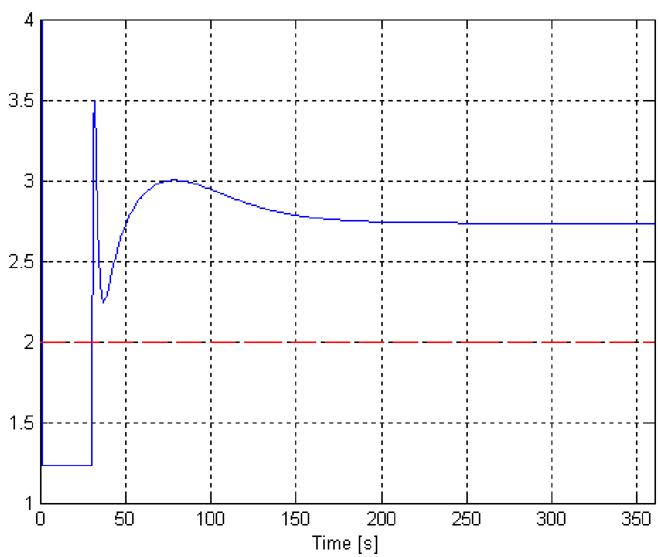
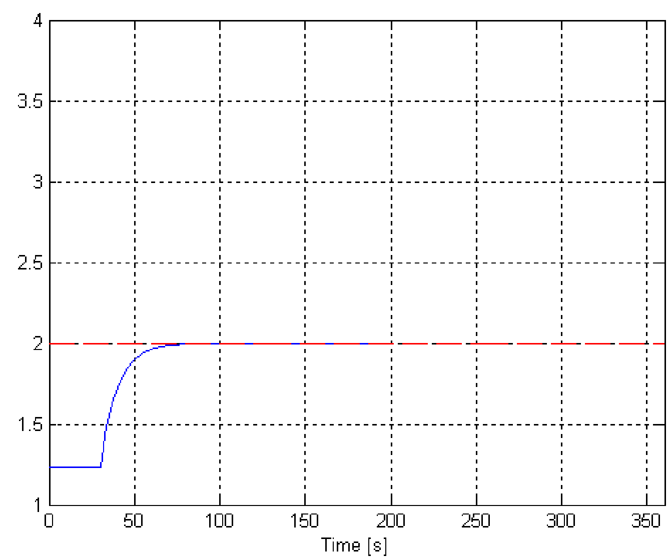
Operability

- The ability (goodness) of a system to be operated as required.
- In process operation, this means whether it is possible to bring the process to different steady state conditions (steady state requirements), by as smooth and fast transition as possible in order to minimize deviations (dynamic requirements) to obtain minimum costs.

