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The power storage potential of the natural gas infrastructure
Using electric compressor drives for levelling renewable energy's fluctuations

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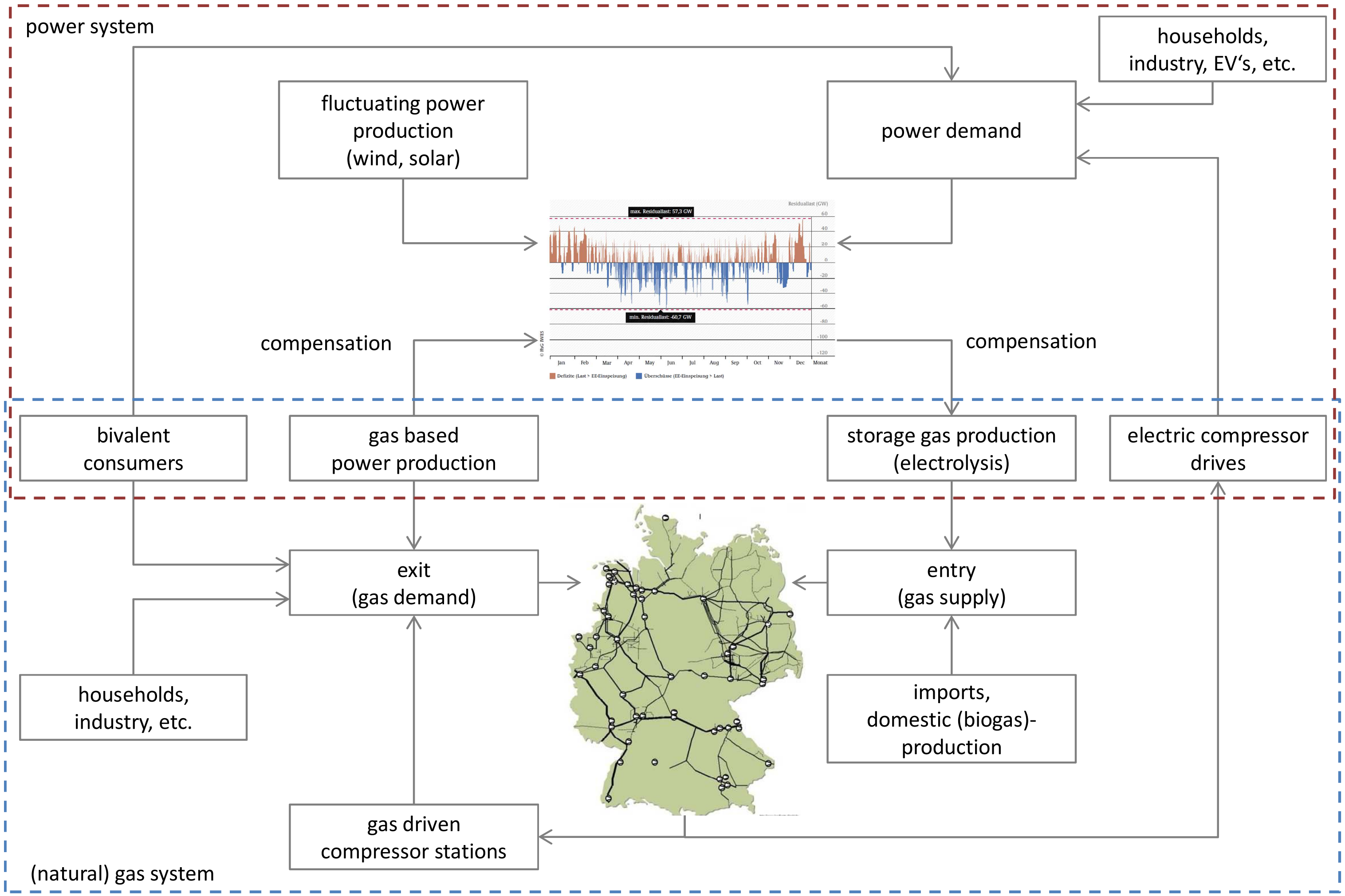
Photo: Wingas AG

- Motivation and research questions
- Background
- Assessing the power storage potential of electric compressors
- Tax and regulatory aspects
- A European perspective
- Conclusions

Gas-power-interconnectors: stabilizing renewable energy fluctuations in the power infrastructure via the gas infrastructure



