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India has set itself a renewable energy (RE) target of 175 GW and 450 GW for 2022 and 2030, respectively. With the country bracing up to meet these targets, and given the intermittent nature of RE, energy storage systems (ESSs) are required to balance the grid.

The most commonly used storage technologies in the Indian grid are pumped-hydro (~96% of the total storage installed) and battery storages. Other storage technologies that can be used are compressed air, flywheels, hydrogen storage, supercapacitors, superconducting magnetic energy storage (SMES), and thermal energy storage (which includes water heaters, ice storage, chilled water storage, and molten salt-based storage).

Applications of energy storage

ESSs have a wide variety of applications in the grid. The four main applications are ancillary services, bulk energy services, transmission and distribution infrastructure services, and customer energy management.

Ancillary services support the smooth and stable operation of the grid by maintaining the grid voltage and frequency within permissible limits (voltage support and frequency regulation). They also manage sudden fluctuations in the load by adjusting the power generation according to demand (load following). Other ancillary services include spinning reserves and black start. Spinning reserves are standby generators that support the grid during a power shortage. When there is an unexpected power outage (partial or total blackout of the grid), the system is restored through a black start. ESSs installed at the generation and transmission level can provide these ancillary services.

Bulk energy services include variable RE integration, seasonal storage, and energy arbitrage. ESSs can store excess energy and supply it when needed, thereby managing RE intermittency and integrating more RE into the grid. Also, ESSs can cater to the seasonal mismatches in demand. Energy arbitrage is the storage of energy in large-scale energy storage devices when the electricity price is low and its sale when the price is high, leading to revenue generation.

The use of ESSs in the transmission and distribution network helps in delaying upgradation of the network, while easing congestion. It is also useful in city limits where acquiring land for laying high voltage lines is a hassle.

Customer energy management services include using ESSs to provide quality and reliable power, reducing peak demand, and time-shifting customer demand to off-peak periods.

ESSs at different levels of the network

ESSs can be classified based on the duration of the discharge of power as short-term (seconds to minutes), mid-term (minutes to hours), and long-term storages (hours to days). Table 1 shows the suitability of different energy storage technologies for various applications and their levels in the network.

The Way Forward

The major challenge in the adoption of ESSs in the grid is their cost. Hence, to improve profitability, a single storage device may be used for different applications, leading to multiple revenue streams. In addition, our energy market and regulatory framework should incentivise storage-specific projects.
(For more details, please refer to our working paper https://cstep.in/publications-details.php?id=1194)

Table 1: Energy storage technologies for various applications and their levels in the network

Levels in the network	Applications in the grid	Short-term			Medium-term			Long-term				
					Battery							
		Flywheel	Supercapacitors	SMES	Lead-acid	Lithium ion	Sodium sulphur	Pumped hydro	Compressed air	H_2 storage	Flow battery	Thermal storage
Generation	Frequency regulation	■	■	■								
	Black start						■	■	■			
	Spinning reserves						■	■	■			
	Load following					■	■				■	■
	Renewable energy integration				■	■	■	■	■	■	■	
	Energy arbitrage				■	■	■	■	■	■	■	■
	Seasonal storage							■	■	■	■	■
Transmission	Voltage support	■	■									
	Transmission congestion relief and upgrade deferral							■	■			
Distribution	Distribution congestion relief and upgrade deferral				■	■	■					
	Power quality		■	■	■	■						
End user	Power reliability				■	■						
	Demand shifting and peak reduction				■	■						■