Energy Storage batteries for optimal VRE-Grid integration

Need, Relevance & Policy Directions

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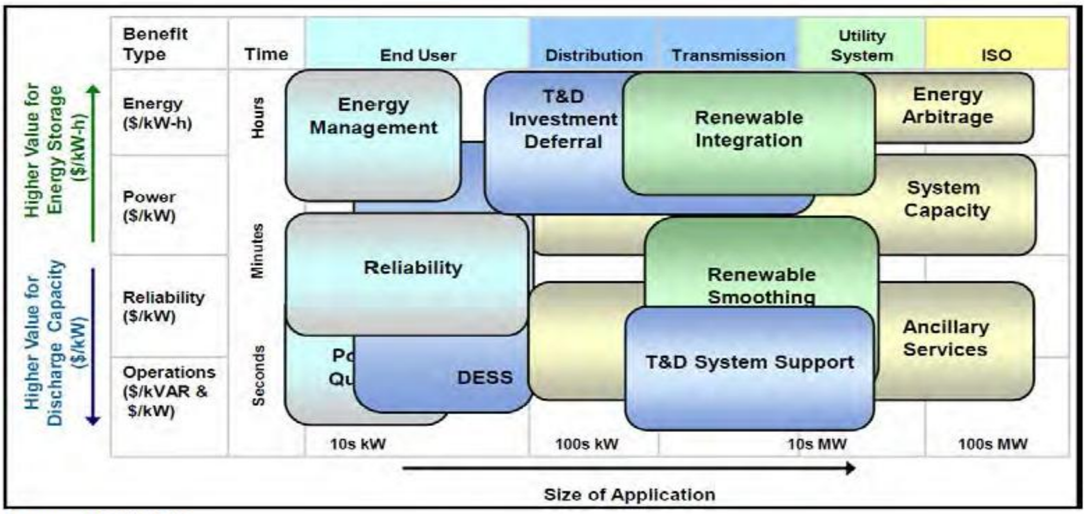
1. NEED & RELEVANCE

Energy Storage technologies can absorb energy and store electricity nearly simultaneously and for a period of time before releasing it to supply energy or power services, and thereby bridge the temporal and (when coupled with other energy infrastructure components) geographical gaps between energy supply and demand. Energy storage technologies can be implemented on large and small scales in distributed and centralized manners throughout the energy system. McKinsey[1] in May'13 called stationary energy storage technology as one of the 12 promising developments that will transform life, business, and the global economy by the year 2025. Energy Storage battery industry today is where solar PV was in 2010[2].

Energy Storage batteries (referred henceforth as ES) has *four* main roles to play in modern electricity infrastructure. *Firs*t, ES reduces electricity costs by storing electricity obtained at off-peak times for use at peak times instead of electricity bought then at higher prices. *Secondly*, in order to improve the reliability of the power supply, ES systems support when power network failures or imbalance occur. Their *third* role is to maintain and improve power quality, frequency and voltage. The fourth role is the fast developing emerging market which is to solve Power Management problems – such as excessive power fluctuation and/or undependable power supply – which are associated with the use of large amounts of Variable Renewable Energy (VRE) and/or unpredictable demand.

Power quality applications of ES (Grid Ancillary services like Frequency support, ramp up/down, etc.) have requirements in the seconds and minutes, whereas load & RE generation time-shifting and T&D grid support applications of ES require discharges in minutes and hours. Bulk power management applications require discharge over multiple hours or time shifting load/generation over multiple days and are to date best served by hydro & pumped-hydro options.

ES is an essential element to effectively manage high grid penetration of VRE generation, and, so, meet the climate change objectives as it is an crucial system integration technology which allows for a perfect management of energy supply and demand, and improving system flexibility across generation, transmission and loads. As a result, ES applications are defined by their mode of operation, its location on the grid and the problem they are designed to address; benefits are defined by the value that a certain application provides as illustrated in Figure 1 below.



