**Battery energy Storage Solutions (BESS) for addressing Energy Transition: Perspectives of India**

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**1. Introduction**

Being world’s third-biggest emitter of GHG’s India has committed to reduce the “emissions intensity” of its gross domestic product (GDP) to 45% below 2005 levels by 2030. India’s pledge is an update to its first nationally determined contribution (NDC), submitted in 2015, which targeted a 33-35% cut. It also includes a commitment that around half of its installed electricity generating capacity will be made up of non-fossil fuel sources by 2030. However, this is conditional on the transfer of technology and finance from other countries. India is working towards achieving 500 GW of installed electricity capacity from non-fossil sources by 2030. By end Feb 2023, total installed renewable energy capacity reached 168.96 GW (64.38 GW solar, 51.79 GW hydro, 42.02 GW wind and 10.77 GW bio power). Another 82.62 GW of green energy capacity is under implementation and 40.89 GW of capacity is under various stages of tendering. This includes 119.09 GW RE and 46.85 GW large hydro. There has been significant emphasis and adoption of large-scale renewable energy options and shift in focus from standalone to hybrid solutions that provide firm (or even “round the clock (RTC)”) renewable energy.

Despite of rapid growth, ambitious targets the typical arguments against renewable based energy generation are predominantly related to (i) integration into the overall power system (grid), (ii) dispatchability, (iii) scheduling and forecasting, (iv) curtailment, clipping and must run status (NREL, 2016). Compared with the conventional power generation (coal, gas, hydro and nuclear fired technologies) the power output from renewables (without energy storage) is not being controllable and thus have such challenges. Moreover, in the present scenario, emphasis is given on reliability and dispatch ability by electrical network operator as pricing systems are moving from a guaranteed tariff to market or demand driven principles. In some parts of the world power operators offer a premium for power during peak demand periods. In view of the above, operators all around the globe are aiming at providing high quality power when needed. Additionally, the power output of renewable energy plants typically depends on intermittent resource (wind power density & solar insolation etc.) is again problematic for stability of electric grid due to continuous harmonics. Moreover, 500 GW of non-fossil fuel-based power would mean a substantial share in future total generation of energy in India. Such large share of intermittent sources will require huge investments in the power grid infrastructure for transmission ensuring smart supply and demand management. There are certain challenges in the integration of renewable directly with the existing grid due to the intermittent behaviour of resource. It is difficult to obtain good quality power, since intermittence of available resource reflect on the voltage and power output of the further changes the voltage profile and frequency response of the and affects the transmission and distribution systems of utility grid. Table 1 summarizes three key characteristics of RE generation, including variability, uncertainty, and non-synchronous generation. These characteristics produces an economic challenge to RE integration thus reduce the energy value (such as the ability to avoid fossil fuel use) and capacity value (the ability to replace conventional capacity).

Table 1. Characteristics of solar PV electricity generation and associated integration challenges

|  |  |  |  |
| --- | --- | --- | --- |
| **RE Resource**  **Characteristic Impact** | | **Potential Economic Challenge to Integration** | |
| **Energy Value & Curtailment** | **Capacity Value** |
| Variability | RE output can vary as underlying resource fluctuates. | Supply/demand mismatch coupled with generator inflexibility leads to curtailment. | RE may not be able to replace conventional capacity during periods of peak demand. |
| Uncertainty | Output cannot be predicted with perfect accuracy. | Part-load operation of thermal plants for operating reserves leads to curtailment. | Capacity needed for provision of operating reserves. |
| Non synchronous generation | RE does not currently help maintain system frequency. | Part-load operation of thermal plants for provision of frequency response leads to curtailment. | Capacity needed for provision of frequency response. |

This is an established fact that energy transition (RE targets, coal Phaseout, coal repurposing etc.) is impossible without intervention of energy storage technologies. Govt, of India has come out with energy storage requirements to execute its 500 GW non fossil fuels-based energy generation target by year 2023 in its revised national electricity plan. In view of the above, it is increasingly clear that energy storage will be important in the drive to boost the integration of variable RE sources into power infrastructures across the entire chain of energy supply, whether it is at generation, transmission, or distribution along with the grid ancillary services. The provision of energy storage technologies can reduce peak demand, improve day-to-day reliability, provide emergency power in case of interrupted generation, reduce consumer and utility costs by easing load balance challenges.

**2. Energy Storage Technologies**

Energy storage technologies comprises of systems those can be classified under five broad categories, these are: mechanical, electrochemical (or batteries), thermal, electrical, and hydrogen storage technologies. These technologies are capable of dispatching electricity within milliseconds or seconds and can provide power back-up ranging from a few minutes to many hours. The suitable duration (long or short) of storage, scale of systems (in MW and MWh) and response time are technology dependent making it important to choose the appropriate technology as per the application requirements and constraints.

