Mathematical model of flexible multi-energy industrial prosumer under uncertainty

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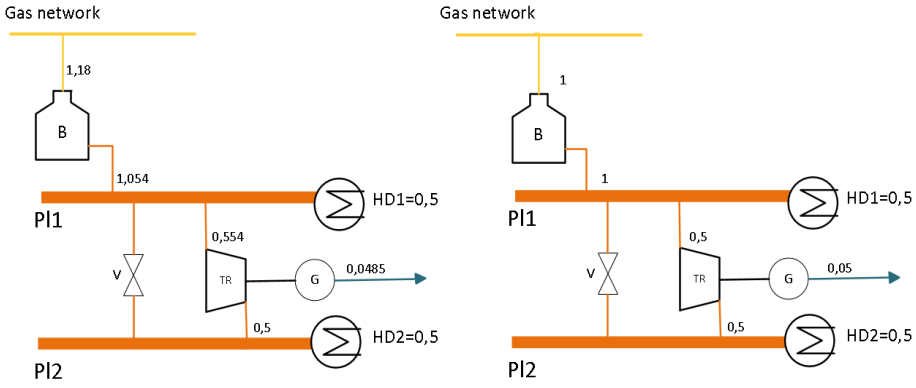
Introduction (1)

- Energy intensive industrial prosumers
- Multi-energy systems:
  - Electricity
  - Gas
- Electricity production: back pressure turbines
- Stochastic variables: price, consumption
- Market bidding
  - Day-ahead market
  - Intra-day market

Introduction (2)

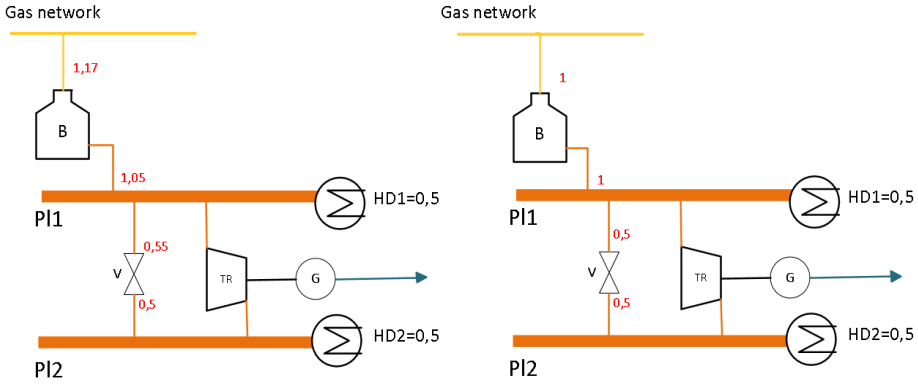
- Two-stage stochastic mixed integer linear program with recourse
- Objective: cost reduction
- Python
- Gurobi optimization solver
- Contributions:
  - Energy flow
  - Stochastic approach

Energy flow



Energy Flow Mass Flow

Fig.1 Energy and mass flow through turbine



Energy Flow Mass Flow

Fig.2 Energy and mass flow through valve

Stochastic approach

- First stage
- Here and now
- Decision must be made before realization of stochastic process
- Scenarios:
  - Price of electricity
  - Consumption

- Second stage
- Wait and see
- Scheduling after the realization of stochastic process for each scenario
- Must follow first stage decisions

- Recourse
- Corrective scheduling after market closure
- Real prices and consumption
- Must follow first stage decisions

Case study (1)