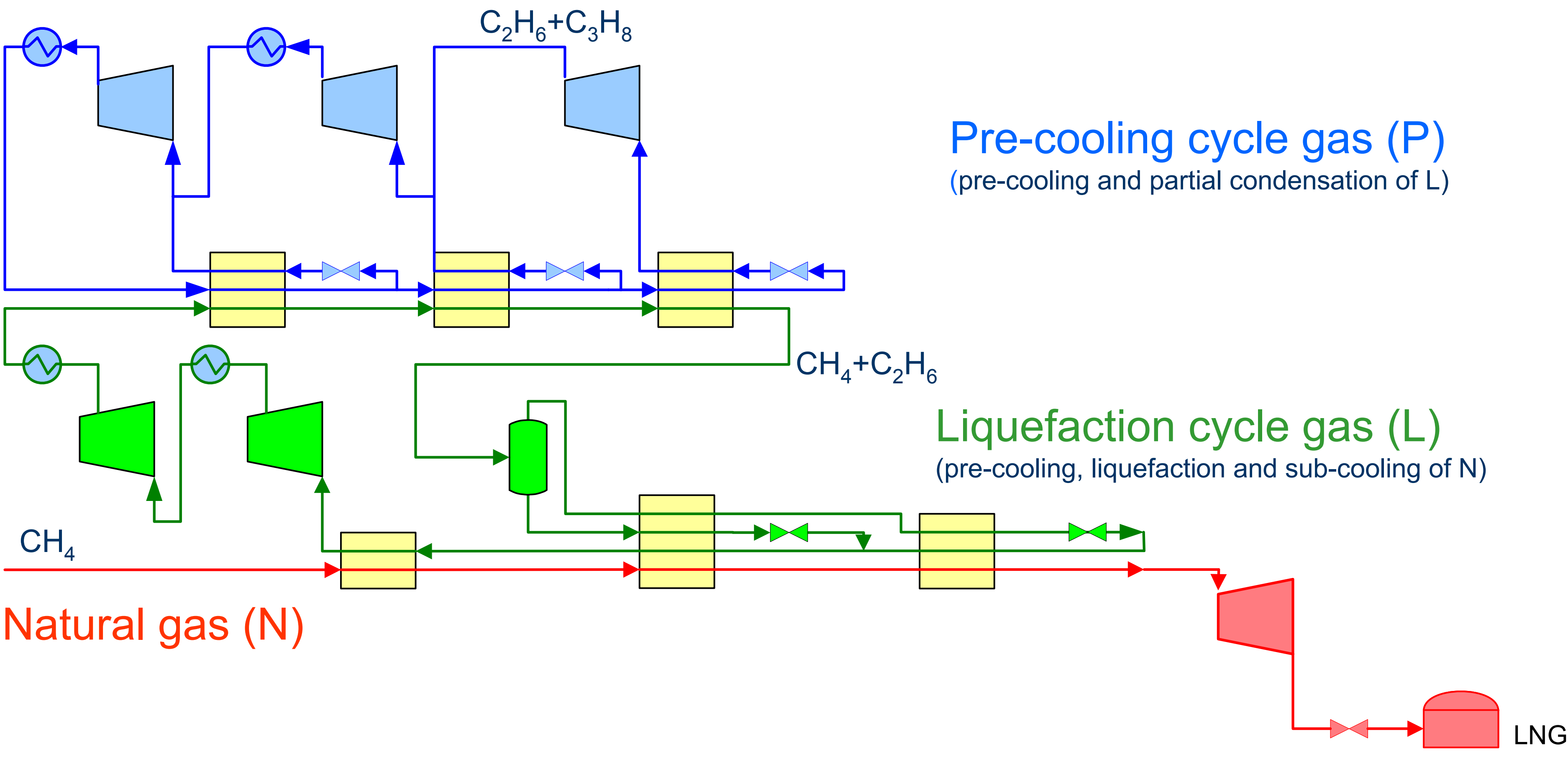




Outline

1. TEALARC LNG plant (Paradowski and Dufresne, 1983), project “Enabling Production of Remote Gas”
2. The impact of process design decisions on optimal control variables using self-optimizing control analysis
3. The impact of process design decisions on dynamic responses
4. Conclusions

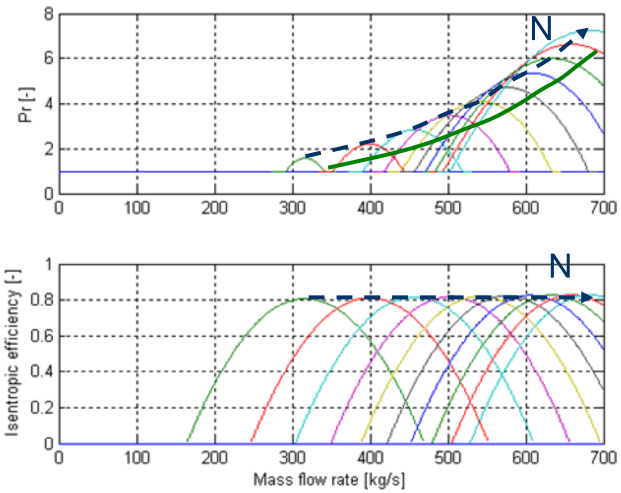
Tealarc LNG plant



Dynamic control relevant model

- Computationally light (bulk flow,..)
- An input-output **causal** dynamic model
- Compressor and expansion valve models defined around a nominal point adapted to steady state Hysys model data

Compressor chart:



