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(Updated 8/4/2023 to include inter-seasonal storage requirements for green hydrogen heating.)

Acentral issue in the low carbon future is large-scale energy storage. Due to the variability ofrenewable electricity (wind, solar) and its lack of synchronicity with the peaks of electricity demand, there is an essential need to store electricity at times of excess supply, for use at times of high demand. This article reviews some of the key issues concerning electricitystorage. In particular, it compares "Green Hydrogen" storage with the available alternatives.

In the UK"s nuclear and fossil-fuelled electricity system of 30 or more years ago, large scale nuclear and coal-fired thermal power stations provided a constant "base load" of power. The peaks in demand were supplied by switching-on "open cycle gas turbine" generators, that can run up to full load in minutes, plus some hydro-electricity, and oil-fired steam turbinesthat can also be switched on quickly from a warm start.

The peak power consumption was 39.3 GW at 17:40 on October 16. The minimum was 22.9 GW, at around midnight. The average value across the whole 24 hour period was 33 GW, as shown bythe horizontal blue dashed line on Fig. 1a. The total electricity consumption during the day was 790 GWh, which is the area under the curve (also equal to the area under the average line). The peaks and troughs in demand were managed mainly by varying the amount of electricity supplied by CCGT and pumped hydroelectricity.

These numbers: 65GWh and 8GW are probably underestimates because of 3 factors:

Conversely, electrification of transport provides opportunities for storing electricity through charging demand management and"vehicle to grid" (V2G)systems. Storage of heat also provides similar opportunities (see later). Sothe overall effect of their electrification on storage requirements is unclear.

The alternative to building generating capacity for the average electric power requirement and storing the peak to trough variation would be to install sufficient generating capacity to meet the peak demand and then "curtail" (switch-off) generators when they aren"t needed at other times of the day.

For our example on October 16th, this would require renewable electricity generation of 39.3GW at 17:40. Of this, only 22.9GW would be needed at midnight, meaning that up to 16.4GW (42% of the installed capacity) would be switched-off for some of the day.

The average "power factor" of wind energy in the North Sea is 38.9% (seethis article). So if all of the peak power was to be provided by off-shore wind turbines, the 39.3 GW of electricity would require 39.3/0.389

=101 GW of installed wind turbine capacity, corresponding to 8,400 of the largest (12MW) offshore wind turbines.

If the average power of 33 GW was to be provided by the installed base and the peak to trough variation managed through intra-day storage, as described above, then the installed base of turbines wouldneed to be 33/0.389 = 85 GW, corresponding to 7100 turbines. The cost of providing the energy storage must be compared with the cost of installing and maintaining the additional 1300 wind turbines to decide which is more financially attractive.

Of course, the economic calculation is more complex than that, because the "levelized cost of electricity" depends on the utilization of the generating assets. So the economics of electricity generation changes ifsome of the wind turbines are to be curtailed for up to half of the day.

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