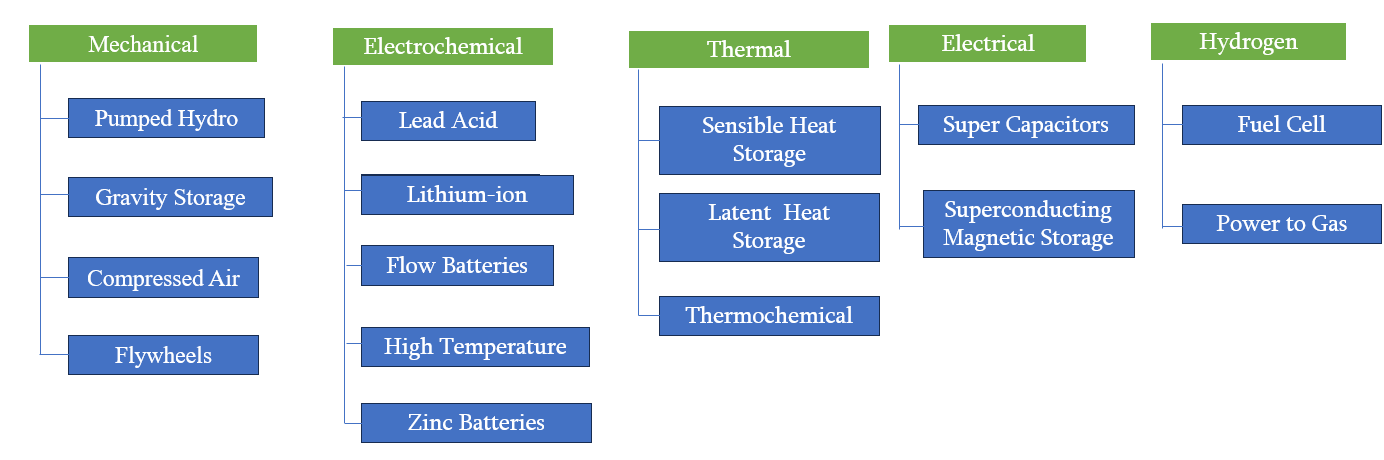


Figure – 1. Classification of energy storage technologies

**2.1 Mechanical energy storage**

This is the energy storage by applying force to an appropriate medium to deliver acceleration, compression, or displacement (against gravity); the process can be reversed to recover the stored kinetic or potential energy. This energy storage works in complex systems that use heat, water or air with compressors, turbines, and other machinery.

**2.1.1 Pumped Hydro Storage (PHS)**

In these systems, the energy is stored as the potential energy of water kept on a higher elevation. Generally, this involves pumping water into a large reservoir at a high elevation—usually located on the top of a mountain or hill. When energy is required, the water in the reservoir is guided through a hydroelectric turbine, which converts the energy of flowing water to electricity. PHS is often used to store energy for long durations (8-24 hours).

**2.1.2 Gravity Storage Technologies**

Gravity based energy storage technologies use the same principle as PHS systems. However, the important difference is that cement or bricks, or rocks are used as the mass moving up or down instead of water. The important advantage of this is that the size of the systems is much smaller due to the higher density of these solids compared to water. Additionally, the requirement of specific geological features can be avoided.

**2.1.3 Compressed Air Energy Storage (CAES)**

A CAES system uses excess electrical energy to compress air using an electrically driven pump, which is stored either in an underground cave or above ground in high-pressure containers. When excess or low-cost electricity is available from the grid, it is used to run an electric compressor, which compresses air and stores it under high pressure. When electrical energy is required, the compressed air is directed towards a modified gas turbine, which converts the stored energy to electricity.

**2.1.4 Flywheel Energy Storage (FES)**

Flywheels store electrical energy as rotational energy in a heavy cylindrical rotating mass. Flywheel energy storage systems typically consist of a large rotating cylinder supported on a stator. Stored electric energy increases with the square of the speed of the rotating mass, so materials that can withstand high velocities and centrifugal forces are essential for its construction. In general, flywheels are very suitable for high power applications due to their capacity to absorb and release energy in a very short duration of time.

**2.2 Electrochemical Storage**

Electrochemical storage technologies include various battery energy storage systems (BESS) that use different electrochemical reactions to store electricity namely lead-acid batteries, lithium-ion (Li-ion) batteries, sodium-sulfur batteries (NAS), flow batteries, Zn-air batteries, and supercapacitors. The batteries, depending on type, may be suitable for a short duration (few minutes) or long duration (8+ hours) applications. For stationary storage applications, two of the main parameters are the cycle life and the roundtrip energy efficiency (%) of the batteries.