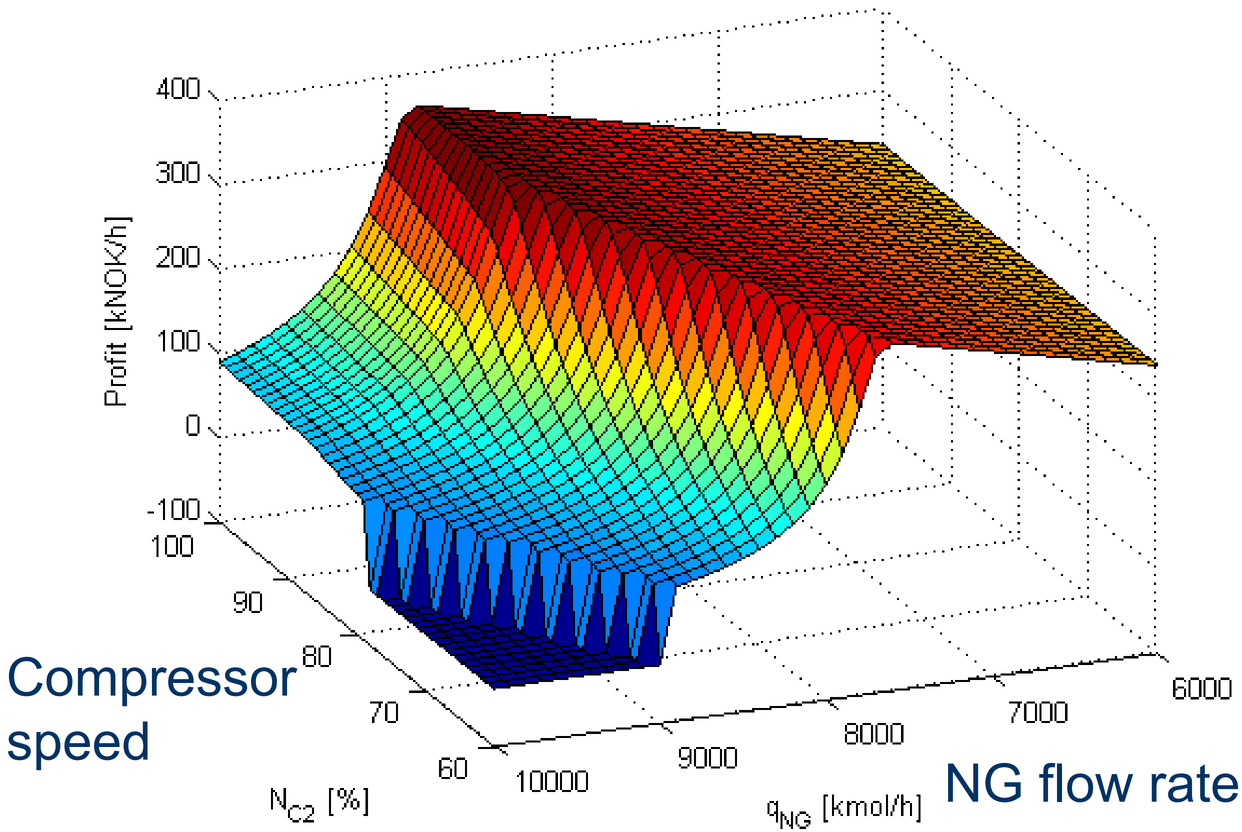
Expansion valve:

$$q = C_V \cdot f(u) \cdot \sqrt{|\, p_u^2 - p_d^2 \,|}$$

Cooling capacity

The cooling capacity is the total capacity of the cooling loops at the optimal production rate.

At higher production rates the cooling loops are not able to cool down to the temperature of liquefaction of the natural gas.



