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Energy-SmartOps

Integrated Control and Operation of Process, Rotating Machinery and Electrical Equipment

Optimisation of industrial compressor stations with centrifugal compressors employing data-driven models and detailed modeling

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Statement of the problem

Industrial compressor stations are used for compressing gases to high pressures in petrochemical facilities or compressing air in large plants [1]. These compressor stations usually comprise of several centrifugal compressors. Electric motors, which power the centrifugal compressors, consume large amounts of energy. This energy can be significantly minimised by optimising the control strategy of the compressor stations without changing the initial equipment.

Fig. 1: A multistage centrifugal compressor [3]

***Key points of this work*:**

- Use of Real Time Optimisation (RTO) to improve the performance of compressor stations.
- Use of both data-driven and meanline models [2] of centrifugal compressors.
- Investigation of a real industrial case study of an air separation plant at BASF. Fig.2 shows a simulation case study motivated by the case study.

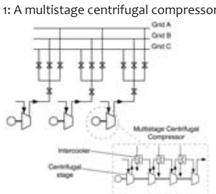


Fig. 2: Simulation case study of a compressor station supplying compressed air to three distribution grids

Objectives

Objective 1: Computation of best optimal set points for fixed configuration.

Objective 2: Integration of Real Time Optimisation and Scheduling.

Objective 3: Development of prototype industrial software.

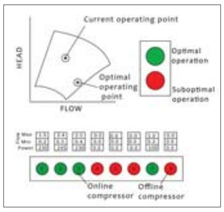


Fig. 3: GUI of the final software to help operators in decision making.

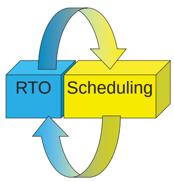
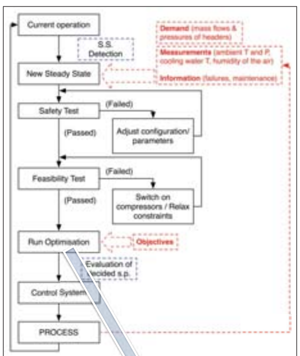


Fig. 4: Integration Real Time Optimisation of load sharing of the compressors and Scheduling (maintenance, cleaning).

Methodology



Optimisation variables to be manipulated:

- Mass flow of air: $m_{a,i}$
- Discharge pressure: $p_{out,i}$
- Mass flow of the cooling water: $m_{w,i}$
- Switching on/off a compressor: $y_{i,j}$

$i=1,..,N$ & $j=1,..,M$

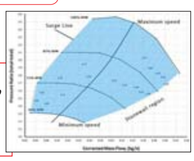
N: # of Compressors, M: # of Headers

Data-Driven models | Mean-line models

Formulation of optimisation problem

MINLP solver (GAMS™, gProms™)

Constraints (mass balances, surge, choke, pressures, operational constraints)



Results

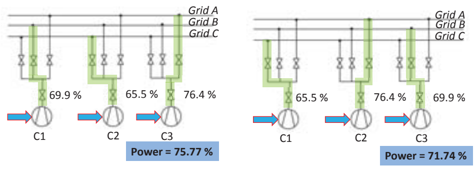
***Description*:**

- Each compressor supplies only one grid.
- Water flow of intercoolers is fixed at 60.42 %.

***Users' demand*:**

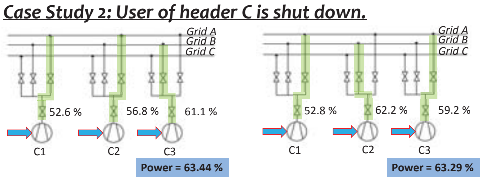
	A	B	C
Mass Flow	76.4 %	69.9 %	65.5 %
Pressure	87.0 %	92.8 %	85.5 %

Case Study 1: Switching of compressors is not available.



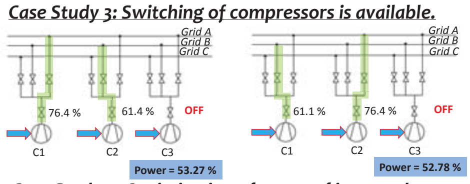
A	B	C
76.4 %	69.9 %	65.5 %
87.0 %	92.8 %	85.5 %

Case Study 2: User of header C is shut down.



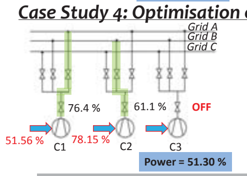
A	B	C
76.4 %	61.1 %	0 %
87.0 %	92.8 %	85.5 %

Case Study 3: Switching of compressors is available.



A	B	C
76.4 %	61.1 %	0 %
87.0 %	92.8 %	85.5 %

Case Study 4: Optimisation of water of intercoolers.



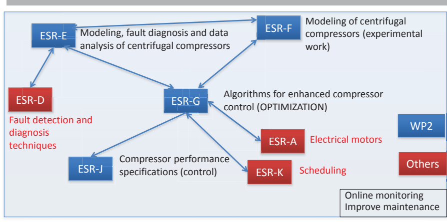
A	B	C
76.4 %	61.1 %	0 %
87.0 %	92.8 %	85.5 %

Fig. 5: Optimal solutions derived from GAMS algorithms and a search method developed in C++.

Conclusions and future work

- ✓ The developed algorithms using data-driven models are robust.
- ✓ The optimal value of the objective function is influenced from initial guesses.
- Use the developed algorithms for more complex case studies.
- Test the developed algorithms in real case studies (BASF plant)
- Develop a structure of the scheduling of compressors over time.
- Develop heuristics for complex case studies to reduce search space for search methods.

Energy SmartOps context



Research objective 2:

Develop new algorithms for overall performance monitoring and control.

Work Package 2:

Turbomachinery

References

[1] Edgar T.F., Himmelblau D.M., Lasdon L.S, 2001, Optimisation of chemical processes 2nd Edition, McGraw-Hill International Edition, Chemical Engineering Series

[2] Cicciotti M., Martinez-Botas R., Geist S., Schild A., Thornhill N.F., 2012, Meanline models of centrifugal compressors for use in industrial online applications, Proceedings of ISFMFE 2012, Jeju, Korea, 24-27 Oct 2012

[3] www.v-flo.com

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