**2.3 Thermal Storage**

The principle of storage of energy in thermal energy storage systems is conceptually different from electrochemical or mechanical energy storage systems. Here, the energy by heating or cooling down appropriate materials using excess electrical energy. When required, the reverse process is used to recover the energy. This category of technologies includes ice-based storage systems, hot and chilled water storage, molten salt storage and rock storage technologies.

**2.3.1 Sensible Heat Storage**

Available energy is stored in the form of an increase or decrease in temperature of a material, which can be used to meet a heating or cooling demand. One of the most well-known technologies of this type is molten salt storage. This type of storage is generally coupled with Concentrated Solar Power (CSP) plants where the heat generated is used to increase the temperature of molten salt. Another important technology in this space is hot and chilled water storage. These are especially relevant where a large part of the electrical load is for space heating or cooling applications.

**2.3.2 Latent Heat Storage**

In these systems, the energy is stored in a material that undergoes a phase change (transition between solid and liquid) as it stores and releases energy. Examples include ice storage tanks for domestic or industrial cooling applications. During periods of excess energy and low demand (usually night-time), the liquid water is converted into ice and stored in large tanks. When the cooling load increases during the daytime and afternoon, the ice is melted to provide space cooling to the connected buildings.

**2.3.3 Thermochemical Storage**

The third category of thermal storage involves storing energy in reversible chemical reactions. Compared to the other two technologies these are much more compact and lightweight. There are multiple variations of this technology most of which are currently in the initial prototype development stage.

**2.4 Electrical Storage**

Super capacitors and Superconducting Magnetic Energy Storage (SMES) systems store electricity in electric and electromagnetic fields with minimal loss of energy. A few small SMES systems have become commercially available, mainly used for power quality control in manufacturing plants such as microchip fabrication facilities. These technologies are ideal for storing and release high levels of energy over short bursts due to their lower price in $/kW (power).

**2.5 Hydrogen Storage Technologies (Power-to-Gas)**

The basic concept of hydrogen storage technologies is to use electricity to perform electrolysis of water to produce hydrogen and oxygen. The hydrogen produced is stored in high pressure containers and can be used as a fuel for direct combustion (cooking and heating applications) or for electricity generation via PEM Fuel Cells.

A detailed comparison between various technologies of energy storage is presented in this section based on various technical and non-technical parameters. Table 2 can be referred to further understand the strength and weakness of each energy storage system.

Table-2 . Technical features of various energy storage technologies

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Key tech. Parameters | PHS | CAES | FESS | SCES | BESS |
| Power range (MW) | up to 3000 MW | ~ 300 MW | 0.01 ~ 0.25 | 0.01 ~ 0.3 | ~ 500 MW |
| Energy rating (kWh) | up to 24 x 10^6 | up to 2 x 10^6 | 25 ~ 5000 | ~ 5 | ~2.5 x 10^4 |
| Energy density (Wh/kg) | 0.5 to 3 | 30 ~ 60 | 5 ~ 80 | 0.05 ~ 15 | ~230 |
| Lifetime (years) | 75 | 20 ~ 40 | 15 ~ 20 | 25 ~ 30 | < 15 |
| Lifecycles (cycles) | >30k | 8k ~ 13k | 20k ~ 100k | 100k ~ 500k | ~10k |
| Round trip Efficiency (%) | 75 to 85 | 40 to 75 | 90 ~ 95 | 85 ~ 95 | 85 ~ 95 |
| Reaction time | minutes | minutes | milli-seconds | milli-seconds | milli-seconds |
| Discharge time | 6 to 8+ hours | 6 to 8+ hours | Sec to 15 mins | milli-seconds to mins | seconds to hours |
| Self-discharge (%/day) | Nil | Nil | 1.3 ~ 100 | 10 ~ 40 | ~0.15 |
| Nominal Voltage (V) | System voltage | System voltage | System voltage | 2.3 ~ 400 | 1 ~ 4.2 |
| Operating temperature (°C) | Ambient | Ambient | 20 ~ 50 | -40 ~ 85 | -20 to 60 |
| Power Cost ($/kW) | 500 to 700 | 500 ~ 1800 | 100 ~ 300 | 100 ~ 300 | 350 ~ 600 |
| Energy Cost ($/kWh) | 5 ~ 100 | 50 ~ 400 | 1000 ~ 5000 | 300 ~ 5000 | ~ 500 |
| Scalability | Scaled down /up within operating range of PTG units | Difficult to scale up/Down | Applicable only for low E/P ratio applications | Scalable by connecting in parallel | Easily scaled up/down |
| Limitations | Topographical and geological considerations | Topographical and geological considerations | Higher self- discharge and cost | Higher self- discharge and cost | No such requirements |
| Application | High energy storage and peaking power applications | Bulk energy storage applications | Only for very short duration power applications | Only for very short duration power applications | Both energy and power applications |
| Renewable integration applications | Energy & Power shifting | Energy & Power shifting | Smoothing, Ramp rate control | Smoothing, Ramp rate control | Smoothing, Ramp rate, Load shifting |
| Application Restrictions | Only Grid/Utility scale applications | Applications with longer discharge duration. | Only Shorter duration discharge applications | Only Shorter duration discharge application | Compatible for all type of applications |
| Installation period (years) | > 4 | >4 | 0.5 ~ 1 | ~ 0.5 | 0.5 ~ 1.5 |
| Land requirement (m2/MW) | Site specific | Site specific | ~5 | ~2 | ~10 |

