Status and Technical Challenges of Advanced Compressed Air Energy Storage (CAES) Technology

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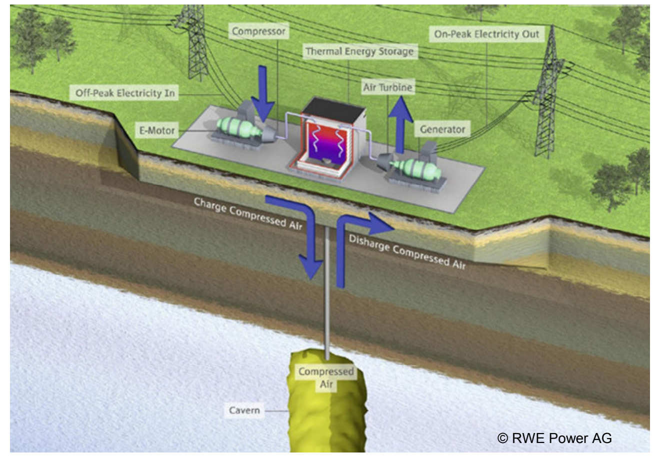


2009 International Workshop on Environment and Alternative Energy

Organized by C3P and NASA, Nov 10 - 13, 2009

GE Global Research, Garching n. Munich, Germany

Motivation for Large-Scale Energy Storage

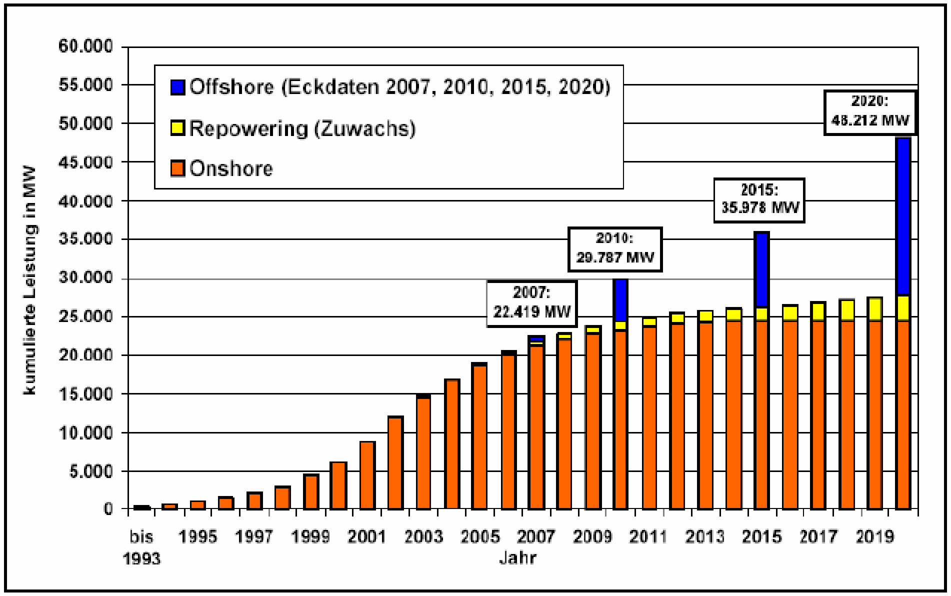
- Substantial increase of **non-demand oriented power generation**

- **New-built regenerative power generation** in particularly off-shore

- Forecast **Germany**:
  48 GW in 2020 vs. 23 GW today

- **Demanded increase of CHP Units** (25% of power generation From CHP in 2020)

Example: Offshore Wind Power in Germany (DENA)



Rapid Growth in Renewables Impacts Technical Requirements for Conventional Power Generation

imagination at work

Alternatives for Large-Scale* Energy Storage

Pumped Hydroelectric Energy Storage

+ very high efficiency (75 … 78%)
+ extremely fast availability
– low extension potential
– long permitting processes

