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Subsections

Pumped Hydroelectric Energy Storage

Pumped hydroelectric energy storage has been in use since 1929, making it the oldest kind of large-scale energy storage technology. In fact, until 1970, it was the only commercially available option for storing energy. Pumped hydroelectric stations are in active operation and new ones are still being built. Time has proven it to be an effective method for storing large amounts of energy.

Operation

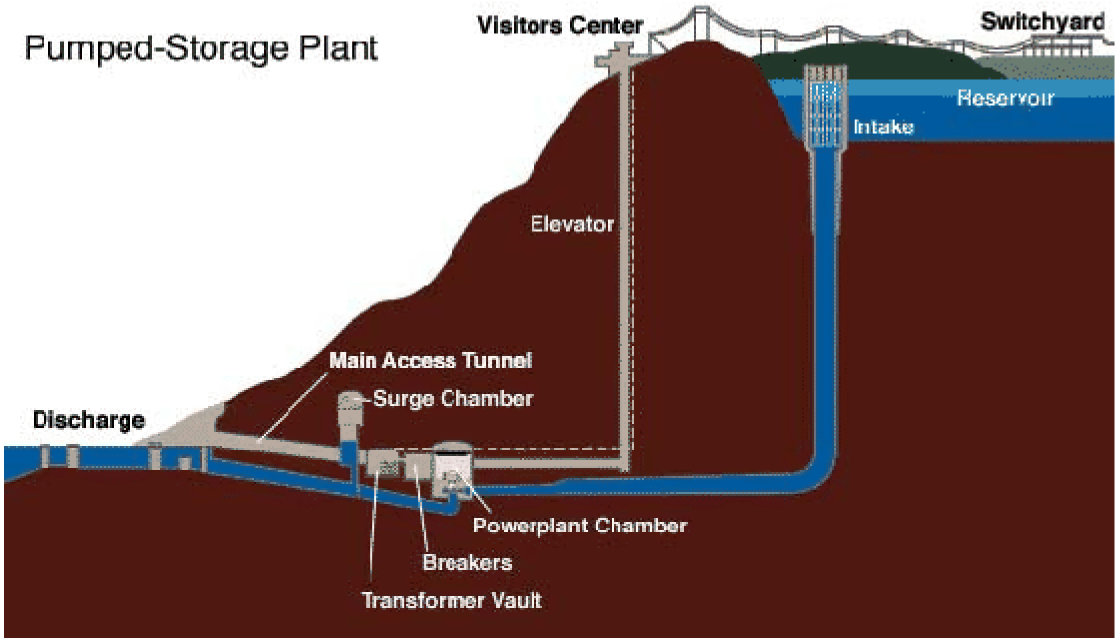

Figure 5.1: Operation of a pumped hydroelectric storage plant.

A pumped hydroelectic storage system consists of two large reservoirs located at different elevations. During peak demand, water is released from the upper reservoir. It drops downward through high-pressure shafts where it passes through turbines and ultimately pools up in the lower reservoir. The turbines drive power generators that create electricity. Therefore, when releasing energy during peak demand, a pumped hydroelectric storage system works similarly to traditional hydroelectricity. When production exceeds demand, water is pumped up and stored in the upper reservoir, ready to be released as needed.

Construction of hydroelectric plants

Balancing between flow or head

The amount of electricity which can be store is dependent upon two factors. These are the vertical distance through which the water falls, called the ``head''; and the flow rate (or the volume of the reservoirs). A common false assumption is `head' and `flow' are substitutable, but in fact the lack of head can not be compensated simply by increasing the volume. This is because high head plants can be quickly adjusted to meet the electrical demand surge. For lower head, the diameter of the pipe would have to be enormous in order to produce the same power. This would not be economically viable, which is why most plants are of the high head variety.