Among EES technologies described above government policies in India are only revolving around PHS and BESS. Present Chapter focuses on battery energy storage systems (BESS) mainly.

**3. Applications of BESS**

Batteries are mature technology for shorter duration storage with back up feasibility of few second to few hours. Due to their availability in various sizes and system mobility features, Electro Chemical Energy Storage System (ECSS) are commercially successful in grid scale utility applications. The most prominent types of BESS are presented in Table-3.

Table 3. Minimum technical specifications of BESS technologies

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **No.** | **Parameter** | **Units** | **Lithium ion** | **Sodium Sulfur** | **Flow Batteries** | **Lead Acid** |
| **1** | Cell Voltage | V | 3~4.2 | 2.1 | 1.5 | 2~2.35 |
| **2** | Specific energy | Wh/kg | 120~230 | 150~240 | 25~75 | 30~50 |
| **3** | Specific Power | W/kg | 150~350 | 150~230 | NA | 200~400 |
| **4** | Coulomb Rate | - | 0.5~4 | <0.17 | <0.2 | >0.2 |
| **5** | Discharge time | Hours | 0.25~2 | > 6 hours | > 5 hours | sec~5hours |
| **6** | Cycle life maximum | No | 6000 | 4000 | 12000 | 2000 |
| **7** | Self-Discharge daily | % | 0.15~0.3 | 0.05~20 | Negligible | 0.1~0.4 |
| **8** | Installation ease | - | Containerized/ Easy | Non-standard containers / Complex | Containerized/ Easy | Time consuming / Easy |
| **9** | Worldwide installation ranking for BESS | - | 1 | 2 | 3 | 4 |
| **10** | Bottomline | - | Proven both commercially and technically | Commercially viable for long duration applications | Commercially viable for long duration and lifetime applications | Not preferable due to lower lifecycle and performance |

BESS can be used as an easy alternate with lower Merit order Dispatch (MOD) cost for several application. These applications are briefly described in the following paragraphs.

**3.1 Peak Load Management**Peak load management deals with curtailing peak power demand at a given interval of time to optimize the electricity charge. Ideally to reduce the peak demand, loads need to be scheduled in such a way that all of them are not operated simultaneously to avoid high load demand. However, practically this is challenging as the utility have no control on consumer loads. Alternatively, incorporating energy storage device can reduce the peak demand from the grid and support the load from energy storage system. Batteries can regulate the power flow by its charging and discharging process. It gets charged when the grid is running in off peak period at lower electricity cost and get discharged to during peak periods at higher cost.

**3.2 Energy Arbitrage**

Conventional electricity market depends on the real-time balance of supply and demand. Cost effective ways of storing electrical energy can help the grid to be more efficient and reliable. Energy arbitrage application is aimed at maximizing the net revenue of utility by purchasing the energy at lower prices and selling it during high-priced time.

**3.3 Electricity market (to avoid DSM Penalties)**

Unscheduled Interchange (UI) mechanism in general is the difference between actual and scheduled generation/demand in a time block. UI charges levied under grid regulations are further utilized for serving as investment on grid strengthening schemes and ancillary services. Frequency of the grid is a function of supply demand imbalance. Penalties are imposed on utilities for deviations in frequency response under both under drawl and over drawl scenario to maintain the grid performance. To attain maximum profit, the entity needs to ensure that the actual demand follows closely with scheduled demand which is highly challenging. Incorporating BESS will be advantageous for utilities, as it can serve the load with better response time and reduce the penalties under sudden load fluctuations or unpredictable scenarios.

**3.4 Distribution Upgrade (Capex) Deferral**

Distribution system shall update its capacity to match with the load growth known as distribution upgradation. Distribution system majorly includes substation transformer and feeders to feed the loads. Upgrading the distribution assets with higher capacity will involve huge capital expenditure. Availability of utility scale storage can be used to store during off peak periods and made to release energy during peak periods. This will help in making the load profile flat and reduces the burden on existing transformers and feeders by shifting the peak demand. In such scenario, need to upgrade the existing equipment can be avoided by extending the life and deferring the investment for few more years ultimately saving effort of replacing equipment and intermittency in the network.

