Technology: Liquid Air Energy Storage

GENERAL DESCRIPTION

Mode of energy intake and output

Power-to-power

Summary of the storage process

During charging, air is refrigerated to approximately -190 °C via electrically driven compression and subsequent expansion. It is then liquefied and stored at low pressure in an insulated cryogenic tank. To recover the stored energy, a highly energy-efficient pump compresses the liquid air to 100-150 bar. This pressurised liquid air is then evaporated in a heat exchange process, cooling down to approximately ambient temperature, while the very low temperature (ca. -150 °C) thermal (cold) energy is recovered and stored in a cold accumulator. The still pressurised air is then heated further using the compression heat that was produced during charging and/or other external heat sources, e.g. renewables or waste heat. Finally, the heated and highly pressurised air is used to drive an expansion machine and thus generate electrical energy. The stored cold energy is reintroduced to the charging process to reduce liquefaction energy consumption.

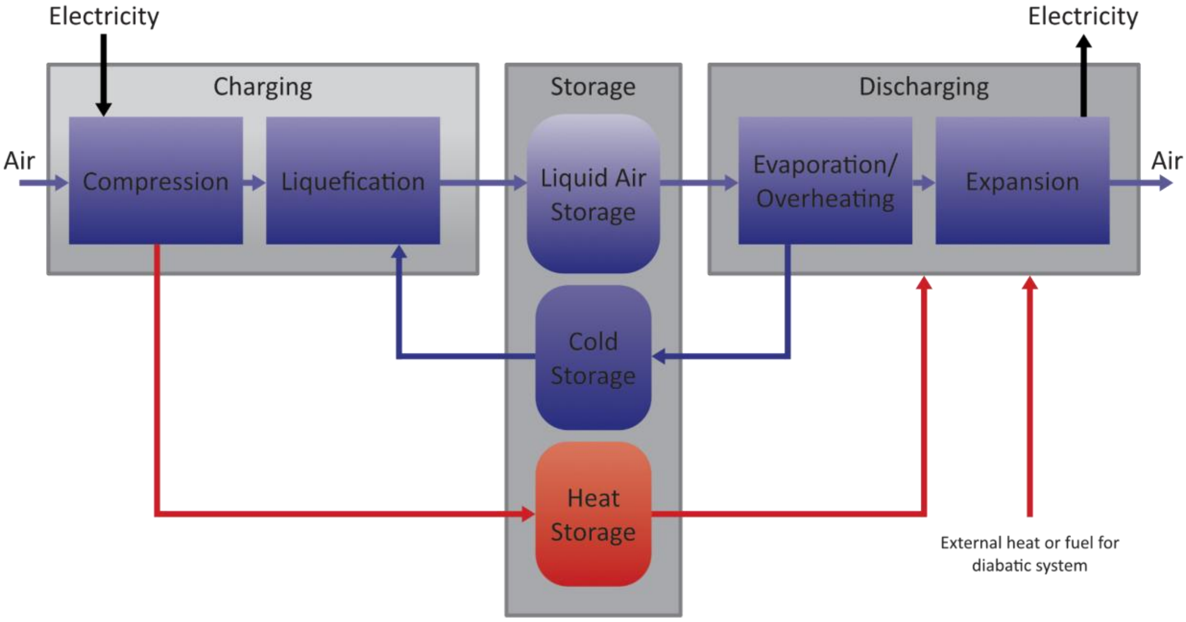

Figure 1: Schematic of LAES system

System Design

LAES systems can be designed to work adiabatically, i.e. without an external heat supply, or to employ external waste heat, e.g. from industrial processes or a gas turbine generation system. Such a system, if integrated with a gas turbine power system, could serve as a combined peak-load power plant, resulting in a significantly higher withdrawal capacity than either of the individual systems.

Using largely standard components and being unconstrained by geological locations, liquid air storage has short planning and construction periods (1.5-3 years) compared to pumped hydro power plants and compressed air storages using caverns. Moreover, they can be built with no regard to topographical or geological constraints. Due to their low capacity-specific investment cost and the fact that the efficiency of air liquefaction increases with volume, liquid air energy storage systems are particularly suitable for large-scale storage (>50 MW) and provision of energy in multi-hour, day, or week balancing.

