Large-Scale Thermal Energy Storage for Electricity Applications

Alberto Benato- University of Padova

The socioeconomic growth of nations is inextricably tied to energy availability, or, in other words, it is dependent on having access to a variety of energy sources at the lowest feasible cost. Currently, only fossil fuels such as coal, crude oil and natural gas can provide this requirement. However, population expansion is hastening energy consumption and increasing the demand for and use of fossil fuels. Nonetheless, such a tendency raises pollutant emissions and exacerbates global climate change. Nut, the worldwide increase in CO2 and greenhouse gas emissions, as well as the repercussions of climate change, have compelled global society to respond by demanding tangible and practical steps capable of altering how energy is generated and natural resources are managed. To this end, EU directives and plans have been established to speed up the installations of renewable-based plants, cut CO2 and greenhouse gas emissions and jump-start the economy after the devastating COVID-19 waves. But the EU's objectives are far from simple. Let us take Italy as an example. To fulfil the assigned goals, Italy has to add 10 GW of wind (of which 0.9 GW will be offshore) and 30 GWp of solar (of which 0.88 GWp will be concentrated solar power) by 2030 [8]. This means jumping from 10.90 GW of wind and 21.65 GWp of solar installed in 2020 to 23.23 GW and 52 GWp, respectively, a rise that could boost renewable electricity production from 41.7% up to 55%, with significant benefits in terms of greenhouse gas reduction and security in energy supplies. Despite these benefits, it is important to underline that wind and solar are characterized by changeable and unpredictable character. Therefore, a synergy between power deployment and storage capacity installations is required. This is the only measure that can assist balance supply and demand without experiencing significant and unexpected power swings, which may cause management and control issues, device malfunctions and local to worldwide blackouts. As previously stated, if Italy is taken as reference, to allow a grid-safe operation after adding other 10 GW of wind and 30 GWp of solar, estimations indicate the need to add approximately 6 GW of centred storage and 4 GW of distributed storage, a requirement of new storage capacity that can not be covered only with pumped hydro and battery energy storage. Therefore, there is a demand for conceptualizing and designing alternative energy storage systems able to be installed near renewable plants and capable of storing large amounts of energy.

Additionally, it can be beneficial that these new storage facilities exhibit a low or even null environmental impact and a capability to use the fossil-based power units' sites, devices and infrastructures. The latter features can revamp conventional plants fed by fossil fuels in storage units, an action that prevents land and raw material consumption.

Baring in mind the requirements, the socio-economical constraints mentioned above, and the available and in-developing storage technologies, it is clear that Thermal Energy Storage for electricity applications (also known as "Carnot Battery") is one of the most promising.

Despite the different plant arrangement, a common working principle for Carnot Batteries can be recognized. During the charge phase, electricity is converted into heat. Energy is stored in the form of thermal energy by creating a temperature difference between two thermal reservoirs. During the discharge or delivery phase, this temperature difference drives a heat engine that converts thermal energy back to electricity.

Carnot Batteries are considered a very attractive solution because compared to Pumped Hydro or Compressed Energy Storage, they are not subjected to geographical restrictions and they do not suffer from low life-time like Batteries.