Pumped hydro storage managua

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Pumped-storage hydroelectricity (PSH), or pumped hydroelectric energy storage (PHES), is a type of hydroelectric energy storage used by electric power systems for load balancing. A PSH system stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation. Low-cost surplus off-peak electric power is typically used to run the pumps. During periods of high electrical demand, the stored water is released through turbines to produce electric power.

Pumped-storage hydroelectricity allows energy from intermittent sources (such as solar, wind, and other renewables) or excess electricity from continuous base-load sources (such as coal or nuclear) to be saved for periods of higher demand.[1][2]The reservoirs used with pumped storage can be quite small, when contrasted with the lakes of conventional hydroelectric plants of similar power capacity, and generating periods are often less than half a day.

The round-trip efficiency of PSH varies between 70% and 80%. Although the losses of the pumping process make the plant a net consumer of energy overall, the system increases revenue by selling more electricity during periods of peak demand, when electricity prices are highest. If the upper lake collects significant rainfall, or is fed by a river, then the plant may be a net energy producer in the manner of a traditional hydroelectric plant.

Pumped storage is by far the largest-capacity form of grid energy storage available, and, as of 2020[update], accounts for around 95% of all active storage installations worldwide, with a total installed throughput capacity of over 181 GW and as of 2020 a total installed storage capacity of over 1.6 TWh.[3]

In closed-loop systems, pure pumped-storage plants store water in an upper reservoir with no natural inflows, while pump-back plants utilize a combination of pumped storage and conventional hydroelectric plants with an upper reservoir that is replenished in part by natural inflows from a stream or river. Plants that do not use pumped storage are referred to as conventional hydroelectric plants; conventional hydroelectric plants that have significant storage capacity may be able to play a similar role in the electrical grid as pumped storage if appropriately equipped.

Taking into account conversion losses and evaporation losses from the exposed water surface, energy recovery of 70-80% or more can be achieved.[8][9][10][11][12] This technique is currently the most cost-effective means of storing large amounts of electrical energy, but capital costs and the necessity of appropriate geography are critical decision factors in selecting pumped-storage plant sites.

The relatively low energy density of pumped storage systems requires either large flows and/or large differences in height between reservoirs. The only way to store a significant amount of energy is by having a large body of water located relatively near, but as high as possible above, a second body of water. In some places this occurs naturally, in others one or both bodies of water were man-made. Projects in which both reservoirs are artificial and in which no natural inflows are involved with either reservoir are referred to as "closed loop" systems.[13]

Along with energy management, pumped storage systems help stabilize electrical network frequency and provide reserve generation. Thermal plants are much less able to respond to sudden changes in electrical demand that potentially cause frequency and voltage instability. Pumped storage plants, like other hydroelectric plants, can respond to load changes within seconds.

The most important use for pumped storage has traditionally been to balance baseload powerplants, but they may also be used to abate the fluctuating output of intermittent energy sources. Pumped storage provides a load at times of high electricity output and low electricity demand, enabling additional system peak capacity. In certain jurisdictions, electricity prices may be close to zero or occasionally negative on occasions that there is more electrical generation available than there is load available to absorb it. Although at present this is rarely due to wind or solar power alone, increased use of such generation will increase the likelihood of those occurrences.[citation needed]

It is particularly likely that pumped storage will become especially important as a balance for very large-scale photovoltaic and wind generation.[16] Increased long-distance transmission capacity combined with significant amounts of energy storage will be a crucial part of regulating any large-scale deployment of intermittent renewable power sources.[17] The high non-firm renewable electricity penetration in some regions supplies 40% of annual output, but 60% may be reached before additional storage is necessary.[18][19][20]

Smaller pumped storage plants cannot achieve the same economies of scale as larger ones, but some do exist, including a recent 13 MW project in Germany. Shell Energy has proposed a 5 MW project in Washington State. Some have proposed small pumped storage plants in buildings, although these are not yet economical.[21] Also, it is difficult to fit large reservoirs into the urban landscape (and the fluctuating water level may make them unsuitable for recreational use).[21] Nevertheless, some authors defend the technological simplicity and security of water supply as important externalities.[21]

Pumped storage plants can operate with seawater, although there are additional challenges compared to using fresh water, such as saltwater corrosion and barnacle growth.[28] Inaugurated in 1966, the 240 MW Rance tidal power station in France can partially work as a pumped-storage station. When high tides occur at off-peak hours, the turbines can be used to pump more seawater into the reservoir than the high tide would have naturally brought in. It is the only large-scale power plant of its kind.

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