Compressed Air Energy Storage

THERMODYNAMICS OF COMPRESSED AIR ENERGY STORAGE
Diabatic CAES Diagram

From Chen et. al., Compressed Air Energy Storage, INTECH
Adiabatic Compressed Air Energy Storage

The adiabatic CAES does not use fossil fuels; it requires a thermal energy storage.

From D.Wolf, Methods for Design and Application of Adiabatic Compressed Air Energy Storage Based on Dynamic Modeling
Power Input

The power input of a CAES system can be produced by a thermal power plant, or renewable energy sources.
Compression

During the compression of a gas, its temperature, density, volume, and pressure change.

A compression process can be either isentropic, isothermal, or polytropic.

Isothermal compression requires the smallest amount of work.

Multistage compression with intercooling between stages is currently the closest to isothermal compression method.

Having the same compressor ratio in all the stages will minimize the required work. [1]
Compressors

The high flow rates needed for the turbine operation, require the use of rotatory compressors.

Axial compressors have efficiencies between 90 to 95%, and are better suited for high flow rates compared to centrifugal compressors. [2]

Centrifugal compressors have efficiencies around 80%-90%. For a CAES system, multistage centrifugal compressor would be required. [2]
Cavern

The cavern by nature has a temperature and pressure ranges that will set some of the working temperatures and pressures.

To prevent heat loses to the surroundings, the compressed air temperature should be similar to the cavern temperature. 

From PB Energy Storage Services Inc.

From KBB Underground Technologies
Heat Exchangers

When two fluids exchange heat without mixing their masses, two convection processes and one conduction process occur.

The rate of heat conduction is directly proportional to the temperature difference of the two sides of the solid, the thermal conductivity of the material, and the area; and is inversely proportional to the thickness of the solid.

\[ \text{conduction rate} = \text{thermal conductivity} \cdot \text{Area} \cdot \frac{T_1 - T_2}{\text{Thickness}} \]
Heat Exchangers

The rate of heat transfer by convection is proportional to the temperature difference, the surface area, and the convection coefficient.

\[
\text{convection heat transfer rate} = \text{convection coefficient} \cdot \text{surface area} \cdot (T_s - T_\infty)
\]

The size of a heat exchanger will be proportional to the difference between the original temperature and the objective temperature, the mass flow rate, and the heat capacity of the fluid.
Heat Storage

Sensible heat can be stored by rising the temperature of a material without producing a phase change.

Latent heat can be stored using a phase changing material that fits with the required temperatures and heat capacity.

Latent heat storage provides higher energy density thus requiring a smaller volume; the heat stored can be taken back at a constant temperature. [3]

From Guédez et al., Reducing the Number of Turbine Starts in Concentrating Solar Power Plants Through the Integration of Thermal Energy Storage

doi: 10.1115/1.4028004
Expansion

For a given mass flow rate, the higher the temperature and the pressure a turbine can stand, the more work it will produce.

Turbines can be considered as adiabatic. [1]

\[ \dot{W}_{out} = \dot{m} \cdot (h_1 - h_2) \]

In current power plants more than one turbine is usually used to get a larger work output.

From http://www.briangwilliams.us/power-generation-technologies/advanced-gas-turbine-design.html
References