Combined motor and dynamo

In the early days, pumped hydroelectric plants used a separate motor and dynamo, mainly due to the low efficiency of dual generators. This increased the cost as separate pipes had to be built. A majority of the modern plants use a generator which can be run ``backwards'' as an electric motor. The efficiency of the generator has increased and it is now possible to retrieve more than 80% of the input electrical energy. This leads to significant cost savings. Also, modern generators are of the suspended vertical construction. This allows better access to the thrust bearing above the rotor for inspection and repair. It also reduces thrust bearing loss.

A case study

Figure 5.2: Upper reservoir of the Dinorwig plant in Wales.

The Dinorwig plant in Wales, is one of the best-known pumped storage plants in the world. The plant was constructed between 1976 and 1982 in Europe's largest man-made cavern under the hills of North Wales. The six huge pump turbines can each deliver 317 MW, producing together up to 1,800 MW from the working volume of 6 million cubic metres of water and a head of 600 m. These pump-turbines are second in size to the 337 MW devices installed at Tianhuanping in China, though this system benefits from over 50 m extra head compared to the Chinese plant.

The value of the system is enhanced by the speed of response of hydroelectric generators: any of the turbines of the plant can be brought to full power in just 10 seconds if it is initially spinning in air. Even starting from complete standstill takes only one minute.