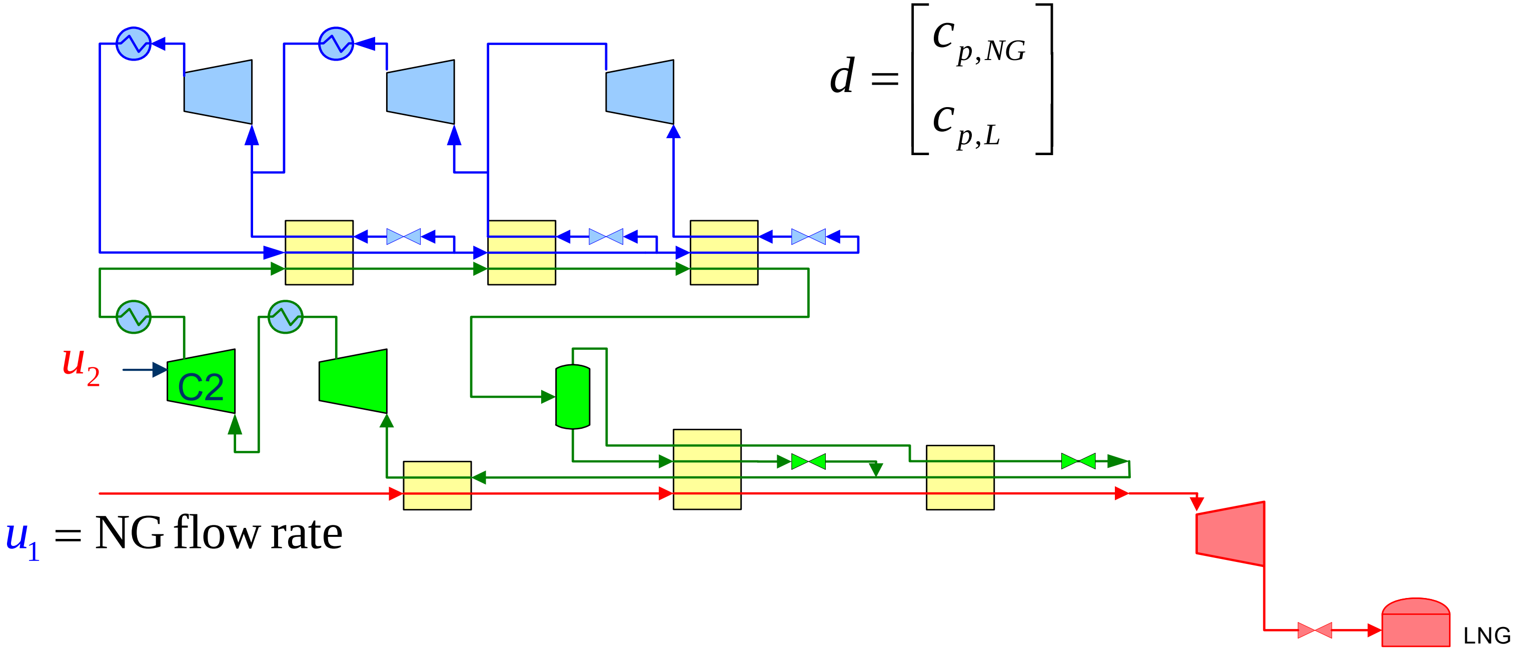
Case 1

- All units operate at constant settings (at constraints)
- NG flow rate available for control

Case 2

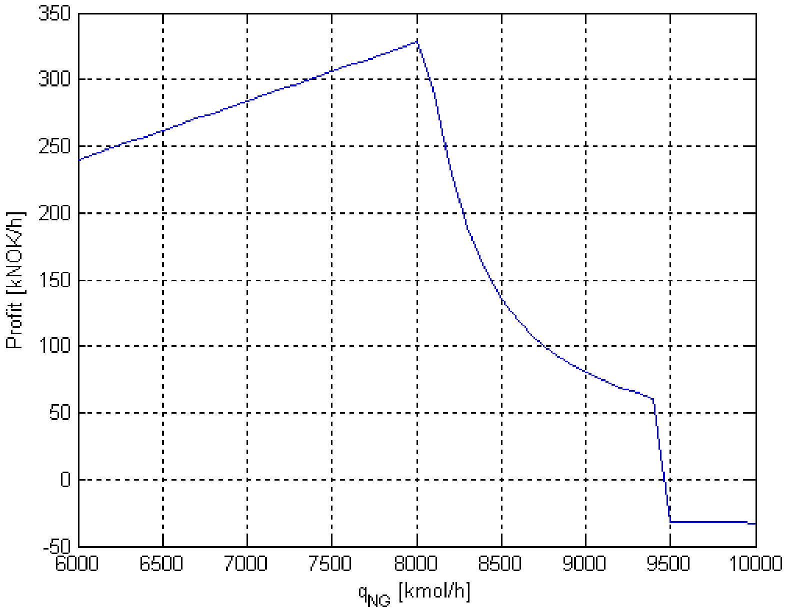
- The NG flow rate is constant
- The compressor speed for C2 is available for control (larger compressor than in case 1)

