Underground Pumped hydro storage

Principle

Since decades pumped hydro storage is a proved technology in the energy-management system to balance the differences between generation and demand of electrical energy. Similar to conventional hydro storage on the surface, underground pumped hydro storage has upper and lower water reservoirs, a machine cavern with electrical facilities as well as supply and dissipation lines to the electrical grid. In contrast to conventional pumped hydro storage the constructions are predominately located in the subsurface. Additional shafts and drifts are necessary for service and transport. The active principle of pumped hydro storage is to use "surplus" electrical energy to pump water from a lower to an upper reservoir. In this way electrical energy is converted into potential energy. The stored energy is proportional to the mass of the water and the vertical height. In event of a strong demand for electrical energy this stored energy can be released by downward water flow and conversion of the moving energy into electrical energy via turbine and generator. Todays pumped hydro storages reach a total efficiency value of more than 75%.

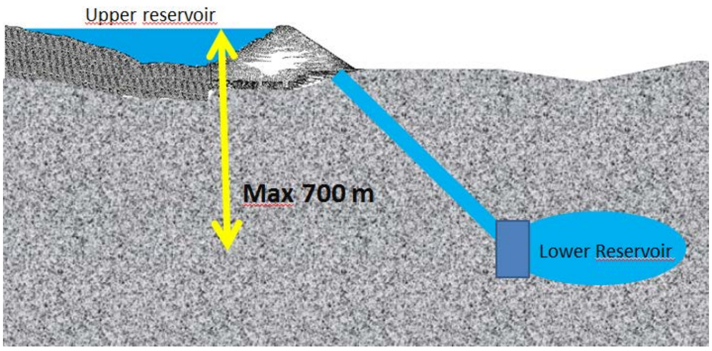

Figure 1. Underground pumped hydro scheme [11]

Characteristics

The pumped hydro constitute a solution for the electricity grid exercise problems caused by the non-programmable energy plants. The scarcity of topographic gradients to be used without constraints as well as problems of public acceptance suggest the evaluation of an "underground pumped hydro" scheme, obtained through the exploitation of cavern reservoirs built several meters below the surface. As early as 1960 Richard D. Harza had suggested the idea to use an abandoned mine as underground lower reservoir, and build an hydro pumped storage plant. The use of mines for such purposes requires extensive studies for certification. At the end of the 60s, Swedish engineers had proposed the exploitation of a surface reservoir and the construction of a new lower artificial reservoir in an underground cavity, with a cross section of 200 m^2 at a depth of 450 m below the ground level [1]. In 1978 it was presented an underground Pumped hydro plant project, 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: a smaller intermediate reservoir is located half-way between the ground and the lower cave. The reservoir in the intermediate cave allows the two stations to operate in series without the need for a machine synchronization.

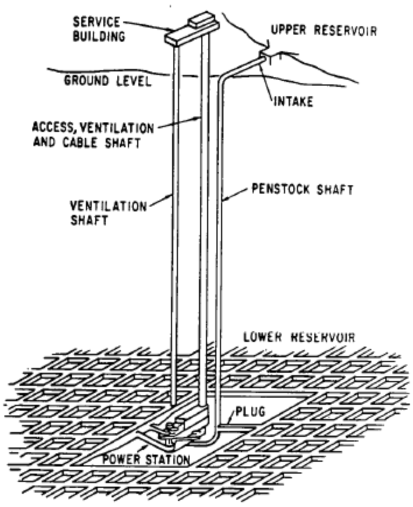

Figure 2. Grid gallery underground pumped lower reservoir example [3]

General performance

Typical Power: from 100 to 1000 MW

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

Cycle efficiency: 80%

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

CO2 emissions:

Maturity level

In 1969, Sorensen had suggested an optimistic future for the development of underground pumping stations [2].
Despite several projects have been studied over the past 50 years, there are currently no large size pumped underground hydro plant in operation. However after 2001, the new market conditions and the general development of not programmable renewable generation sources revived the need for a subsequent upgrade of large storage technologies, and the interest starts to grow again.

