PHES: A Multifunctional and Cost-Effective Energy Storage System

Center for Study of Science, Technology and Policy

Hanumanth Raju GV

India has set some ambitious renewable energy (RE) targets for itself — 175 GW by 2022 and 450 GW by 2030. This assigns an important role to grid-scale energy storage systems (ESS) for enabling smooth integration of RE into the grid to assure stability and round-the-clock electricity supply to the downstream consumers.

The prominent ESS include pumped-hydro energy storage (PHES), compressed air energy storage (CAES), flywheels, secondary batteries (lead acid/sodium sulphur/lithium-ion/nickel-cadmium), flow batteries, hydrogen storage, fuel cells, supercapacitors, superconducting magnet energy storage (SMES), and thermal energy storage.

Of these, pumped-hydro energy storage is recognised as one of the most mature bulk energy storage technologies globally. In India, the total PHES capacity developed till date is 4,785.6 MW (3,305.6 MW operational and 1480 MW non-operational), while another 1580 MW is in the construction stage.

This blog provides an overview of the technical aspects of PHES, and examines why it is most suited to complement India's storage needs and drive its transition to an RE-dominant future.

About PHES:

PHES is a type of hydroelectric storage with two reservoirs — upper and lower — which are at different altitudes. When power demand is low (during off-peak times), water is pumped from the lower reservoir to the upper reservoir, consuming power from the grid through a pump motor (recharging process); during instants of peak demand, water is released from the upper reservoir to the lower reservoir, generating power through the turbine-generator (discharging process). This process is repeated during each cycle.

Given below are some technical specifications to help understand PHES better:

PHES: Technical Specifications

Maximum power rating (MW)	3000
Discharge time (total time taken to release the maximum power of an energy storage device)	4 – 16 hours
Maximum cycles/lifetime	>15,000 cycles / 30 – 60 years
Round-trip Efficiency (ratio of electrical output to electrical input)	70–85 %
Specific Energy (Wh/kg) (ratio of energy stored to volume of storage device)	30 – 250

Applications and Challenges:

PHES is specifically used for bulk power storage, seasonal storage, transmission-congestion relief in the grid, and upgrade deferral.

The prominent challenges faced by PHES include delay in environmental clearance for developing new plants; high capital investment, and considerable land and time requirements to set up plants; and high dependence on topographical components.

In addition, PHES faces the issue of low recovery due to the existing pricing mechanism, which does not account for the many services it provides to the grid, such as RE smoothing, peak-load shaving, and ancillary services.

The USP

PHES offers some unique benefits, which help it score over its ESS competitors.

With a lifetime of over 40 years, and an efficiency of 70–80 %, PHES is capable of providing multiple services to the power grid. It can support frequency and voltage deviations in the grid, and can also deal with the seasonal mismatches in RE in the long run, owing to its bulk storage capability. Further, PHES can provide bulk storage with longer discharge durations (as compared to other ESS), making it the first choice for large-scale deployment in co-located RE-generation projects (projects located near the PHES plant).

PHES carries a cost advantage as well. The capital cost per kilowatt hour for any ESS is proportional to their energy density (ratio of quantum of energy stored to volume of storage device) rating. In comparison to the other ESS, PHES has low energy density, due to which its capital cost/kWh is also less (between $ 5–100/kWh). This, along with an impressive lifetime, makes PHES a good choice economically too.

In Conclusion

Though any one ESS technology cannot meet the diverse needs of energy storage, PHES — with its multi-functionality and cost-effectiveness — is the front runner for achieving robust grid integration, and hence, for driving India’s RE transition. However, for large-scale adoption in India, PHES has to become competitive. This calls for a suitable pricing mechanism that factors in the additional benefits of PHES, as well as separate regulatory and policy frameworks that recognise its specific services.

For in-depth discussions on the topic, please join our upcoming virtual event "The Role of Pumped-Hydro Storage in the Indian Grid", 30 July, from 4:00 PM–5:30 PM. Register here.