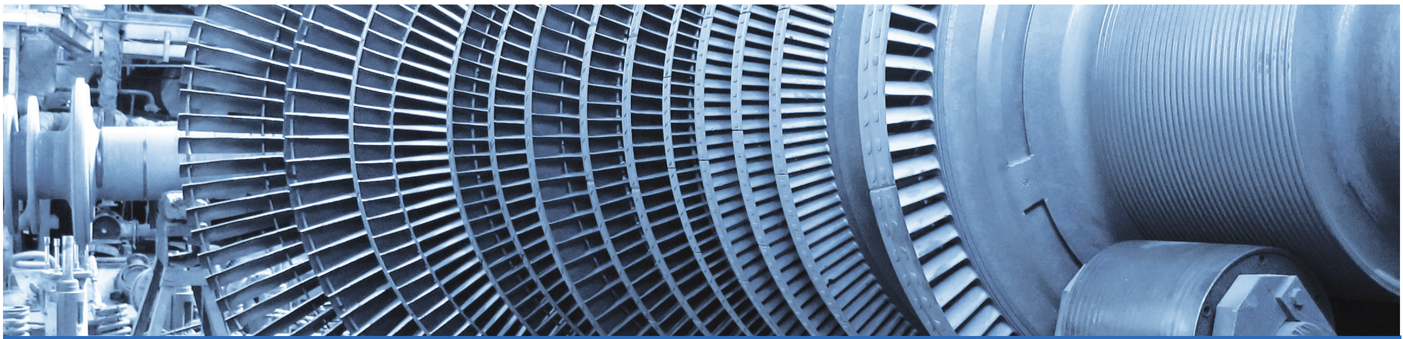
Pumped Hydro Storage



Mechanical Energy Storage

1. Technical description

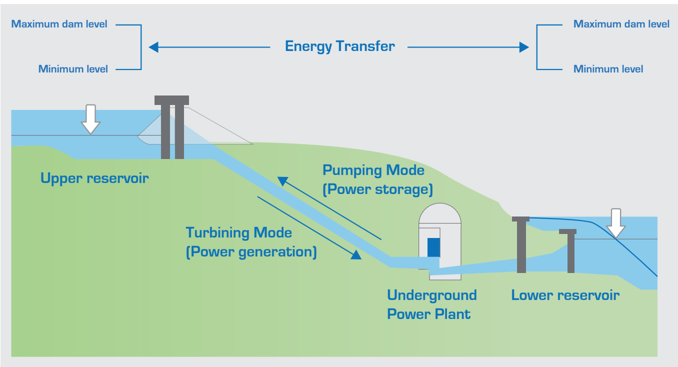
A. Physical principles

The principle of Pumped Hydro Storage (PHS) is to store electrical energy by utilizing the potential energy of water.

In periods of low demand and high availability of electrical energy, the water will be pumped and stored in an upper reservoir/pond. On demand, the energy can be released respectively and transformed into electrical power within a short reaction time.

Because of this, PHS can adjust the demand supply to balance respectively reduce the gap between peak and off-peak periods, and play an important role of levelling other power generation plants and stabilizing of the power grid.

Illustration: Charging principle of PHS



(EASE-EERA recommendations for a European Energy Storage Development Technology Roadmap towards 2030)

B. Important components

The main components are the following:

- Two water reservoirs/ponds (upper and lower),
- Power waterway to connect both reservoirs/ponds
- Hydro power station equipped with ternary machine sets or pump-turbines

C. Key performance data

Power range [1]	10 MW – 3.0 GW
Energy range	up to some 100 GWh
Discharge time	min – some 10h
Cycle life	technically unlimited
Life duration	> 80 years
Reaction time	some sec – few min
Efficiency [2]	70 - 85 %
Energy (power) density	0.5 - 3 Wh/kg
CAPEX: energy	40 - 150 €/kWh
CAPEX: power	400 - 1,500 €/kW

(1) in general no limitation
(2) cycle efficiency

D. Design variants (non exhaustive)

Examples for design variants:

- Variable speed PHS
- Synchronous / asynchronous motor-generators
- Hydraulic short circuit operation
- Black-start availability
- Daily/weekly/seasonal storage
- River PHS
- Seawater PHS (demonstration project)

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2. State of the art

Generally speaking, PHS is the most mature storage concept in respect of installed capacity and storage volume.

Besides balancing the peak and off-peak periods, PHS provides ancillary services such as: frequency, primary and voltage control to the power grid. In order to fulfil the power system control, PHS can switch within seconds for different operation modes.

Another aspect to increase the operation range of PHS is by using asynchrony motor-generators. The so called doubly feed induction machines (DFIM) increase the flexibility particularly during pumping mode. While the efficient pumping for synchronous motor-generators is in the range of 90-100% of the nominal power (P_N), DIFM can operate in pumping modus between 65-100% of P_N.

3. Future developments

Future developments for modified PHS concepts:

- Hydraulic gravity storages (HGS): the HGS principle is derived from hydropower pumped storage technology and is based on conventional pump-turbines and motor-generators. The hydrostatic head on the turbine contains a piston in a vertical shaft in the generation mode; the piston is lifted by water pressure in storage (pump) mode. Independent from the position of the piston, the head on the turbine remains constant.
- Underfloor PHS systems: the concept is equivalent to conventional PHS, but instead of surface reservoir/ponds the storages are arranged below ground; e.g. existing mines.

Both concepts are in the development stage and are far from commercial attractiveness.

Seawater PHS Okinawa, Japan

4. Relevance in Europe

There are over 170 GW of pumped storage capacity in operation worldwide. Europe is the second biggest zone, with 57GW, accounting for approximately 33% of the market. Opportunities are mostly focused on mountainous regions in Switzerland, Austria, Germany, Spain and Portugal. With the common target of 20% renewable energy use by 2020, many EU member states have introduced large economic support programmes to renewable generation such as feed-in tariffs. In this context, PHS systems could facilitate their expansion. The International Energy Agency's lowest scenario expects the PHP capacity to reach 91 GW in 2050, while the highest estimate proposes a capacity of 188 GW. This means an average growth of 1.2 to 3.6 GW/year. Taking an average value of 1,000 €/kW, this corresponds to a market of 1.2 to 3.6 bn€/year on average.

5. Applications

Due to their flexibility, large-scale storage possibilities and grid operations benefits, PHS systems will enable utilities to efficiently balance the grid and to develop their renewable energy portfolios. In fact the installation of intermittent renewable generation has added a new degree of uncertainty to the dispatch of interconnected power system. Pumped storage is therefore set to play a key role in enabling renewables' grid integration while helping countries meet their ambitious targets of cutting GHG emissions and of building additional clean renewable energy capacity.

6. Sources of information

- EASE Members
- Alstom
- EnBW
- E.ON
- Hitachi Power Europe
- RWE
- IEA Hydropower Technology Roadmap (2012)
- Bogenrieder, W.: 2.6. Pumped storage power plants. Heinloth, K. (ed.). SpringerMaterials - The Landolt-Börnstein Database DOI: 10.1007/10858992_7