Focus on provision of power or energy

Energy

Suitable fields of application

Power-to-power energy storage for daily/weekly balancing, provision of operating reserve, integration of waste heat, renewable generation, operation as a peak load power plant, load shifting

Figure 2: Condenser, cryogenic liquid tank for 350 MWh_{el}, hot gas expander (l.t.r.) (© Linde)

State of development/commercial availability

R&D ongoing since early 2000s. First pilot plant (350 kW/2.5 MWh) built and tested 2010-2013, then donated to University of Birmingham for further research in 2014; first pre-commercial plant (5MW/15MWh) built and tested near Manchester 2015-2020; first commercial plant (50MW/300MWh) under construction due to completion in 2026.

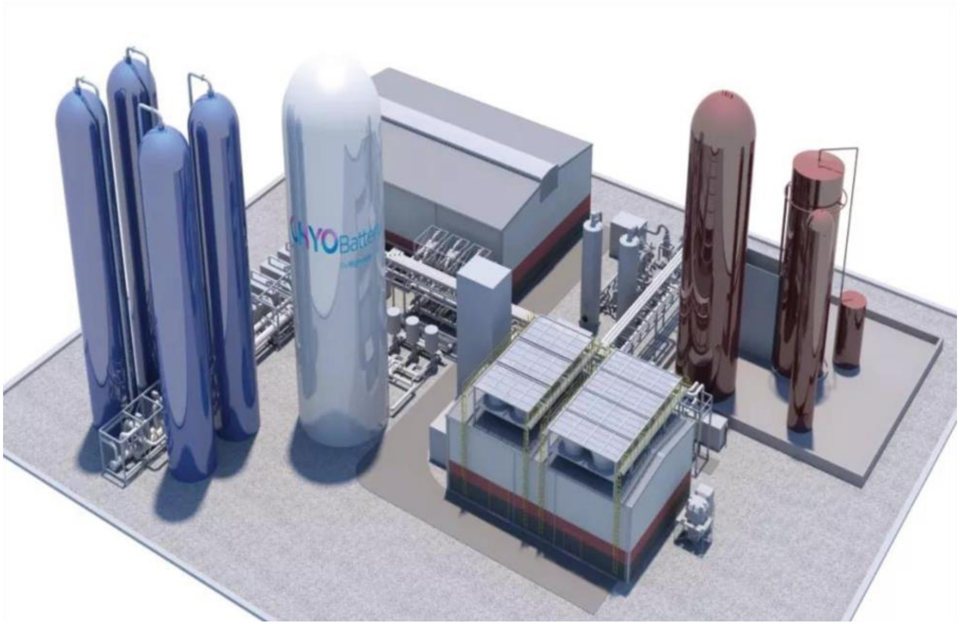

Figure 3: Exemplary layout for LAES plant (© MAN Energy Solutions)

TECHNICAL SPECIFICATIONS

Specific energy storage density	kWh/m^3	kWh/t
	60-230	irrelevant
Specific power density	kW/m^3	kW/t
	irrelevant	irrelevant
Typical/feasible storage size	MWh_{out}	kW_{out}
	50-5,000	25-600
System efficiency	50-65 %	
Storage duration	Hours-days	
Response time	Minutes	
Service life (maximum)	Cycles	Years
	20,000	~30
Loss per time in %	5-15 per month	

Notes

The specified system efficiency (power to power) refers to an adiabatic system with no external heat supply.

ECONOMIC SPECIFICATIONS

Investment cost per $\text{kW}_{\text{el\_out}}$:	1,100-3,000	(2030: 900-1,400)
Investment cost per $\text{kWh}_{\text{el\_out}}$:	50-200	(2030: 40-160)

Notes

The investment cost per kW is based on the output-specific parts of the storage such as compressors and turbines, while the investment cost per kWh is based on the capacity-specific parts such as the liquid air storage and the heat/cold storage. To calculate the overall investment for a system, both must be added together. For a system with an output of 50 MW_{el} over a period of 8 h (= 400 MWh_{el}), investment thus calculates as

$$50\ MW_{el} \cdot 2.000\ €/kW + 400\ MWh_{el} \cdot 100\ €/kWh = 140\ \text{m}\ €$$

Operating and maintenance cost (based on investment/kW and kWh)

1-2 % of total investment per year

Cost of supplied energy in concrete application: Due to the wide variety of application areas and electricity procurement models, no concrete examples are presented here. These can, however, be calculated based on the investment costs, system efficiency, and boundary conditions for specific applications.