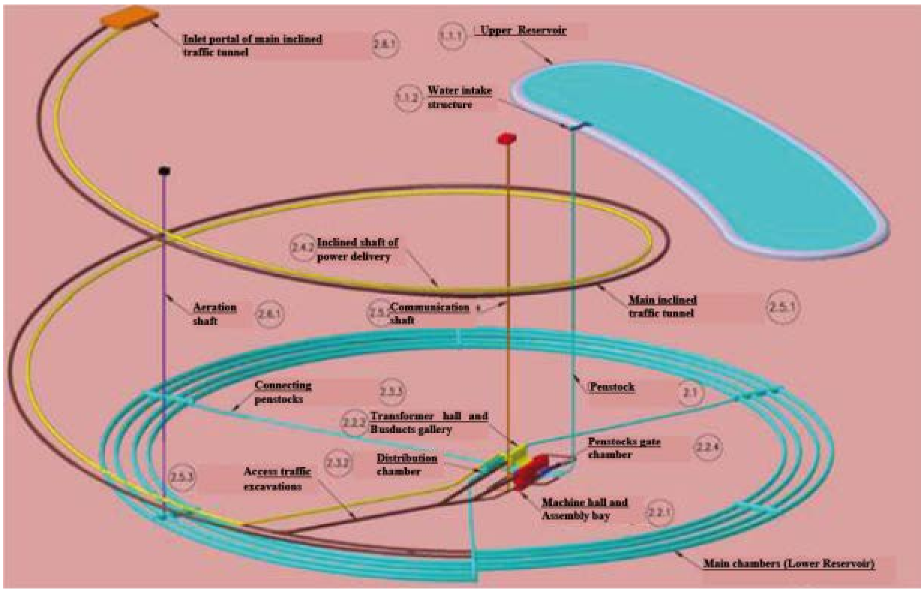

Figure 4. Scheme of a 1000 MW pumping plant with a spiral shape gallery underground reservoir [10]

In the last few years it is proposed not only pumped installations with the construction of new underground reservoirs, but also the possibility of exploitation of existing cavities, such as the ore, coal or limestone abandoned mines with different experiences [4][5][6]. In 2006 a project for the underground hydro pumped plant in Yangyang in Korea was presented, with an exploitable head of 1500 m and 1000 MW of installed capacity (four 250 MW machines each), developed with a two stages pumped system.
From the point of view of the excavations, the technology has made prodigious progress with of so-called Tunnel Boring Machines (TMB), which allow to adapt to a very variable conditions of soil and rock along a tunnel. TBM are currently extensive experienced, in particular in the context of rail roads and tunnels, but they can be adopted to build an spiral underground reservoir[7](Figure 4.). They have been developed shields that allow to simultaneously perform the excavation and the installation of the final coating with precast concrete segments. Recently has been proposed and applied to the Italian territory, a replicable methodology to calculate the underground pumped hydro storage potential [8]. For this purpose, reservoirs currently used for hydropower, irrigation, drinking and industrial, are evaluated to be a possible part of the system. Suitable areas from the point of view of lithology are selected for the construction of new underground spiral shape gallery reservoirs, built with a TBM. Afterwards, the tool estimates costs and revenues and assesses a financial feasibility.

Potential, Barriers and Challenges

The refinement of energy is of limited profitability under the current political-economical conditions. Therefore for underground pumped hydro storage it's also difficult to achieve economic efficiency. Other important challenges for the large-scale application of underground pumped hydro are the dynamical stress behavior of the rock mass as well as fluid-mechanical and chemical properties of mine waters [4]. Validation and testing of both individual system components and their coaction can respond to these challenges. Against this background it is suggested to realize underground test facilities which allow to study these effects under real conditions.

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
- Barrier 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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