**3.5 Reactive Power Management**

Reactive power management is an important aspect of power system operation. Generators, transmission line susceptance and capacitor banks are the prime source for reactive power. To meet the reactive power needs of consumer load, excessive flow of reactive power in the lines may lead to voltage instability and uneconomical operation of network. Utilities may face both high voltage and low voltage issue due to unbalance in the network at different operating conditions. Thus, it calls for dynamic compensation as an effective solution against. traditional static compensation using reactors/capacitors. Battery energy storage system with an appropriate inverter can operate in both inductive and capacitive mode like STATCOM. The inverter can act as a voltage source and operate in all four quadrants to supply or consume reactive power apart from its basic role of energy charge and discharge. The design of system allows the inverter to provide reactive power to the LV grid and/or downstream load connections which reduces the overall reactive power requirement from the grid. Hence, the excessive flow of reactive power in the lines leading to voltage instability and uneconomical operation of network can be avoided by using BESS.

**3.6 Asset Optimization**

By placing battery energy storage system at appropriate locations, overloading of transformers and cables can be significantly reduced which will also provide saving in terms of technical losses. Operational costs can also be lowered through effective monitoring of equipment degradation with BESS support.

**3.7 Renewable energy based Electric Vehicle Charging**

BESS are essential for EV integration and utilized as spinning reserve to meet the power requirement, since it should supply energy at any point of time irrespective of system conditions. During off peak period EV can be directly charged from the grid, whereas during peak period battery can assist in EV charging to avoid the penalty due to higher peak demand and maintain grid stability and reliability. It will also help to maintain huge variations in energy is to be handled in an effective manner to ensure grid reliability, stability and managing huge number of source & load points to maintain system frequency.

**3.8 System Resiliency Improvement**

For a power system to be resilient, it must be capable of islanding and operating independently from the grid during outages. If network is installed with additional transfer switches and appropriate controls, then these systems can act as self-sufficient grids, generating energy and powering critical loads until utility services are restored. The battery energy storage system is extensively used with renewable energy sources to provide backup power during electric grid outages.

**3.9 Off-gird/ standalone Power Supply**

BESS could be well integrated with renewables like rooftop solar, there is reduced fuel consumption as it promotes environment friendly solution for the locations where electricity grid is not available or extended. Response time of batteries is also very less when compared to conventional generator making it an attractive solution.