$$d = \begin{bmatrix} c_{p,NG} \\ c_{p,L} \end{bmatrix}$$

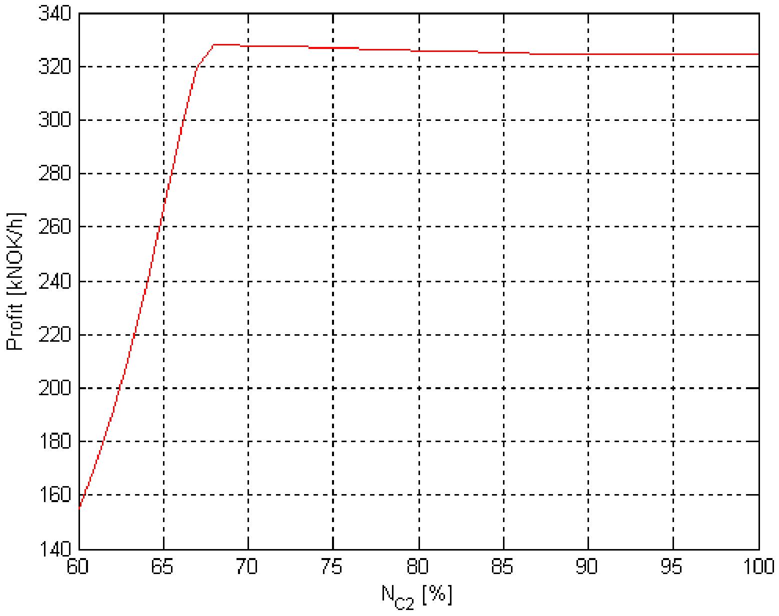


The profit as function of NG flow rate and compressor speed

Case 1:

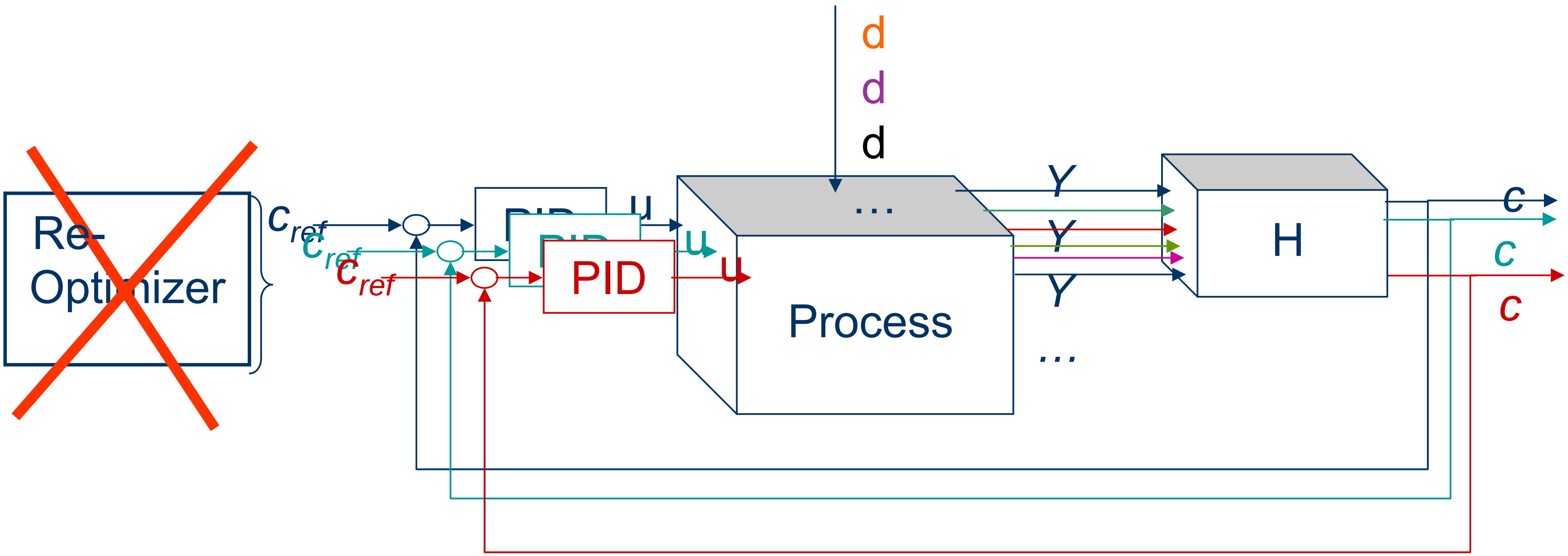


Case 2:



The optimum is located at 8000 kmol/h NG and 68% compressor speed. Profit ≈ 328 kNOK/h as in case 1.

