VALUE OF PUMPED STORAGE HYDROPOWER FOR CENTRALIZED AND DECENTRALIZED ENERGY SYSTEMS

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Introduction

Pumped Storage Hydropower (PSH) is a well-known technology for efficient storage of electrical energy. The efficiency varies according to site-specific properties, but is generally close to 80%. Compared to conventional batteries, the cost per kWh is lower, and the lifetime of the scheme is significantly higher. Compared to power-to-gas technology, the efficiency is higher. The amount of energy storage possible in a PSH scheme varies from a few kWh to several TWh.

This paper will focus on two types of PSH. Large scale schemes to serve the centralized system, and small-scale hybrid schemes with combined energy and heat storage to serve the decentralized system. The centralized system depends on a limited number of large energy production and storage schemes to serve the major population and the industry. The decentralized system depends on a large number of small energy production and storage schemes to serve a smaller local population. The current energy system in Europe is centralized, but there is a transition towards decentralized due to the ongoing “Energiewende”.

For large-scale energy storage, the use of Norwegian hydropower reservoirs is discussed and findings from the Norwegian CEDREN research program are presented. In addition, a new large PSH project utilizing a fjord as lower reservoir will be examined. A solution for separating the seawater and the freshwater in the lower reservoir will be visualized. This power plant will utilize the largest existing hydropower reservoir with freshwater in Norway, which stores over 7.8 TWh of energy. The proposed PSH plant can be operated over 150 hours at full installed capacity of 50.000 MW. Such large-scale energy storage power plants in Norway can be connected with high-voltage DC subsea cables to European offshore wind parks. The offshore wind parks are part of the centralized energy system. An example is Denmark, which is currently balanced to a large extent by Norwegian hydropower. New HVDC cables from Norway to Germany and the United Kingdom are currently under construction, and more are planned to follow.

For the decentralized system, small PSH systems may contribute with energy storage. A combination of a possible hybrid PSH system with combined energy and heat storage might be an interesting solution to combine the advantages of PSH electrical storage with the advantages of the high specific heat capacity of water, in order to store seasonal heat for households and public facilities. Such small storage systems with a lower and an upper reservoir might have a head in the range of 10 to 100 m. The energy storage will enable more use of solar power in the decentralized grid. Further, it is possible to install waterborne heat storage in these small PSH schemes to capture the load peaks at midday and shift them to the evening and the morning. The heat storage will also enable a seasonal shifting of the heating peaks. These small hybrid PSH systems can be constructed with water reservoirs in buried pipes, which needs to be sufficiently isolated. By utilizing such small PSH schemes with waterborne heat storage, both electrical energy and heat energy from the sun can be stored for short or long periods. One cubic meter of water can store 96 kWh if heated from 8 to 90 degrees Celsius.

Depending on the size and number of the hybrid PSH schemes, a large amount of heat energy can be stored. Such small storage plants can extend the value of solar plants and provide energy to neighbor households. The hybrid decentralized PSH can also extend operational fields of public utility companies.

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Discussion and Outlook

The connections from Norway to the continental grid are strengthened. From 2019, a 560 km long HVDC cable with the capacity of 1400 MW will be in operation between Germany and Norway, and in 2021 a 700 km long HVDC cable of 1400 MW will connect Norway with England. These cables will enable indirect storing of energy without major pumping capacity, and will allow new large offshore wind farms to be integrated efficiently to the European power grid. However, there is a limit to how much energy can be indirectly stored through exchange of power between countries. In the future, it may become necessary to store large volumes of energy locally, and provide large amounts of power in a short period of time. An economical and long term solution needs to be found, and PSH is a mature and capable technology.

Two complementing PSH schemes are presented below; (1) a large 50.000 MW PSH utilizing a fjord as a lower reservoir serving the centralized grid, and (2) a small 100 kW PSH with buried pipes as reservoirs serving the decentralized grid. For the large PSH, the separation of fresh- and seawater is an important challenge. Fig. 1 shows the large PSH scheme with rubber tubes that can be filled and emptied with water to store large amounts of water without visibility. Further research, simulation and discussion of future demands is necessary.

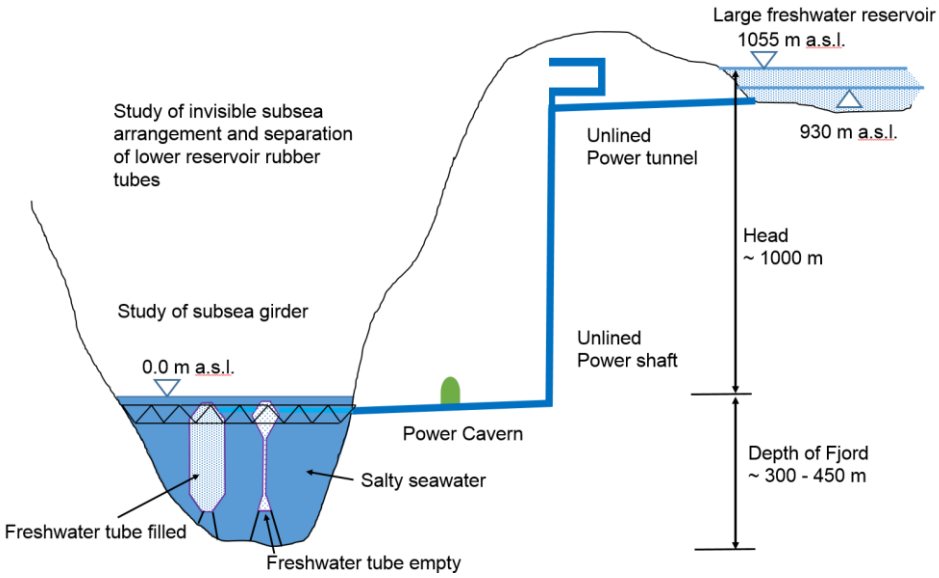

Figure 1: Scheme of a large PSH system with separated freshwater and seawater.

For small decentralized systems it is possible to use buried pipes to construct small PSH systems. Such systems can constructed by private persons or companies in areas with available potential height. Future discussions and further research as well as a very high renewable integration may allow such systems to be profitable. It depends primarily on the electricity prizes.

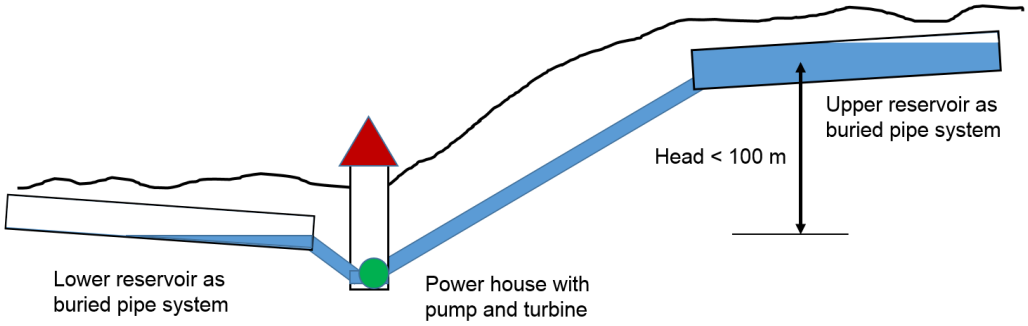

Figure 2: Scheme of a small PSH system with buried pipes as lower and upper reservoir.

This paper has discussed the possibility of utilizing PSH schemes for both large-scale centralized grids and small-scale decentralized grid. PSH schemes are available in different sizes and may fulfil the needs of the future energy system. The PSH provides many benefits such as flexibility, high efficiency and long lifetime.