Underground Pumped Hydro Storage

Principle

An Underground Pumped Hydro Storage (UPHS) has upper and lower water reservoirs like a conventional surface Pumped Hydro storage (PHS), a powerhouse in a cavern with electrical facilities as well as supply and transmission lines to the electrical grid. The main difference compared to a PHS, is that UPHS facilities are predominately located under the ground level. Additional shafts and drifts are necessary for service and transport.
The advantage of the UPHS is that during periods of low energy demand, the surplus of electrical energy can be used to pump water from the underground lower reservoir to the upper reservoir and stored in the form of potential energy. The stored energy is proportional to the mass of the water lifted up and the vertical height between the reservoirs. During periods with high demand, the water is released through turbines to the underground lower reservoir in order to produce electricity.

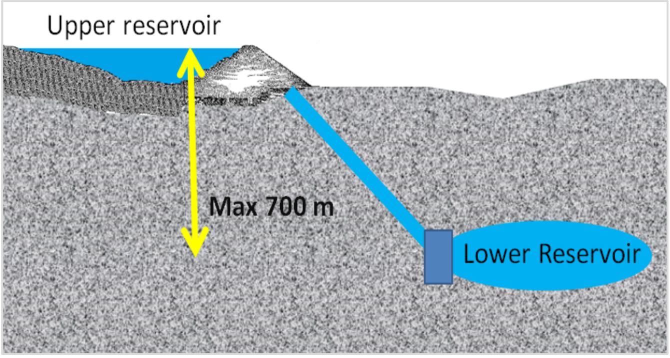

Figure 1. Underground pumped hydro scheme [8]

Characteristics

UPHS is a variant of PHS that has been proposed in different projects. In principle, the same technology could be used in UPHS and in PHS. UPHS is therefore a large-scale storage facility, with typical power varying from 100 to 1000 MW, and energy capacity from 1 to 15 GWh depending on the size of the reservoirs. Today's conventional PHS reach a total efficiency value of more than 75%. Similarly, UPHS has the potential for being one of the most cost-effective large-scale storage technology.
The underground reservoir can be either newly built for the purpose of the UPHS, or re-used from abandoned mines.

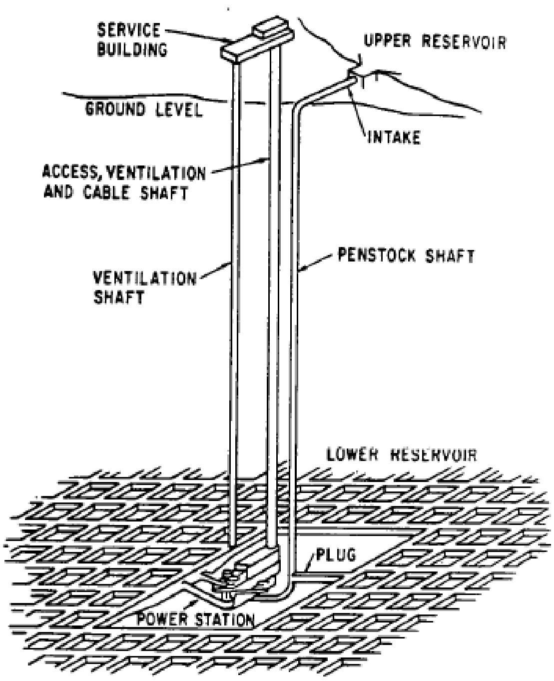

Figure 2. Grid gallery underground pumped lower reservoir example [3]

General performance

Typical Power: from 100 to 1000 MW

Head range: 750 m in one stage, 1500 m in two stages configuration.

