Advancement of Operational Performance of the
Huntorf CAES

Heat recovery concept for compressed air energy
storage power plant

Jasmin Lückert
Uwe Krüger Uniper Kraftwerke GmbH
Uwe Gampe
Guntram Buchheim

London, 12/09/2016
CAES Huntorf (first commissioning 1978)
Functional principle

Charging mode
8 h at 2.5 bar/h
46 to 66 bar, max. 72 bar
108 kg/s

Discharging mode
2 h at 10 bar/h
66 to 46 bar
417 kg/s

1 Air-storage cavern
2 HP combustion chamber
3 HP turbine
4 LP combustion chamber
5 LP turbine
6 Generator/motor
7 LP compressor
   (axial 20 stages)
8 Intercooler
9 HP compressor
   (centrifugal 6 stages)
10 Aftercooler
11 Gearbox
12 Coupling

Caverns: 2x155000 m³
usable volume
46...72 bar

09/12/2016
CAES Huntorf

Cycle Efficiency (conventional) 42%

\[ \eta_{\text{cycle}} = \frac{P_{\text{out}}}{P_{\text{in}} + \dot{Q}_{\text{in}}} \]

- \( \eta_{\text{cycle}} \): Cycle efficiency
- \( P_{\text{out}} \): Electrical Power output
- \( P_{\text{in}} \): Electrical power input
- \( \dot{Q}_{\text{in}} \): Heat flow input

HPC: High Pressure Compressor
LPC: Low Pressure Compressor
HPCC: High Pressure Combustion Chamber
LPCC: Low Pressure Combustion Chamber
HPT: High Pressure Turbine
LPT: Low Pressure Turbine
Objective

→ Recovery of waste heat from compressor air cooling and turbine exhaust heat, exergetic storage and utilization for fuel saving in turbine operation (CAES discharge mode)

Tasks

• Steam generation and storage

• Thermodynamic analysis of turbine operation with steam injection
Steam Production Potential in CAES Huntorf

**Air compression waste heat recovery (Option 1)**
- During charging mode
- Evaporator behind low-pressure compressor

**Turbine exhaust heat recovery (Option 2)**
- During full load in discharging mode
- Evaporator behind low-pressure turbine

- Ambient air
- Low-pressure compressor
- Evaporator 1
- Ruths storage
- Boiling temperature at 20 bar: 212°C
- 52,000 kg steam per 8 h

- Low-pressure turbine
- Evaporator
- Ruths storage
- Boiling temperature at 20 bar: 212°C
- 380,000 kg steam per 2 h
Ruths-Storage
Functional Principle

- Steam storage for direct steam supply
- Saturated water/steam inside storage tank
- Operation of the storage between maximum and minimum pressure

storage density:
\[
b = \frac{m_{\text{steam}}}{V_{\text{tank}}} = \frac{\beta}{v'_{\text{max}}} \frac{h'_{\text{max}} - h'_{\text{min}}}{0.5 (h''_{\text{max}} - h''_{\text{min}}) - h'_{\text{min}}}
\]

\( h \) ... specific enthalpy
\( m \) ... mass
\( V \) ... volume
\( \beta \) ... degree of filling
\( v \) ... specific volume
' ... fluid
" ... vapor
Steam

Possible utilisation in CAES Huntorf

- Steam injection to the low-pressure turbine during partial load (low-pressure combustion chamber turned off)
  - Improvement of cycle efficiency
  - Improvement of turbine efficiency
  - lower part load possible
  - Fuel saving

09/12/2016
Steam Injection

Fuel saving

![Graph showing fuel requirement vs. power for different steam injection rates. The graph includes a legend indicating operating data, 10% steam injection, 40% steam injection, and condensation.]

- Operating data
- 10% steam injection
- 40% steam injection
- Condensation

09/12/2016
• Avoiding of condensation inside the turbine - *water drop erosion*

• Change of pressure level inside the turbine

→ Thermodynamic analysis
Performance Calculation
Low Pressure Turbine with steam injection

Advancement of Operational Performance of the Huntorf CAES

09/12/2016
Performance Calculation

Validation

320 MW

200 MW

09/12/2016

Advancement of Operational Performance of the Huntorf CAES
Performance Calculation
Low pressure turbine with steam injection

HPCC in operation
LPCC out of operation

\[ \frac{\dot{m}_{\text{steam}}}{\dot{m}_{\text{HPT}}} \]

0% 5% 20% 30%

09/12/2016
Performance Calculation

Low pressure turbine with steam injection

HPCC in operation
LPCC out of operation

5 p.p. higher isentropic efficiency
\( \frac{\Delta h}{\Delta h_s} \)
Summary and Outlook

CAES Huntorf

- Improvement of an existing compressed air energy storage (CAES) plant to meet current demands of energy market
  - Changed requirements profile for operation
  - Efficiency improvements at partial load with in-process waste heat utilisation
- Solution: combination of available technologies
  - Steam injected gas turbine (STIG)
  - Ruths storage

Project partners: Uniper (formerly E.ON) and TU Dresden

- Determination of operation limits due to condensation with performance calculation
- First operation tests with steam injection
»Wissen schafft Brücken.«