**4. Status of BESS Deployment across the Globe**

BESS eliminates the biggest problem for renewable energy – power intermittency. The EIA expects a 10 GW increase in battery storage capacity, a trend that would see more than 60% pairing with solar generators. Lot of factors are aiding this growth including a decline in battery costs, and favourable times for wind and solar energy. The notable BESS projects across the globe are briefly summarized in the Table-4 below.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Table 4. List of representative grid-BESS projects **Project** | **Battery Type** | **MWh** | **MW** | **Hour of Storage** | **Country** | **Location** | **CoD** | **Remark(s)** |
| Moss Landing Vistra Battery | lithium-ion | 1,600 | 400 | 4 | United States | Moss Landing, California | 2020 | 300 MW / 1,200 MWh Phase 1 commissioned in 2020, 100 MW / 400 MWh Phase 2 in 2021 |
| [McCoy Solar Energy Project](https://en.wikipedia.org/wiki/McCoy_Solar_Energy_Project) | Battery, lithium-ion | 920 | 230 | 4 | United States | [Blythe, California](https://en.wikipedia.org/wiki/Blythe,_California) | 2021 | Battery storage paired with 250 MW solar project[[](https://en.wikipedia.org/wiki/List_of_energy_storage_power_plants#cite_note-20) |
| Moss Landing PG&E Elkhorn Battery | Battery, lithium-ion | 730 | 182.5 | 4 | United States | Moss Landing, California | 2022 | 256 Tesla Megapack battery units |
| Slate Project | Battery | 561 | 140.25 | 4 | United States | Kings County | 2022 | Paired with 300 MW solar plant |
| Valley Canter Battery Storage Project | Battery, lithium-ion | 560 | 140 | 4 | United States | Valley Canter, California | 2022 |  |
| Victorian Big Battery | Battery, lithium-ion | 450 | 300 | 1.5 | Australia | Moorabool | 2021 |  |
| Alamitos Energy Center | Battery, lithium-ion | 400 | 100 | 4 | United States | Long Beach | 2021 |  |
| Dalian VFB | Battery, vanadium redox flow | 400 | 100 | 4 | China | Liaoning, Dalian | 2022 |  |
| Buzen Substation | Battery, sodium-sulfur | 300 | 50 | 6 | Japan | Buzen | 2016 | Buzen Substation |
| Minety Battery Energy Storage Project | Battery, lithium-ion | 266 | 150 |  | United Kingdom | Minety | 2021 |  |
| Rokkasho Aomari | Battery, sodium-sulfur | 245 | 34 | 7 | Japan | Rokkasho | 2008 |  |
| Gateway Energy Storage | Battery, lithium-ion | 230 | 230 | 1 | United States | Otay Mesa, California | 2020 |  |
| Huanghe Hydropower Hainan Storage | Battery | 202.8 | 202.8 | 1 | China | Hainan, Qinghai | 2020 | Connected with adjacent 2.2 GW photovoltaic Huanghe Hydropower Hainan Solar Park |
| Crossett Power Management | Battery | 200 | 200 | 1 | United States | Crane County, Texas | 2022 |  |
| Crossett Power Management | Battery | 200 | 200 | 1 | United States | Crane County, Texas | 2022 |  |
| Flower Valley II | Battery | 200 | 100 | 2 | United States | Reeves County, Texas | 2022 |  |
| Gambit battery storage project | Battery, lithium-ion | 200 | 100 | 2 | United States | Angleton, Texas | 2021 |  |
| Kunshan Energy Storage Power Station | Battery, lithium-ion | 198 | 111 | ? | China | Kunshan | 2020 |  |
| Pillswood | Battery, lithium-ion | 196 | 98 | 2 | United Kingdom | Cottingham | 2022 |  |
| Hornsdale Power Reserve | Battery, lithium-ion | 193.5 | 150 |  | Australia | South Australia, Jamestown | 2017 | Tesla Powerpack is charged using renewable energy and delivers electricity during peak hours |
| Hokkaido Battery Storage Project (provisional name) | Battery, vanadium redox flow | 60 | 15 |  | Japan | Hokkaido | 2015 | Vanadium redox flow battery from Sumitomo near several solar energy projects on Hokkaido Island, operational in December 2015. |
| Lake Bonney Battery Energy Storage System | Battery | 52 | 25 |  | Australia | Millicent, South Australia | 2019 |  |
| Gannawarra Energy Storage System | Battery | 50 | 25 |  | Australia | Kerang, Victoria | 2018 | Co-located with Gannawarra Solar Farm |
| Jardelund | Battery, lithium-ion | 50 | 48 | 1 | Germany | Jardelund | 2018 |  |
| National Wind and Solar Energy Storage and Transmission Demonstration Project (I) | Battery, lithium iron phosphate | 36 | 6 | 6 | China | Hebei, Zhangbei |  |  |

**5. Utility Scale BESS Interventions in India**

**India got its first grid-scale advanced lithium-ion battery storage system in 2019 when a 10 MW (megawatt) / 10 MWh (megawatt hour) system offering one hour storage was deployed on Tata Power distribution networks in Delhi. The project by AES and Mitsubishi with energy storage technology and integration services provider Fluence, itself a joint venture of Siemens and AES initiated the process of investigating the optimal deployment of energy storage for the distribution of Tata Power’s 2,000 MW electricity network. In March 2021, Tata Power in collaboration with lithium-ion battery and storage company Nexcharge installed a 150 KW (kilowatt)/528 kWh (kilowatt hour) battery storage system offering six-hour storage to improve the supply reliability at the distribution level and reduce peak load on its distribution transformers. The BESS systems designed to charge during the off-peak hours and discharge the power during peak hours, are expected to support the distribution transformers to manage peak load, regulate voltage, improve power factor, regulate frequency, settle deviations, support grid stabilisation, prevent overload of power transformer, manage reactive power and defer CAPEX (capital expenditure). More recently Tata Power Solar Systems received a letter of award from the Solar Energy Corporation of India (SECI) for the engineering, procurement and construction (EPC) of an INR 9.45 billion (US $126 million) 100 MW solar project with a 120 MWh battery in Chhattisgarh.**

**6. Regulatory Regime of BESS in India**

In the backdrop of the ambitious target of installing 500 GW of non-fossil fuel-based generation capacity by 2030, India has so far crossed the milestone of 150 GW of RE capacity. However, power generation through VRE sources such as solar and wind mainly occurs during periods with low power demand. Furthermore, the energy generated is infirm or inconsistent in nature. Thus, utility scale applications BESS is projected as the most suitable option for India because it is one of the most viable solutions with the existing and upcoming VRE resources to the pertinent issue.