** "100+MW power for hours"*

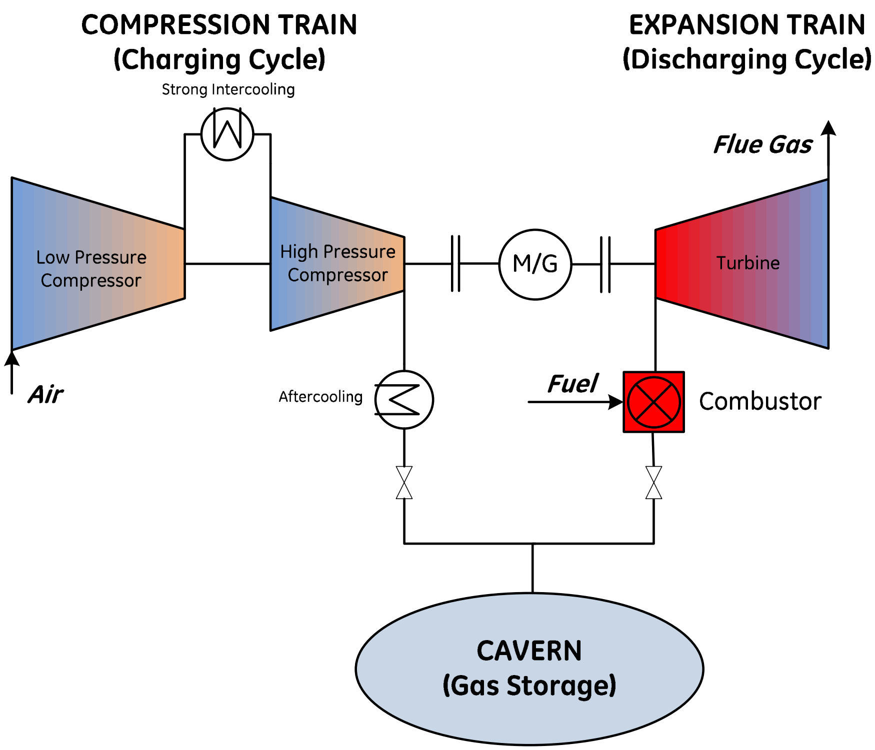
<u>C</u>ompressed <u>A</u>ir <u>E</u>nergy <u>S</u>torage (CAES)

+ low above-surface space requirements and impact
+ installation close to off-shore wind parks possible *(example: North Sea Coast of Germany)*
– low efficiency of commercially available concepts (54%)

CAES Concepts with Higher Efficiency Technically Feasible
Significant Development Needed Prior to Commercialization

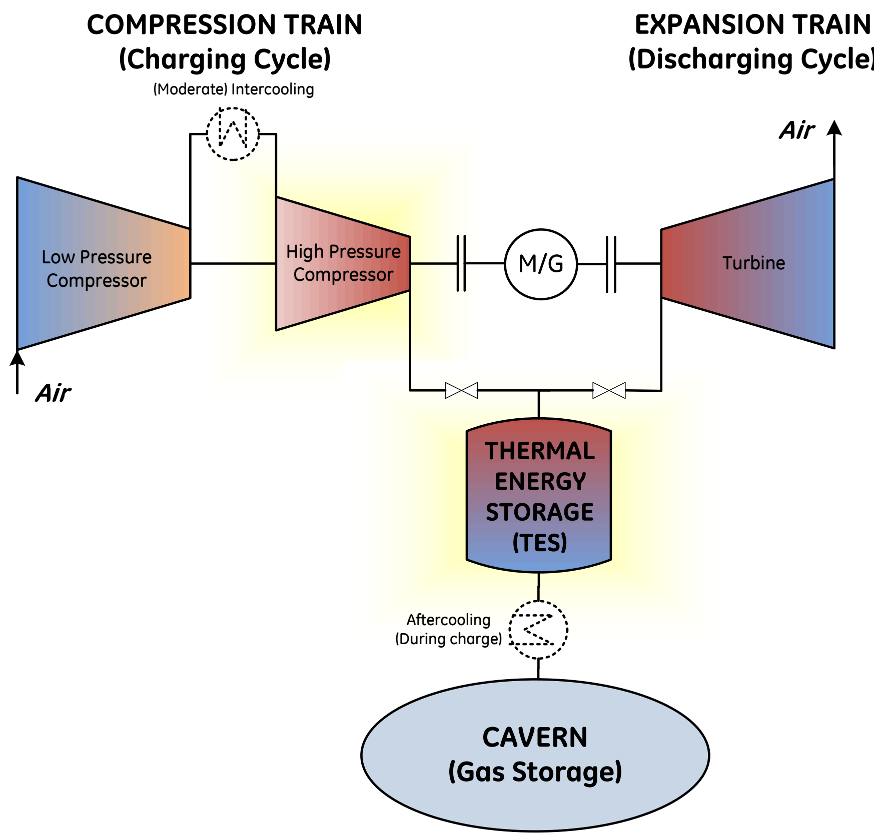
Compressed Air Energy Storage Concepts

Conventional CAES System



Only two commercial units installed
Efficiency max. 54 % with recuperation

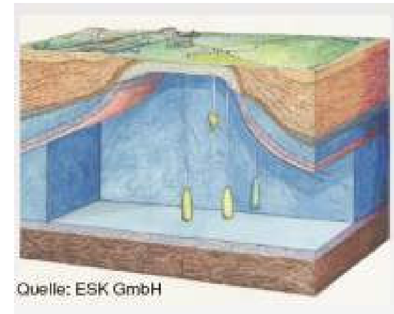
Advanced Adiabatic System (AA-CAES)



