PUMPED HYDRO-ELECTRIC STORAGE SYSTEMS

(PHES)

Le stockage de l’énergie électrique

Direct storage of electrical energy is a difficult operation, ecially for large-scale storage. It is therefore necessary to nsform it into another form of energy that is more easily rable.

Multiple storage methods are available: whether chanical (potential or kinetic storage), chemical drogen, fuel cell), electrochemical (batteries), or thermal d or heat storage), each industrial storage method has its antages and disadvantages (Figure 1).

The technological choice must be adapted to each specific and take into account the technology's degree of maturity all the real costs associated with it.

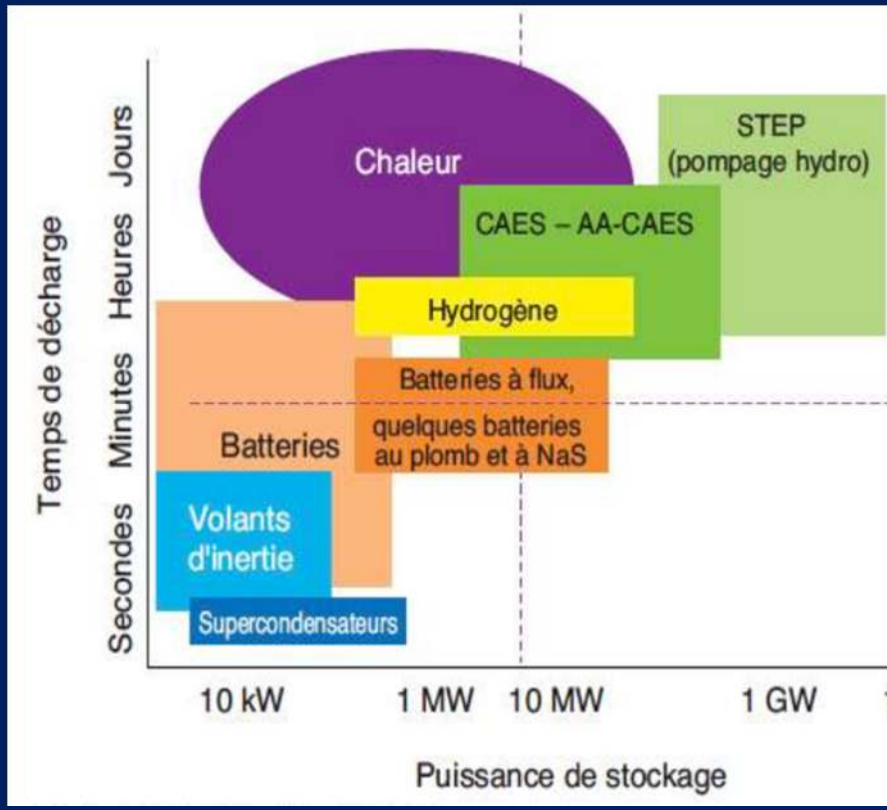

Figure 1

Pumped hydro-electric storage

Pumped storage power stations are a special
e of hydroelectric facility. These plants have
reservoirs located at different altitudes.
eir equipment allows energy to be stored in
ential form by pumping water from the lower
ervoir to the upper reservoir when demand is
or the cost of energy is low.
Conversely, when demand is high or the
ce per kWh is high, they return electricity to
grid by turning the water from the upper
ervoir (Figure 2).

Basically, gravitational potential energy of the
g water is converted to kinetic energy which is
converted to electric energy.