Solar Energy Corporation of India (SECI), a CPSU under Ministry of New and renewable energy, has called for the expression of interest for procurement of 1000 MWh BESS. This will be published along with the RFS bid document and the draft comprehensive guideline for procurement and utilization of BESS as a part of generation, transmission and distribution assets and with all ancillary services.

Central Electricity Authority (CEA) suggests the use of Pumped Hydro Storage System (PHSP) and Battery Energy Storage Systems (BESS) for commercial deployment. Further, the study by CEA, under its planning model selected the BESS from the year 2027-28 onwards and a BESS capacity of 27,000 MW/108,000 MWh (4-hour storage) is projected to be part of the installed capacity in 2029-30. This is in addition to 10,151 MW of PHSP anticipated to be a component of the installed capacity in 2029-30. Later, on March 11, 2022, the MoP notified new guidelines on procurement and utilization of BESS as part of generation, transmission and distribution assets, along with ancillary services. Apart from this, few business cases have been identified in the MoP guidelines in which BESS can be utilized. This includes BESS coupled with RE/ with transmission infrastructure, storage for distribution/ for ancillary services. Thus, the new guidelines are furnished with the aim of facilitating the procurement of battery storage systems to be utilized either in combination with renewable energy or as a standalone asset. With the falling battery prices, the BESS guidelines will serve as a base to streamline future developments in this sector. These guidelines will also play a critical role in achieving the nation’s renewable energy and decarbonisation goals i.e., to reach net zero emissions target set by India. As per the report of NITI Ayog in India, report India’s annual market could surplus $ 15 billion by 2030 and the battery demand expected to rise 260 GWh in the accelerated scenario by 2030.

**7. Utility scale use Cases of BESS in India**

The Government of India is in the early stages of shaping the policy and regulatory framework for energy storage in the country. This brief collates inputs from businesses on ways to strengthen the framework and policy measures. Following business cases have been identified regarding utilization of BESS in supply of energy and grid maintenance:

**7.1 RE supply with BESS**

In this case, the BESS is included as part of the RE Project, and ownership of the RE and BESS assets lies with the Generator. These Projects may also be utilized to meet Peak power and firm dispatchable RE requirements of Procurers. In brief, for charging purposes, BESS developer can procure input energy from the generation (wind/solar/both) owned by it.

**7.2 BESS with transmission infrastructure**

This model is aimed at maximization of the utilization of the storage Asset, increasing duration of usage of transmission system and Strengthen Grid Stability. These systems will enable large-scale optimization of transmission infrastructure by optimum utilization of transmission capacity and reducing network congestion. As a result, the requirement of augmentation of evacuation and transmission infrastructure gets drastically reduced.

7.3 **Storage as an asset for balancing services and flexible operations**

The BESS, with fast ramp rate, is particularly suited for second-by-second management of interchange flows. The system operator (for eg. POSOCO and SLDCs) may use BESS for frequency control and balancing services to manage the inherent uncertainty/variations in load and generation.

7.4 **Storage for Distribution:** This case aims at maximization of the utilization of the Storage Asset and strengthening DISCOM operations. Connected at the load centres, it may be suitably utilized by the Discom to manage its peak load, grid resilience, portfolio management and flexible operations. BESS can also be used to facilitate large scale expansion of electric mobility segment as part of major consumers for the Discoms. BESS can also be used as an optimum tool to achieve asset shifting by the Discoms, thereby increasing asset life.

**7.5 BESS as Merchant Power:** Along with the business cases mentioned at Sl. No (i) to (iv) above, it is possible that a certain component can also be earmarked for utilisation as merchant capacity by the BESS developer. This component may be traded in power market as per extant regulations.

**8. Business Model for BESS**

Unlike the only solar or only wind type of utility scale RE projects, BESS projects’ viability depends on applicable use cases and appropriate business models. There are several business models investors are exploring as per the regulatory environment in various markets.

**8.1 Business Model 1**:

In this model for charging purposes, BESS developer can procure input energy from the generation (wind/solar/both) owned by it.

8.2 **Business Model 2**

This would be tolling arrangement where BESS developer would procure power from the buyer (local distribution licensee/open access consumer) during off-peak period and give it back during peak period after discounting for cycle efficiency of the BESS. The tariff for such an arrangement shall be mutually agreed by the BESS developer and the buyer. In case of tolling arrangement by the distribution licensee, it shall obtain approval for the arrangement from the appropriate Commission.

**8.3 Business Model 3**

In this model for charging purposes, BESS developer can procure input energy by entering into an agreement with any other entity recognized under the Act. Under this model, the BESS developer would procure power for charging from the market or by entering into a PPA with any supplier. The tariff for procuring power from the BESS shall be discovered primarily through competitive bidding route.