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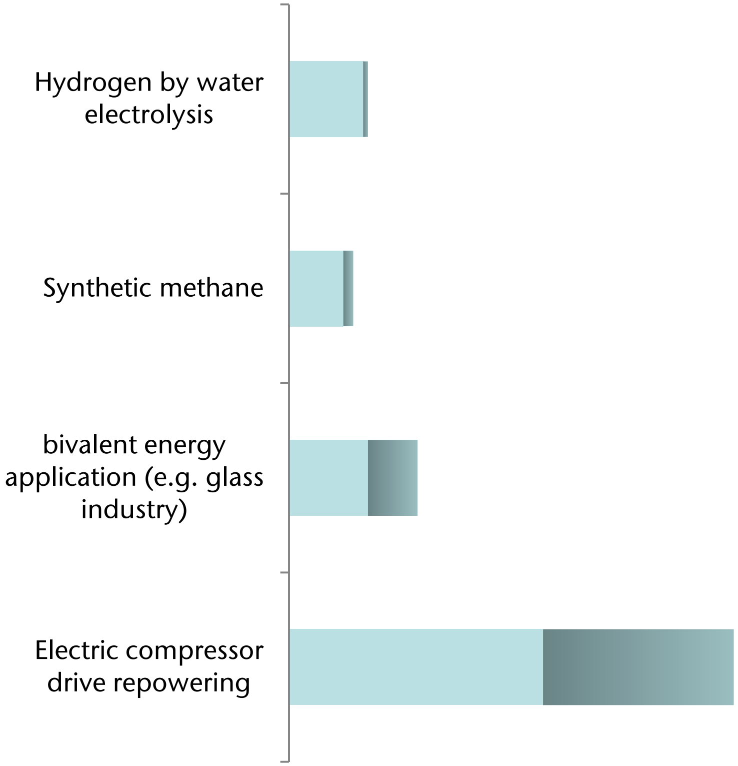
Residual load curve taken from Umweltbundesamt (2010): „Energieziel 2050: 100% Strom aus erneuerbaren Quellen"

Replacing gas drives with electric drives in the gas infrastructure: A hidden power storage resource



The electric drive repowering of compressor stations may be compared to storing electricity by means of water electrolysis.

Depending on the former gas turbine efficiency, up to 4.5 MWh of saved fuel gas remain in the gas grid for one MWh of (renewable) electric energy used for the compressor drive

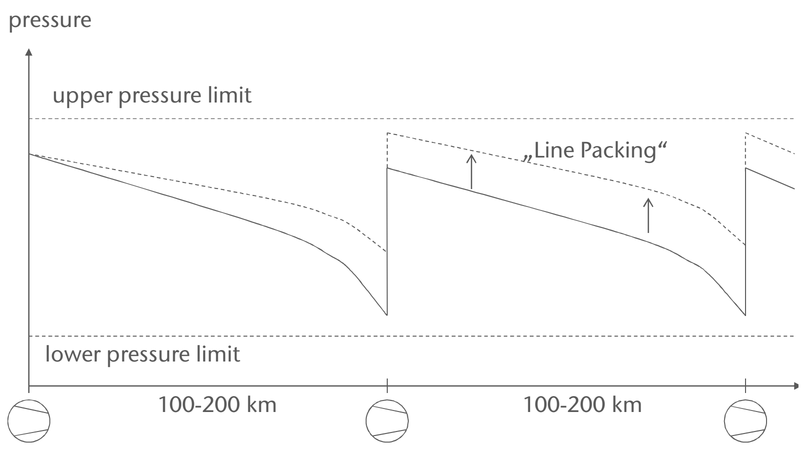
Electric drives have additional advantages:

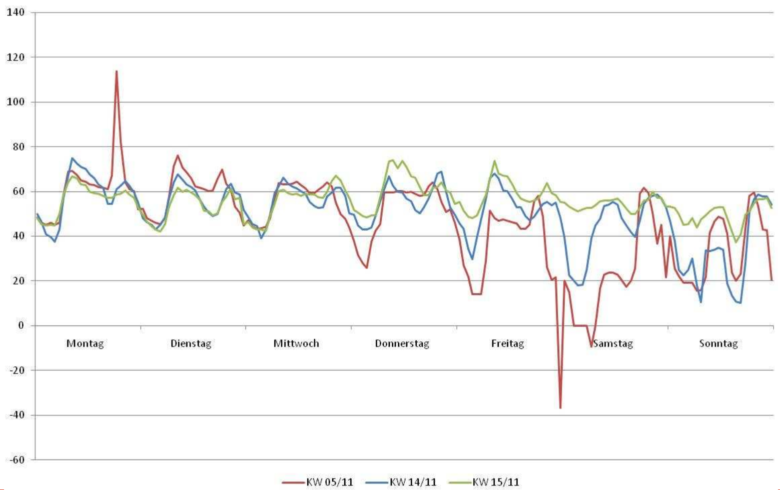
- The electric drive is more reliable than a gas turbine
- Lower investment and maintenance cost
- Virtually no local air emissions
- Less noise emissions
- Higher acceptance with local people
- Easier authorization process than gas turbine driven compressor stations
- Electric drives may be used for demand side management, providing additional power grid services

But:

- Environmental assessment depends on power generation technology
- Reliable power grid access is needed nearby, otherwise the power supply may be too expensive
- Power storage potential is limited in time and space to the compression needs of the gas infrastructure
- Electric drives need additional power generation capacity

The gas compressibility may be used for demand side management by „line packing“ with electric compressor drives





„Line packing“ means increasing the pipeline pressure for additional gas storage at times of low gas demand (e.g. at night – see upper graph)

The operational flexiblity of unused gas pipeline capacity can also be used for demand side management by shifting the compressor‘s hours of operation within the limits given by the pipeline pressure and the current needs of gas transportation

This will also lower the energy cost for the operators by increased use of „off-peak“ power rates and sometimes even negative power prices (see graph below), but additional cost may occur due to:

- Increased compression energy demand
- Deterioration of pipelines by increased pressure fluctuations
- Additional start-up/shut-down procedures of the compressors

The demand side management potential will be increased by inter-company cooperation of the pipeline operators by flexibilizing the pressure limits

Incorporating gas storage facilities may also increase the line packing flexibility

Power price taken from EEX. Demand side management concept first described by Schmeal (1997)

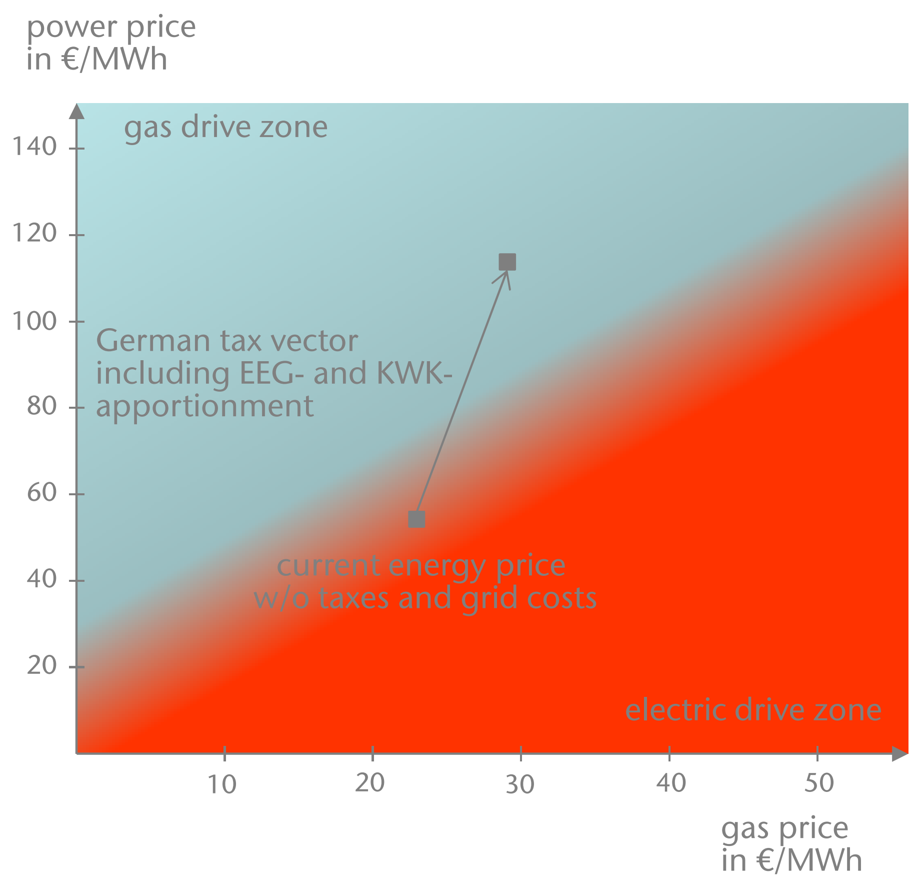
Co-simulation of energy infrastructures is needed for quantifying the power storage potential of electric compressor drives