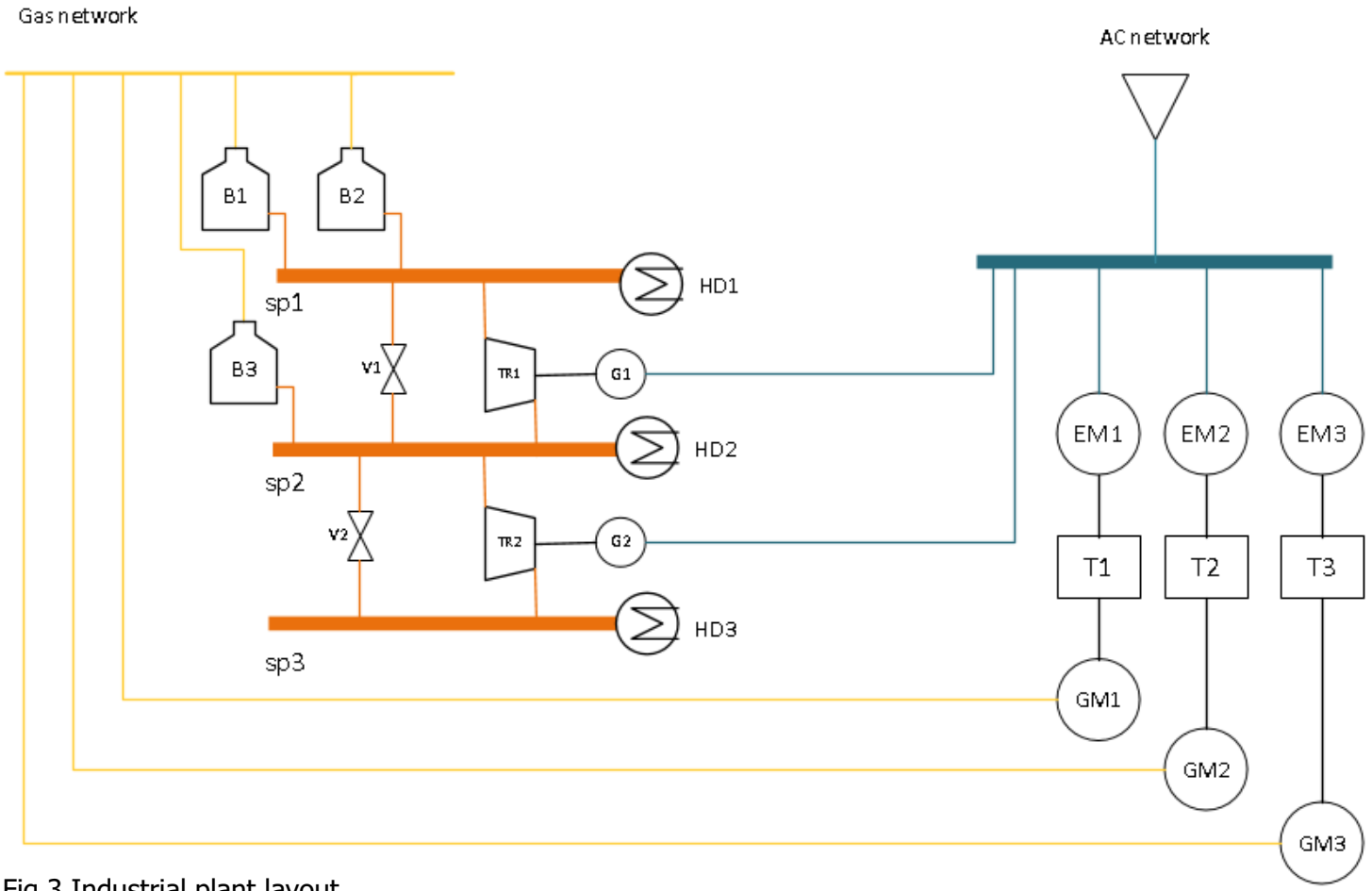


Fig.3 Industrial plant layout

Case study (2)

- 3 price prediction scenarios (PP)
- 3 price realization cases (RP)
- 3 consumption scenarios (C)

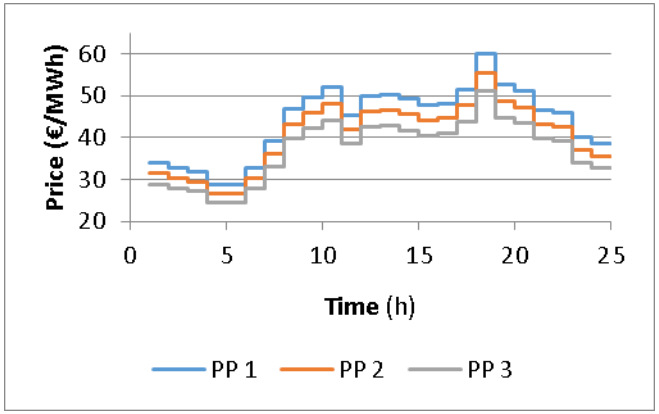


Fig.4 Price predictions

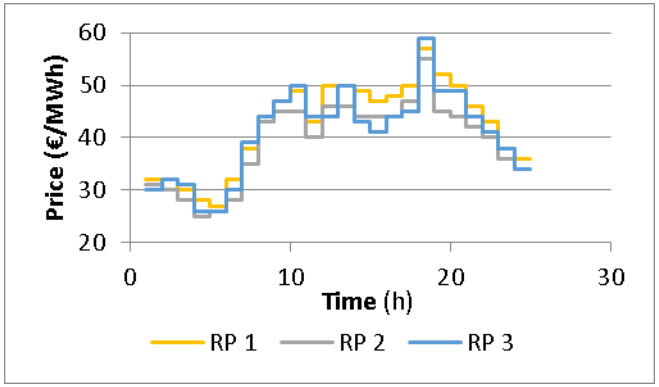


Fig.5 Price realizations

Test models (1)

- Efficiency and market model (EMM)
  - Goal: Plant's operation efficiency
  - Uses mass model
  - Doesn't take prices into consideration
  - Must compete on the day-ahead market
  - Recourse stage: only to calculate losses, balancing energy and real cost

Test models (2)

- Business as usual (BaU)
  - Doesn’t use optimization
  - Doesn’t have flexibility between electricity and gas
  - Predetermined devices
  - Must compete on the day-ahead market
  - Must balance it self on the intra-day market

Results (1)

- First stage:
  - Gas volume: 1194,99 MWh.
  - Electricity volume: fig. 6
- Second stage:
  - Average cost: 54061.45 €