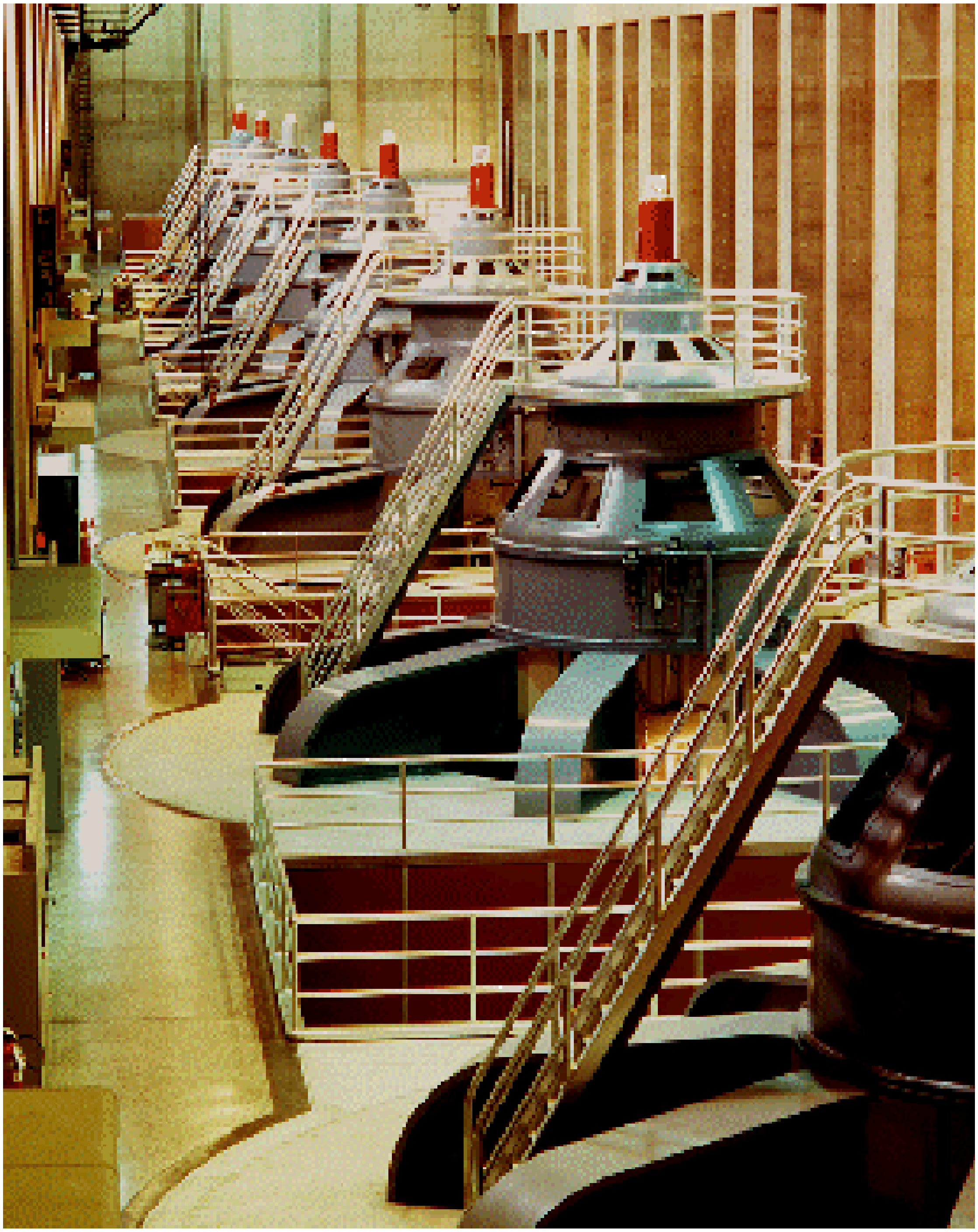

Figure 5.3: A series of generators.

Advantages and disadvantages

Out of all large-scale energy storage methods, pumped hydroelectric storage is the most effective. It can store the largest capacity of electricity (over 2000 MW) and the period of storage is also among the longest; a typical plant can store its energy for more than half a year. Due to the rapid response speed, pumped hydroelectic storage systems are particularly useful as backup in case of sudden changes in demand.

Partly due to the large scale and the relative simplicity of design, the operating cost per unit of energy is among the cheapest; the cost of storing energy can be an order of magnitude lower in pumped hydroelectic systems than in for example superconducting magnetic storage systems. Unlike hydroelectric dams, a pumped hydroelectic system has little effect on the landscape. It produces no pollution or waste.

However, the pumped hydroelectic storage system has its drawbacks too. Probably the most fundamental one is its dependence on specific geological formations. There have to be two large volume reservoirs along with sufficient amount of `head' for the building to be feasible. This is uncommon and often forces the location of the plants to be in remote places, like in the mountains, where construction is difficult and the power grid is not present.

Although its operating cost is cheap, the capital cost of a pumped hydroelectric plant is massive, as it often involves building dams and enormous underground pipes. In terms of environmental issues, it disturbs the local habitat as the water level fluctuates daily. Also, the full amount of water has to be pumped up or down in one go, that is, the system must be `drained' completely before `recharging', although elaborate planning could get around this.

Current state and future development

In 1997, 290 pumped hydroelectic storage plants, representing a maximum combined total of 82.8 GW of installed energy capacity existed worldwide, and another 25 were under construction. In 1998 10% of Japan's total energy comes from pumped hydroelectic energy storage.

Instead of using two different altitude overground reservoirs, underground pumped hydroelectric storage facilities are now being developed by excavating lower reservoirs out of solid rock as much as 300 m underground. These new facilities can be completely isolated from natural water sources such as the ocean or river basins and are designed to move the same water up and down the huge vertical distance thus giving greater energy per unit volume than a natural system. Using the sea as the lower reservoir is another possibility, although questions have been asked about the effect of seawater on the ecology of the upper reservoir and on equipment corrosion. Generators are improved and standardised in order to increase the efficiency and reduce cost at the same time.

However, a large percentage of pumped hydroelectric potential has already been developed in North America and Europe. Much of the remaining potential in the world exists in the developing countries of Africa and Asia. Harnessing this resource would require billions of dollars, because pumped storage facilities generally have very high construction costs. Together with some political opposition, it is more likely that the trend would be towards building smaller scale and cheaper capital cost energy storage systems.