- Timing of compression energy demand essential for determining the power storage and demand side management potential
- The hourly fluctuating power price is used as simplified model for the power system – this price is taken as input into the gas model

$$Min\ C = \sum_{CS} \sum_{t} power\ \ price_t * P_{CS,t}$$

- One more feedback loop as the compressor power demand is in part determined by the gas fired power generation's gas demand
- First result: Model too complex from mathematical point of view: Development of new solution methods needed
- For a simplification, compressor stations may be classified:
  - Base load compressor stations: transit pipelines
  - Off-peak compressor stations: storage compressors, especially short term storages supplying power plants
  - Peak load compressor stations: pipelines supplying power plants
  - Load profiles have to be determined for compressor stations supplying households and industry
  - But: the load profile of compressor stations is normally a combination of these classes
- Assessment of the maximum storage potential is possible via the CO_2 emissions register in Germany:
  - 930,000 tons of CO_2, equivalent to 4.6 TWh or 460 million m³ of fuel gas at 40 pipeline compressor stations with gas turbine drives
  - 300,000 tons of CO_2, equivalent to 1.5 TWh or 150 million m³ of fuel gas at 13 storage compressor stations with gas turbine or gas motor drives
- From this fuel gas, only the part that can be replaced by a renewable electricity surplus can be considered as storage gas. At other times, the former fuel gas is needed for gas fired power generation

The impact of taxation and legislation on the choice of the compressor drive technology



From the compressor operator's point of view, the decision on the compressor drive is dictated only by the economics

This decision depends on the relative price of power and gas, as can be seen by the „break-even cost line":

$$p_{electricity} = \frac{\eta_e}{W_{mech}} * (\Delta_{CAPEX} + \Delta_{OPEX}) + \frac{\eta_e}{\eta_g} * p_{gas}$$

At current energy prices without energy taxation and grid costs, the decision depends on local circumstances (differences in capital and operating costs as well as the annual work load)

Different taxes and other legislatory costs on both fuel options affect the technology preference. In Germany, the gas drive option is heavily favored due to:

- reduced fuel gas tax
- high electricity tax
- EEG- and KWK- apportionment on electricity consumption

→ The german energy legislation, aiming at an increase of both efficiency and the share of renewables, effectively impedes a technology that could help to achieve these aims

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The European perspective

- The European gas infrastructure may offer additional power storage and demand side management resources:
  - >15.000 MW gas pipeline compressors in the EU-27
  - >5.000 MW in the Ukraine
  - > 40.000 MW in Russia
- Some initiatives to replace gas turbines with electric drives are underway (France, Ukraine), but with a CO_2 reduction/fuel gas savings perspective
- Highest benefit in countries with large installed compressor base high share of renewables, e.g. Germany, Great Britain, the Netherlands
- Trans-national line pack will increase the Demand Side Management potential
- Short connection from the compressor station to the power grid is needed, otherwise the investment cost may be too high
- Reliable power infrastructure is mandatory for security of gas supply, but most compressor stations have a backup unit that could remain gas-fired

Map source: ENTSO-G

Conclusions and outlook

- The gas infrastructure will play an important role for securing supply in an energy system with a high share of fluctuating renewable energy sources
- Electric compression, together with using the saved fuel gas in combined cycle power plants is a „low hanging fruit“ for levelling part of the fluctuations via the natural gas infrastructure, but it is limited in space and time to compressor locations and the operational needs of gas transportation and storage
- 15.000+ MW of installed pipeline compressors in EU-27 are worth considering
- Development of new mathematical solution methods is needed for exact quantification by determining the compressors‘ hours of operation and the degree of freedom until which shifting these hours is possible
- An active role of legislatory and regulatory instances may be needed to realize the power storage potential – e.g. in Germany, current circumstances are contradictionary to the political aims of energy efficiency, CO_2 reduction and renewables integration
- For determining the efficiency of a technology within a system with a high share of renewables, not only the amount of resource use/ CO_2 emissions is relevant – but also the timing!

…but how do you do power storage with this gas infrastructure?

Thank you for your attention.

Paper will be available soon.
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