Cycle efficiency: 75%

Energy capacity: from 1to 15 GWh

Discharge time: 8-16 hours

Response time: seconds to minutes

Technical lifetime: 40-80 y

Energy to Power ratio: 8 to 16 MWh/MW

Maturity level

Despite several projects have been studied over the past 50 years, with promising future development [2], there are currently no large size UPHS in operation. In 1960 a project was based on using an abandoned mine as underground lower reservoir for the UPHS. The use of mines for such purposes requires extensive studies for certification. Some years later, Swedish engineers proposed the exploitation of a surface reservoir and the construction of a new lower artificial reservoir in an

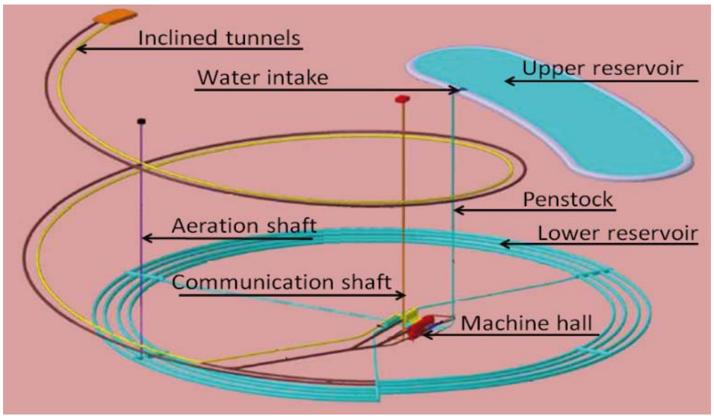

Figure 4. Scheme of a 1000 MW pumping plant with a spiral shape gallery underground reservoir [7]

underground cavity, with a cross section of 200 m^2 at a depth of 450 m below the ground level [1]. In 1978 an UPHS project was presented, with a lower reservoir conformed by a grid of 15x25m elliptical tunnels, to a depth of 1000 m (Figure 2). To increase the useful head of more than 1500, a two-stages configuration could be used, in which a smaller intermediate reservoir is located half-way between the ground and the lower reservoir operating in series, without the need for a machine synchronization. In 2006, in South-Korea, a two-stage UPHS project was also presented with an exploitable head of 1500 m and 1000 MW of installed capacity. Recently, a replicable methodology was applied to calculate the UPHS potential as well as the financial feasibility for the Italian territory [8]. In this study reservoirs currently used for hydropower, irrigation, water supply and industrial use, are evaluated to be a possible part of the system. Locations suitable for the construction of new underground spiral shape gallery reservoirs are selected according their lithological characteristics.

Potential, Barriers and Challenges

UPHS has the potential to contribute to the integration of intermittent renewables sources (wind, solar) in the energy system by allowing storage of electricity at the time of high production and low demand and release it at the demand of higher demand and low production. Like a traditional PHS, the main advantages are the following: high cycle efficiency, capacity to deliver large power over long periods, long life-time. In addition, UPHS has low landscape impacts: it does not require high surface topographic gradients and offers the possibility of exploiting existing cavities, such as ore, coal or limestone abandoned mines [4][5][6].
The excavation technology has also made large progress with the so-called Tunnel Boring Machines (TBM), which allow to adapt to variable conditions of soil and rock along a tunnel. TBM are currently extensively experienced, mainly for rail roads and tunnels, but could easily be adopted to build a spiral underground reservoir [7](Figure 4). Shields allowing simultaneously excavation and installation of the final coating with precast concrete segments have also been developed.
However, there are still several remaining challenges that will need to be tackled for a large deployment of UPHS. For example, the absence of regulatory framework for the procurement of electricity storage under the current electricity market limits severely the profitability of UPHS. The main technical challenge that UPHS meets is the dynamical stress behavior of rock masses, as well as fluid-mechanical and chemical properties of mine waters [4]. Underground test facilities allowing studies of effects under real conditions would be a major step forward.

Potential

- Established technology
- Very long life time
- High efficiency
- Low cost in comparison to batteries storage.
- Very low landscape impact.
- High potential of exploitation.
- Flat areas are also suitable

Barriers

- High investment costs
- Long construction time
- Barriers in the use of existing surface reservoirs.

Challenges

- Dynamic stress behavior of rock mass.
- Definition of an energy storage regulatory framework

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