Ep ---------→ Ek ---------- → Eelectric

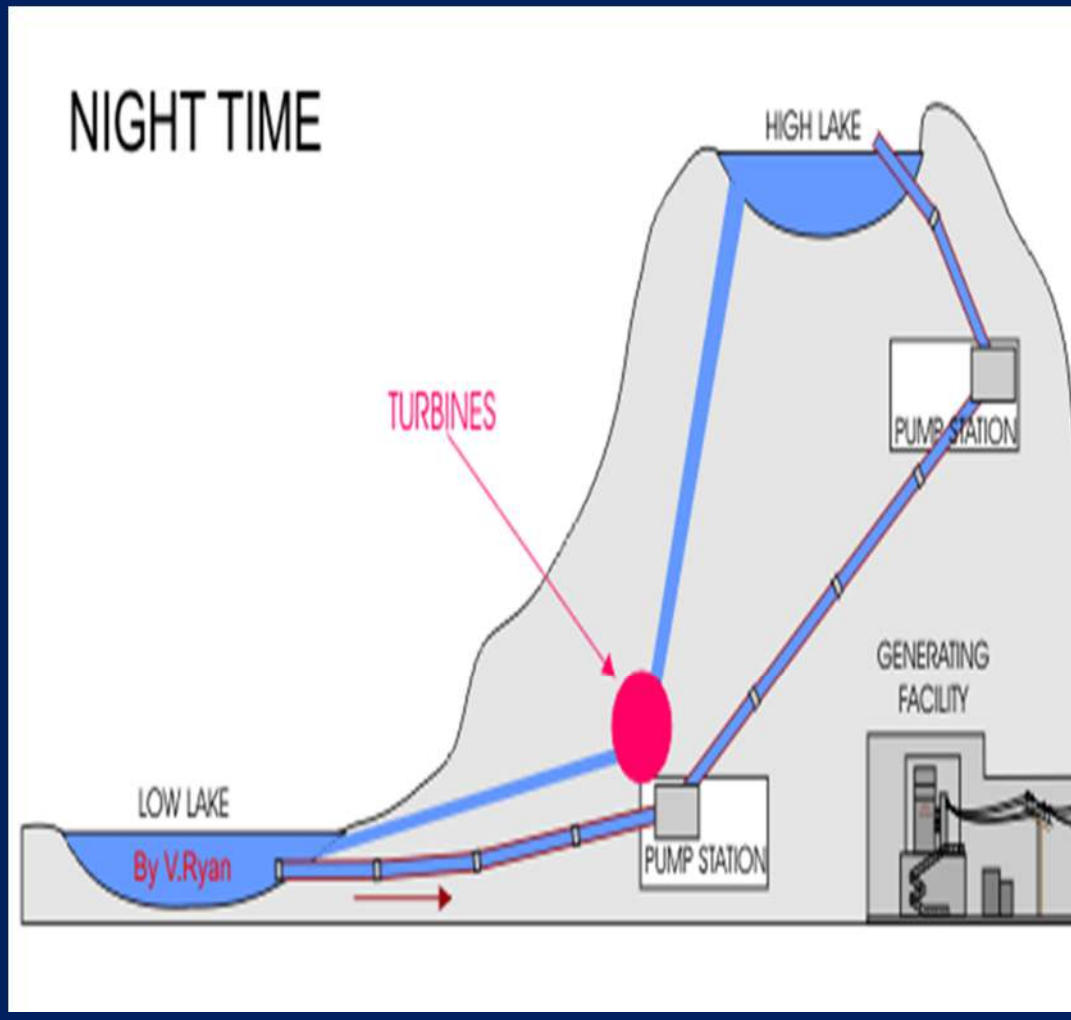

Figure 2

Pumped storage energy was widely developed in the 1970s and 1990s to optimize the operation of large thermal and nuclear power plants. Powerful stations, with installed capacity of up to 3,000 MWe, were built for this purpose in Europe, the United States, Japan, and, later, China (Figure 3).

https://www.youtube.com/watch?v=_PH0IJ-_qOI&t=37s

Figure 3

Characteristics of PSH

Several parameters characterize the services provided by a PSH:

- **The maximum energy stored in the form of gravitational potential energy, which is proportional to the volume of water stored and the head, and which varies from a few GWh to several hundred GWh;**

- **The time constant, which is the ratio of the maximum storable energy to the maximum power in turbine mode; depending on the volume of their reservoirs, we will speak of a daily if these volumes only allow operation for a few hours, and a weekly when they allow continuous operation for several dozen hours;**

- **The efficiency over a complete cycle, which is the ratio between the energy produced by the turbine and the energy consumed by pumping.**

Efficiency

me pumped storage systems can go from zero to full output in tens of seconds. The larger systems take nger to come up to full output. However, real outputs are usually achieved in only a few minutes from itch on.

r a pumped storage system that operates through a height difference of Δh, the gravitational potential ergy available is $= mg \Delta h$ Where:

- m is mass
- g is the gravitational field strength

the maximum power P available from the water is equal to the rate at which energy is converted in the achine and is:

$$P = (mg \Delta h)\, t = (v\rho g \Delta h)/\, t$$

here t is the time for mass m to move through the generator, v is the volume of water moving through the nerator in time t and ρ is the density of the water.

Exercise:

Water from a pumped storage system falls through a vertical distance of 260 m to a turbine at a rate of 600 kg/s. The density of water is 1000 kg/ m^3. The overall efficiency of the system is 65%

- Calculate the gravitational power energy
- Calculate the power output of the system.

SOLUTION

In one second the gravitational potential energy lost by the system is

$mg \Delta \boldsymbol{h} = 600 \times g \times 260 = 1.5$ MJ

The efficiency is 65%

∴ Output power = 1.5 × 10^6 × 0.65 = 0.99 MW

Advantages of PSH

Pumped storage plants offer numerous advantages, including:

- High energy efficiency
- Energy storage
- Flexibility and stabilization of the electrical grid
- Reduction of CO_2 emissions
- Energy resilience

Disadvantages of PSH

- High upfront capital costs, long project development times and social impacts, such as habitat disruption and displacement of communities.
- A major technical limitation is the need for specific geography with a significant elevation difference to create two reservoirs, which limits potential locations, and inherent energy inefficiency where output is always less than input.