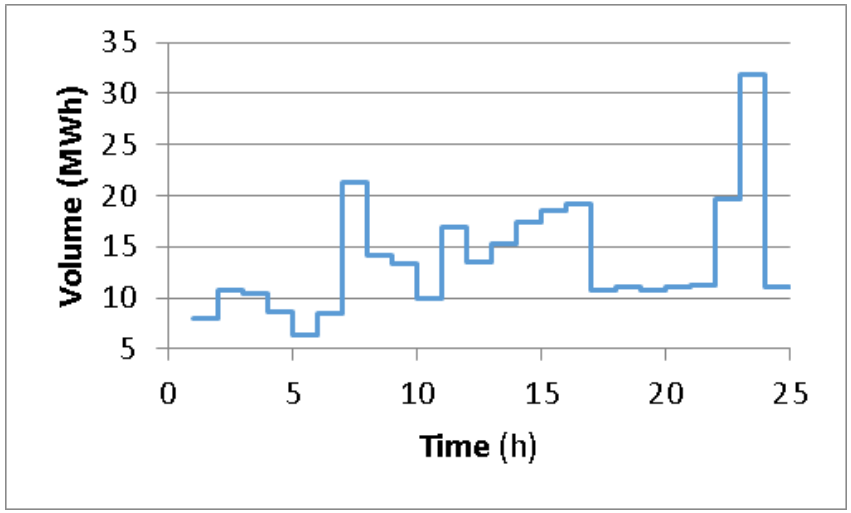


Fig.6 Volumes of electricity bought from day-ahead market

Results (2)

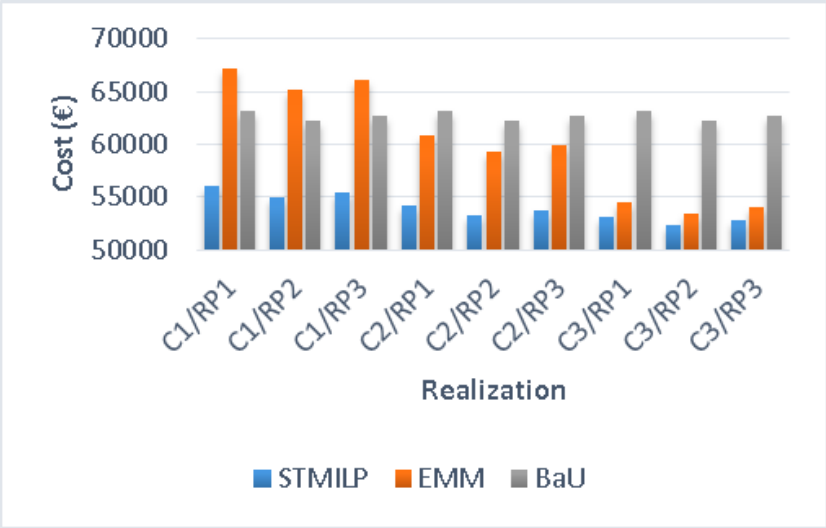


Fig.7 Total cost in recourse stage

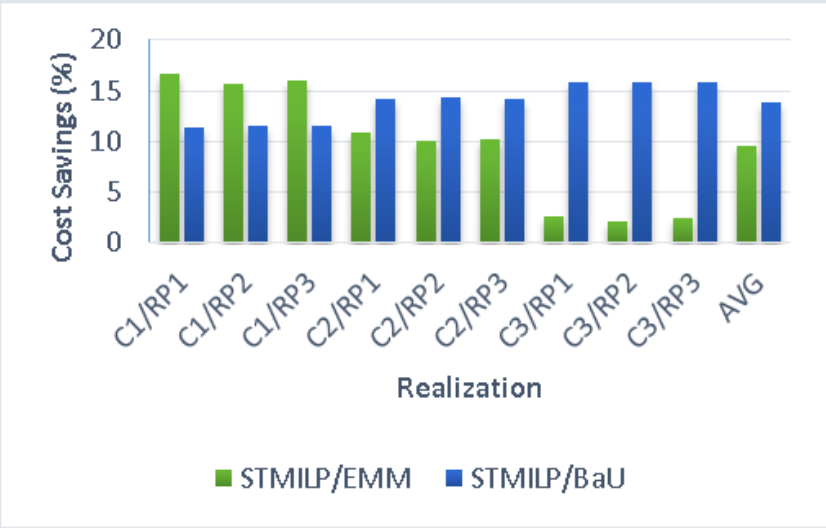


Fig.8 Total and average savings

Conclusion

- Energy flow:
  - Provides more realistic model
- Consumption scenarios:
  - Cover for variations in consumption
  - Lowers penalties
- Price scenarios:
  - Create favorable position on the market
  - Reduce effects of market variability
- Cost variation is reduced
- Saving:
  - Around 10-15% in total cost

What to watch for?

- Is optimization good?
- Realistic model:
  - Proper device models and input parameters
  - EMM average saving is 4% when compared to BaU
  - In some cases BaU is cheaper that EMM
  - EMM has high cost variability
- Predictions sensitivity:
  - Price predictions: can lead to unfavorable market position
  - Consumption scenarios: can lead to increased need for balancing on intra-day market

Acknowledgments

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