**8.4 Business Model 4 (BESS as a Distribution Asset)**

BESS could be owned and operated by the distribution utility. Thus, Discoms can establish BESS either through Capex or OPEX /Energy Storage Service Agreement (ESSA) route. In case of Capex route, discoms would undertake competitive bidding for procurement of the system. Discoms may supply power to BESS for charging and scheduling of ESS shall be the responsibility of discoms. Such BESS shall primarily be charged from RE sources and Discoms shall utilize such ESS for compliance towards RPO as per applicable norms.

**8.5 Business Model 5 (BESS as a Transmission Asset)**

BESS could be useful for congestion management, ancillary services, and deferral of new investment. These applications would require BESS at transmission level. The transmission licensee shall not enter into any contract or otherwise engage in the business of trading of electricity on exchanges.

**9. Drivers and Barriers for BESS Deployment in India**

**9.1 Drivers**

* **National Energy Storage Mission:** The Government of India has created the draft National Energy Storage Mission to promote energy storage
* **National Tariff Policy:** Mandatory procurement of RE power for DISCOMs and Waiver on inter-state transmission charges for RE power transmitted through the grid to promote open access for large end customers (1 MW and above)
* **National Programme on Advanced Chemistry Cell (ACC) Battery Storage:** The Government approved INR 18,100 Crore PLI scheme for building manufacturing facilities for battery storage in India. The plan is to set up a 50 GWh manufacturing capacity

**9.2 Barriers**

* **9.2 Barriers** Unavailability of high tariffs for BESS integrated VRE. Higher tariffs are difficult proposition for already financially weaker DISCOMS (Distribution companies)
* Even if peak rates in India are higher than off-peak rates by 15 to 20%. This is far less than when compared to US, UK, Australia where the difference is around 200-400%
* Traditionally India has manufactured Lead Acid Batteries. [India domestic manufacturing](https://www.outlookindia.com/business/india-needs-to-invest-10-billion-for-ev-li-ion-batteries-by-2030-report-news-226420) for Lithium-ion and other technologies is at nascent state. Almost 70-75% Lithium ion batteries are imported from China and Hong Kong. Increasing shipping costs increases the project costs.
* Higher import duties is another hurdle for large scale adoption
* The ancillary market services by BESS including (Voltage regulation, Frequency regulation, Black start facility, Inertia) needs to open up further.
* [**Technological challenge**](https://ieefa.org/resources/evolution-grid-scale-energy-storage-system-tenders-india)**:** The NTPC tender (500 MW/3,000 MWh)requires a 6-hour BESS solution, while BESS is not a viable option beyond a 4-hour solution. There is a focus to increase the duration to 6- 8 hours, these are still not on a commercial scale resulting in the need for redundancies.
* **Lack of standardization :** On account of diverse technical requirements and different policy processes there is a lack of standardization within BESS. Each supplier has different tech specs which can be a hindrance to scale.
* **Electricity losses (Transmission & Distribution in India):** As per one of the [working papers](https://csep.org/working-paper/a-granular-comparison-of-international-electricity-prices-and-implications-for-india/) from Center for Social and Economic Progress, **India has highest transmission losses (technical + non-technical) in the range of 21%**compared to 6% in France & Australia and 10% for South Africa and Indonesia. Commercial losses are higher than the typical AT&C losses, which are only reported for the distribution networks. Overall rates of loss can be affected by a number of factors, including maintenance requirements, quality of infrastructure, distance between generator and consumer, poor monitoring and the occurrence of theft. This creates another hindrance in wide scale adoption of BESS
* **Restriction to open access:** Only end consumers with sanctioned load of 1MW and above are eligible to procure power through open access route. Few states try to limit purchase through open access to protect state-owned DISCOMs. This decreases avenues for dispatchability of power by BESS.

**BESS charging with coal:** India's grid infrastructure has been developed with coal plants in mind. So to mitigate additional infrastructure for grid evacuation, utility scale BESS would have high prospects of charging via thermal power (coal + gas). This would have implication on the prospect of BESS being green energy to be used with VRE -thereby creating ESG issues and subsequently reduced investments.**9. Key Market Players**

Make a Table mentioning Developers, OEms in separate columns.

**List of Market Players**

* GE (U.S.)
* ABB (Switzerland)
* Samsung SDI (South Korea)
* Hitachi Chemical Co., Ltd. (Japan)
* Siemens Energy (Germany)
* Total (France)
* LG Chem (South Korea)
* Fluence (U.S.)
* Narada (China)
* VRB Energy (Canada)
* Kokam (South Korea)
* EVE Energy Co., Ltd. (China)
* Black & Veatch (U.S.)
* Hitachi ABB Power Grids (Switzerland)

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