Advanced, zero-emission concept
Efficiency target 70 %

Key Technical Challenges of Adiabatic CAES

Thermal Energy Storage (TES)
- Inventory
- Insulation
- Active cooling
  (600…650 °C, 50 … 100 bar)
- Condensation



Adiabatic Compressor
- Requires specific redesign
- Simultaneous challenge wrt
  - temperature
  - pressure
  - load change stresses

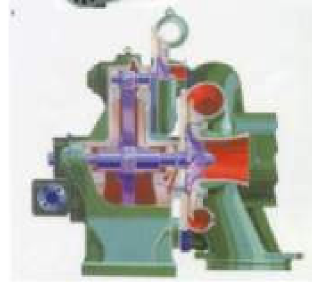
Cavern

Known technology from natural gas storages, but
- Higher discharge rate
- Larger drilling diameter
- Larger volume

TES & Compressor: Substantial Development Need
Turbine & Cavern: Moderate Development Need

Example: Compressor Considerations

- Compression requires combination of at least two casings
- Comparison of alternative turbomachinery options
- Aerodynamic selection and thermodynamic evaluation of compressor stages
- Thermomechanics at > 600 °C biggest challenge:
  - material selection
  - thermal expansion and thermostresses
  - sealing concepts
  - max. temperatures for bearings, lubrication



Compressor Development for Aggressive Environment

Example: Boundary Conditions of Joint RWE & GE Feasibility Study

Project Phases

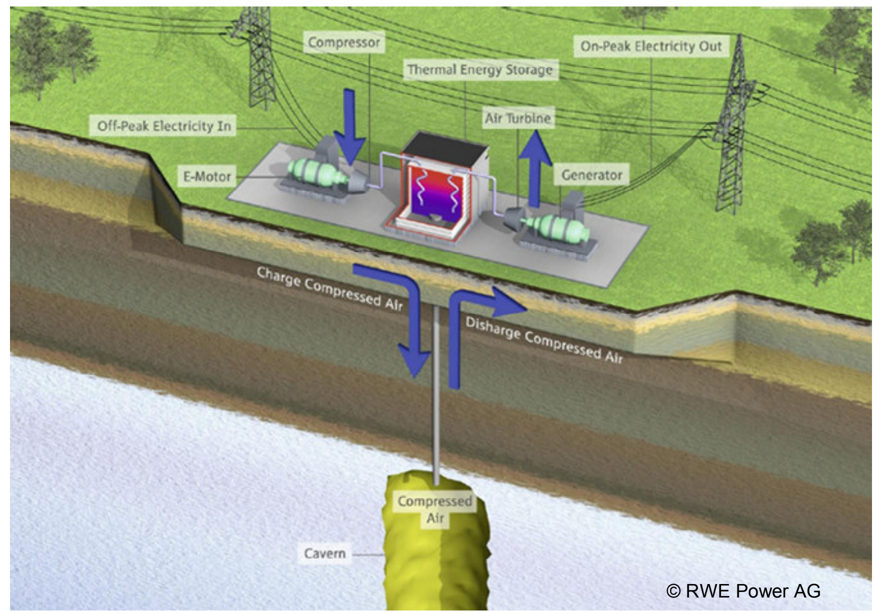
2008 → 2012+

Feasibility → Development Program → Demonstration

- ~ 260 MW Turbine
- ~ 200 MW Compressor
- Daily Cycle
- ~ 70 % Target Efficiency
- 4 … 6 h Turbine Operation
- 8 … 12 h Compressor Operation

→1040 … 1560 MWh Capacity

→Add. Revenue: Minute grid reserve



imagination at work

Conclusions

- Increasing need for large-scale storage driven by non-demand oriented power generation
- AA-CAES without alternative in many geographical areas, in Germany in particular at the coastline
- AA-CAES development needs to be started now for large-scale implementation in the next decade
- Most substantial R&D need related to
    - Turbomachinery and
    - Thermal Energy Storage
- Results of feasibility study of RWE and GE show promising results

Increasing Interest in Advanced Adiabatic CAES,
but Still Substantial R&D Needs