ITN ENERGY-SMARTOPS WORKSHOP "Optimization to provide energy savings by better integration of operations across the process-mechanical-electrical interfaces", LADENBURG, GERMANY, 22-24 Oct 2013.

Energy-SmartOps

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

Optimization of industrial compressor stations with centrifugal compressors employing data-driven models

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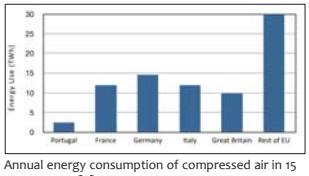
Compressor station in industry

Compressor stations comprise compressors, single or in series, operating in parallel. They are used in many industrial fields:

1) **Transportation of natural gas** (e.g. conveying natural gas through long pipes).
2) **Process systems** (e.g. providing compressed air for air separation process).
3) **Utilities** (e.g. providing compressed air for controls and actuators).

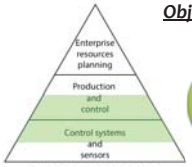
A compressor station [1].



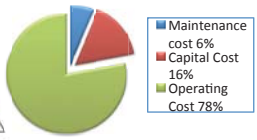
Annual energy consumption of compressed air in 15 EU countries [3].

A multistage centrifugal compressor [2].

Optimal operation of compressor stations

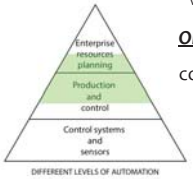


Objective 1: Short term optimization: Real time optimization:



Cost distribution of compressed air system within a life cycle[3].

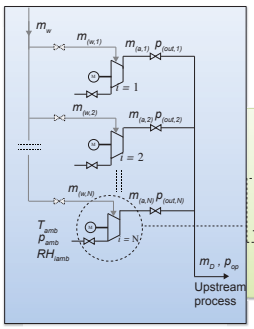
- Estimates optimal load sharing online.
- Monitors performance.
- Deals with disturbances.
- Applies only in steady states.



Objective 2: Long term optimization: Scheduling of the compressors:

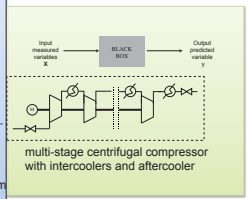
- Estimates optimal schedule of compressors.
- Improves maintenance plan.
- Decreases overall costs.
- Involves complex problems to be solved.

Short term optimization

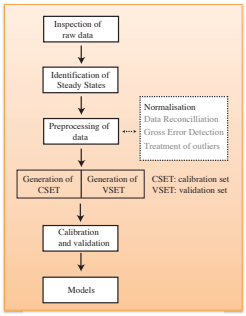


1. Compressors operating in parallel.

2. Develop black box models of each multistage compressor.



3. Use process data from past operation to develop regression models.



4. Optimize operation of compressors.

Min operational cost = Power consumption + Purchase cost of cooling water

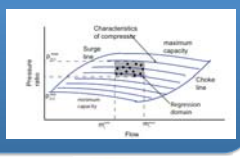
s.t.

Process models (regression models)

Feasible area of compressors (regression domain)

Operational restrictions

Boundaries of variables



Illustrative example

Description:

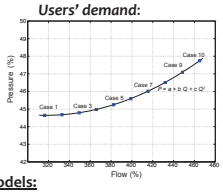
There are six industrial compressors operating in parallel: five of them have similar rate capacities, i1 has lower rate capacity than the others.

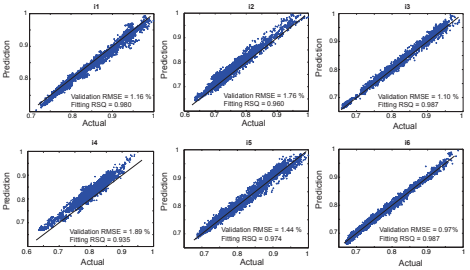
There are ten case studies for different demands.

The comparison between conventional practice, equal split of load, with the optimization method is presented.

All quantities are normalized and made dimensionless for reasons of confidentiality.

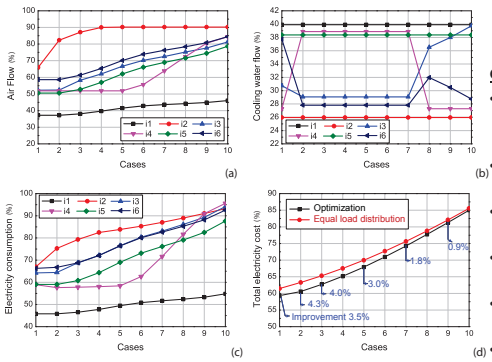
Users' demand:





Models:

- The values of the electricity consumption are scaled as a pecentage.
- A polynomial model used to estimate the electrical power consumed as a function of key process parameters such as inlet air and water flow, outlet pressure.
- Data of nine months of past operation is used for regression.
- The accuracy of the models can be improved with an adaptive parameter estimation algorithm. This is imperative for online applications.



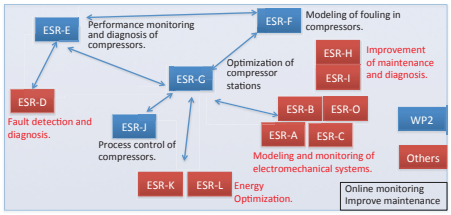
Optimization:

- The results show the distribution of load and water flow of each compressor.
- The most efficient compressor i2 operates close to its limit.
- Compressor i1, with the least efficient control, contributes at a low flow rate.
- Performance of compressors is expressed implicitly.
- There is higher benefit in lower demands.
- This is because of higher flexibility of the compressors.

Conclusions

- ✓ The methodology of this work is transferable and can be applied to compressor stations generically.
- ✓ The optimization achieved a reduction in energy consumption compared to current industrial practice.
- ✓ The processing of the process data influences the optimization results. The tuning of the parameters of the filters has to be investigated further.
- ✓ The offline analysis highlighted the potential for online applications such as Real Time Optimization. This is the next step after this work.

Energy SmartOps project



Research objective:

Develop new algorithms for overall performance monitoring and control.

Work Package 2:

Turbomachinery

References

[1] Gazprom; ww.gazprom.com; accessed 16:09:2013.

[2] V-FLO Group of Companies; www.v-flo.com; accessed 16.09.2013.

[3] Saidur, R., Rahim, N.A., Hasanuzzaman, M., 2010, "A review on compressed-air energy use and energy savings," Renewable and Sustainable Energy Reviews, Vol. 14, pp. 1135-1153.

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