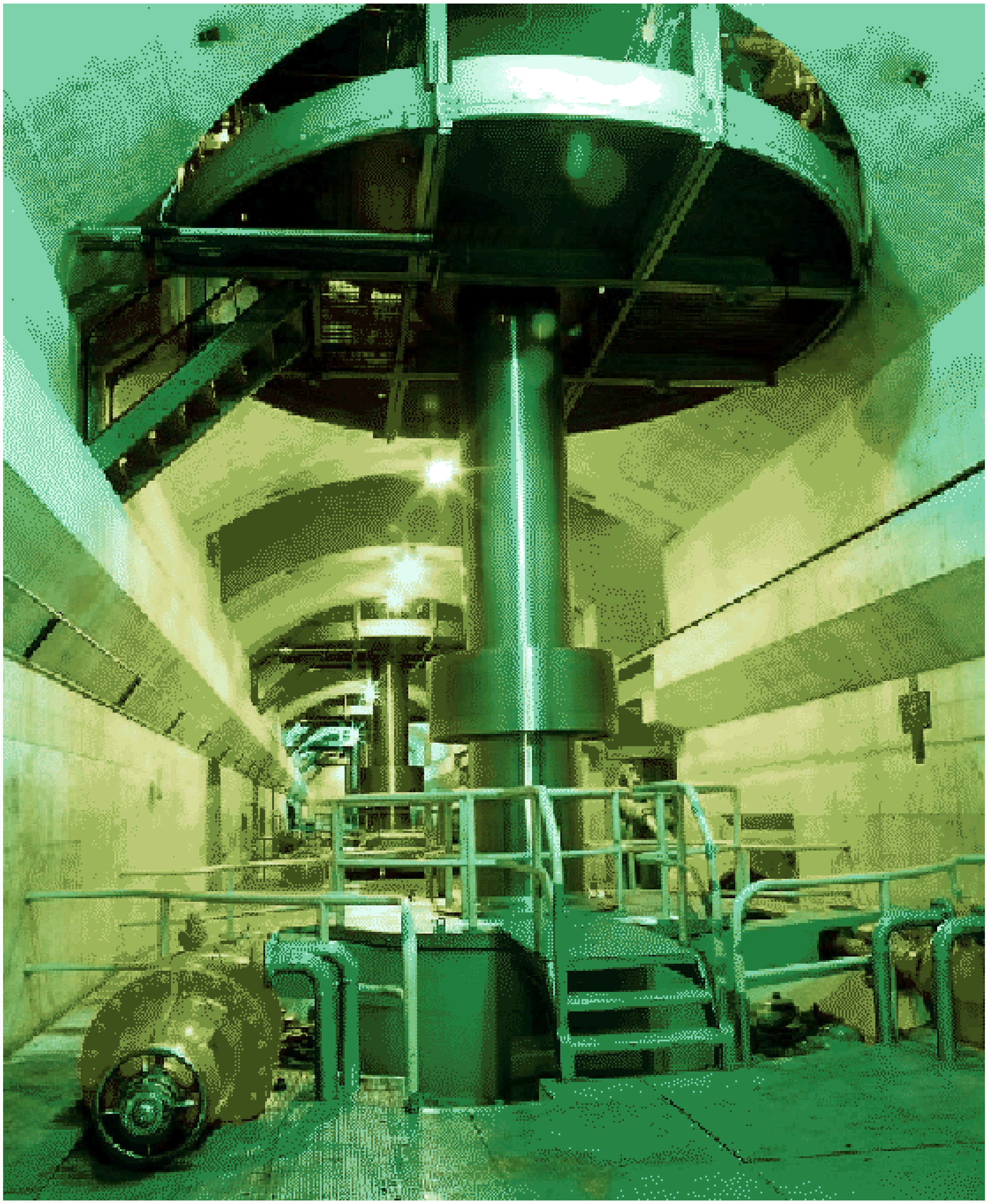

Figure 5.4: Inside of a generator.

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