Self-optimizing control



Self optimizing control involves methods for selection of controlled variables in order to make the *optimal* plant operation robust to presence of disturbances and model uncertainties at constant setpoints.

Optimal measurement combinations

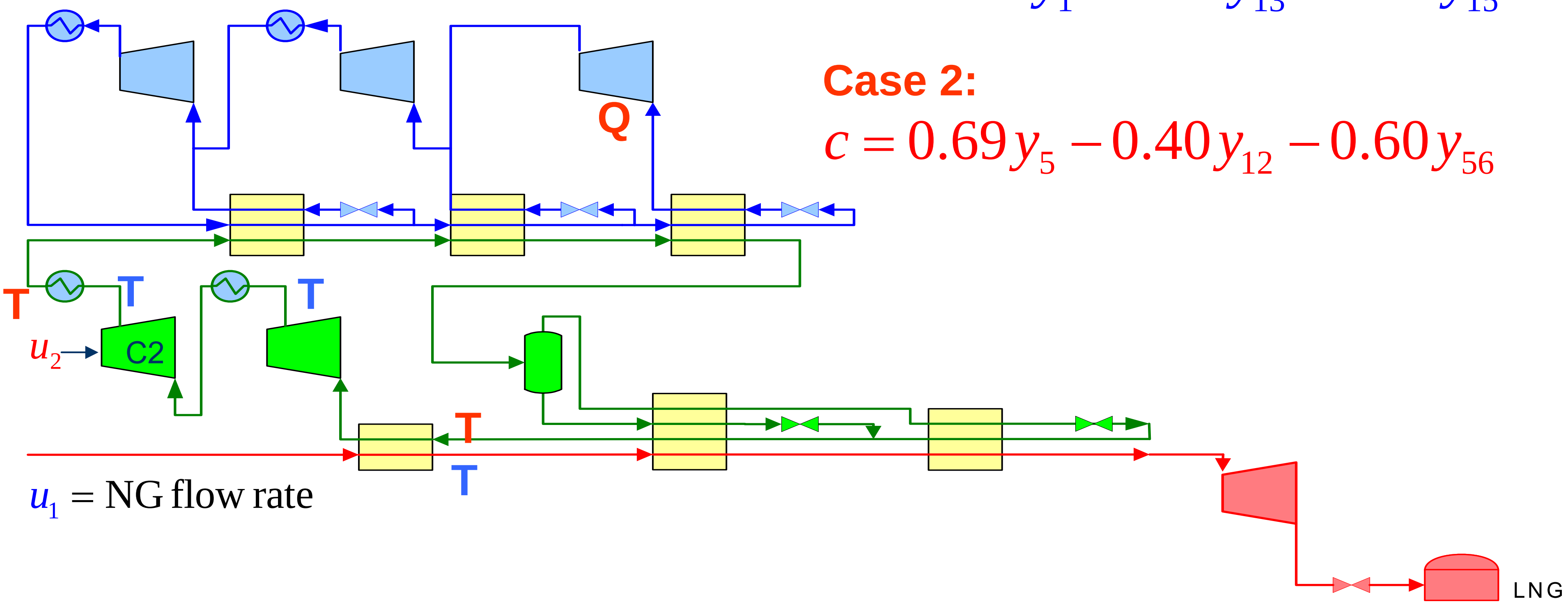
A capacity increase, moving the plant bottleneck from a compressor (using the NG flow rate as manipulated variable for control) to the NG flow rate (using the compressor speed as manipulated variable for control), gives different optimal combinations of measurements as controlled variables:

Case 1:

$$c = -0.77 y_1 + 0.44 y_{13} + 0.46 y_{15}$$

Case 2:

$$c = 0.69 y_5 - 0.40 y_{12} - 0.60 y_{56}$$



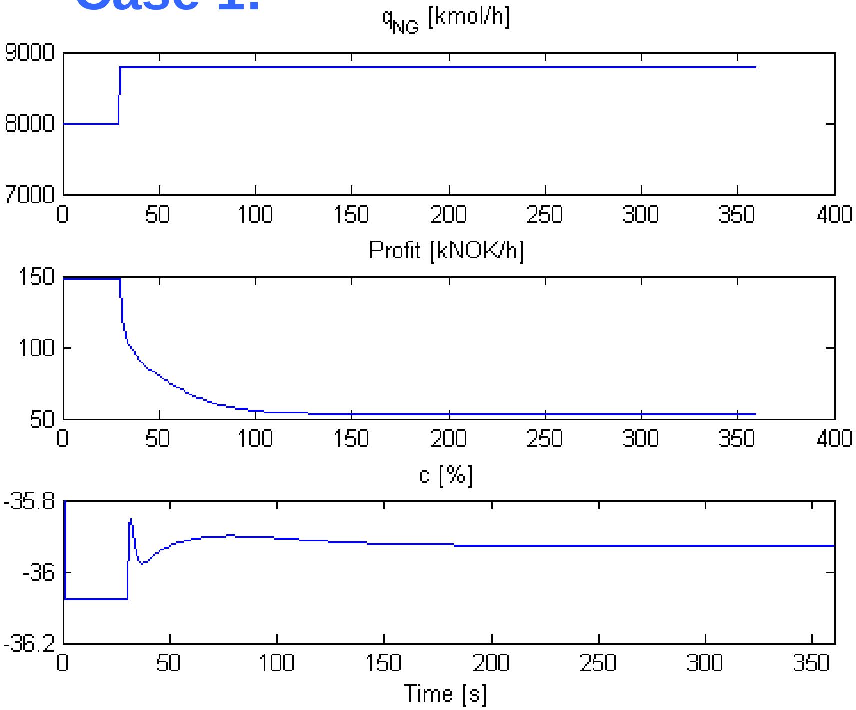
u_2

u_1 = NG flow rate

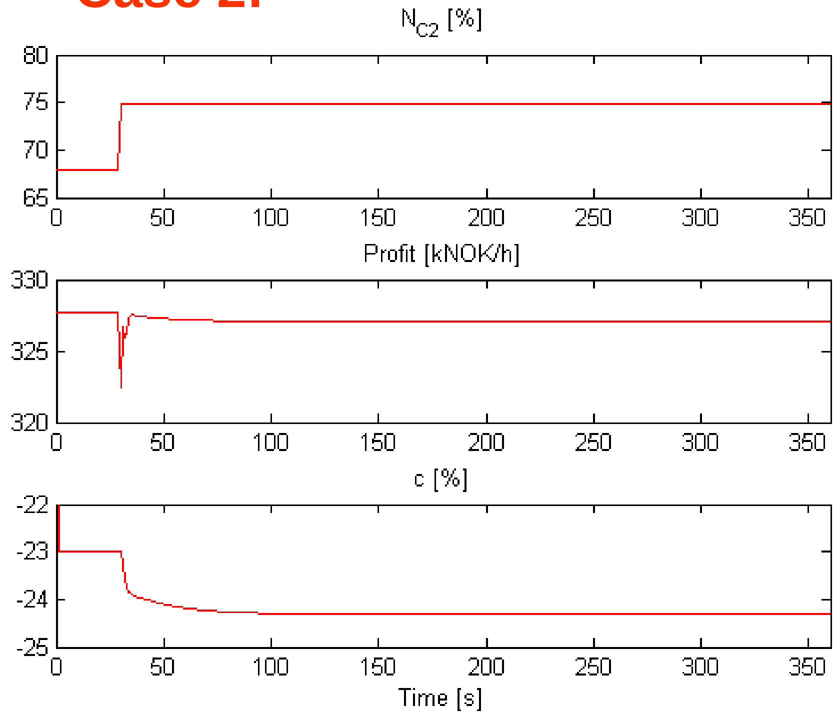
Dynamic step responses

10 % step in q_{NG} and N_{C2}

Case 1:



Case 2:



Conclusions

- A change in process constraints may influence control design and operability by:
  - Changing what to control (i.e. the optimal combination of controlled variables)
  - Affecting the ease of control (affecting the dynamic order)
- The model for control design can also be used to evaluate more detailed design of process units:
  - Analyse sensitivity from design parameters to controllability
  - Identify critical parameters, e.g. heat exchanger sizing, compressor sizing.

A systematic procedure for **integrated process and control design** can improve both design and operation. This area should be further explored.