Source: EPRI 2010

Figure 1

[1]www.mckinsey.com/.../McKinsey/.../MGI_Disruptive_technologies_Full..

[2]http://www.cleanenergyauthority.com/solar-energy-news/energy-storage-is-today-where-solar-was-in-2010-112514

Apart from the direct business application of a co-located ES with Wind/Solar PV project in the form of Schedulable Power on Dispatch (SPOD) based PPAs like Peaking Power Supply (e.g. the recent 1.2 GW SECI tender awarded to Greenko & REnew in Mar'20) or the contemplated Flexi Power supply tender by SECI in coming times, there are a large number of other applications that can also be served by ES often simultaneously. Applications served are a function of the location of ES in the grid and/or its ownership and/or in relation to its positioning vis-à-vis meter, as illustrated in the *Table 1* below. This table could be a guide towards considerations required for monetizing each of the value services provided by ES on the principles of Who Owns , Who Pays and How much?

Table 1: Energy Storage applications by grid location

Benefit	Power System or the System Operator	Generator	T&D	End Consumer	Possible benefits to be monetized by Regulatory Treatment
System Capacity	Y				Fixed charge and generation compensated, as Ancillary Service
Load-following	Y	Y	Y		Compensated as Ancillary Service
Frequency Regulation (AGC Service)	Y				Compensated as Ancillary Service
Spinning Reserves	Y				Compensated as Ancillary Service
Reactive Power Compensation	Y		Y		Compensated as Ancillary Service
Black Start	Y				Compensated as Ancillary Service
Wind/Solar Integration: Firming up and Ramp Support	Y			Y	To meet CEA interconnection guidelines, for meeting Grid system stability. Reduces frequent ramping of Coal PP & so reducing system costs that are passed on to end customer
Solar/Wind Integration: Off-peak Storage	Y	Y		Y	Used to shift dispatch generation to peak times, and realizing benefits either by enjoying price arbitrage or sharing the avoided system cost of having Peakers (which is passed on to end customers)
Reduced Solar/Wind curtailment		Y	Y		Used to avoid power curtailment and thus sharing the benefits with Solar/Wind generators
Transmission Upgrade Deferral or decongesting	Y		Y	Y	Delay upgrade of transmission lines due to load growth, and sharing the gain on NPV basis (which is eventually passed to customers via ARR filings)
Distribution Upgrade Deferral or decongesting	Y		Y		Delay upgrade of distribution equipment due to load growth, and sharing the gain on NPV basis (which is eventually passed to customers via ARR filings)
Distribution Losses	Y		Y	Y	Electricity savings due to better system efficiency (which is eventually passed to customers via ARR filings)
Power Reliability	Y			Y	Power backup services, needs to be monetized via as additional grid ancillary service
Power Quality				Y	Avoids losses from voltage sags

Benefit	Power System or the System Operator	Generator	T&D	End Consumer	Possible benefits to be monetized by Regulatory Treatment
	Y				and momentary outages, needs to be monetized via additional grid ancillary services
Limiting Retail Demand Charges	Y			Y	Lower demand payments by reducing peak power consumption and thru' sharing of savings
Reduce Retail TOU Energy Charges				Y	Reduce energy costs through load shifting and thru' sharing of savings
Reduction of State's DSM penalties	Y			Y	Needs to be monetized via sharing of savings as additional grid ancillary service with the State SLDC

A time-scale wise granular description of various target applications that can be served by ES is shown below in Figure 2.

2. INDIAN CONTEXTUAL SITUATION

- The share of VRE penetration would be multiple times higher during monsoon/windy months and be seriously threatening grid stability. Even at the current 7-9% grid penetration levels of VRE into the grid (on an annual and national average basis), % share of VRE in the energy mix during the monsoon/windy months is already in excess of 30-40% in pockets of states like Tamil Nadu, Rajasthan, Gujarat and Karnataka.
- Necessity and urgency for deploying ES batteries in India is possibly much higher than other countries because:

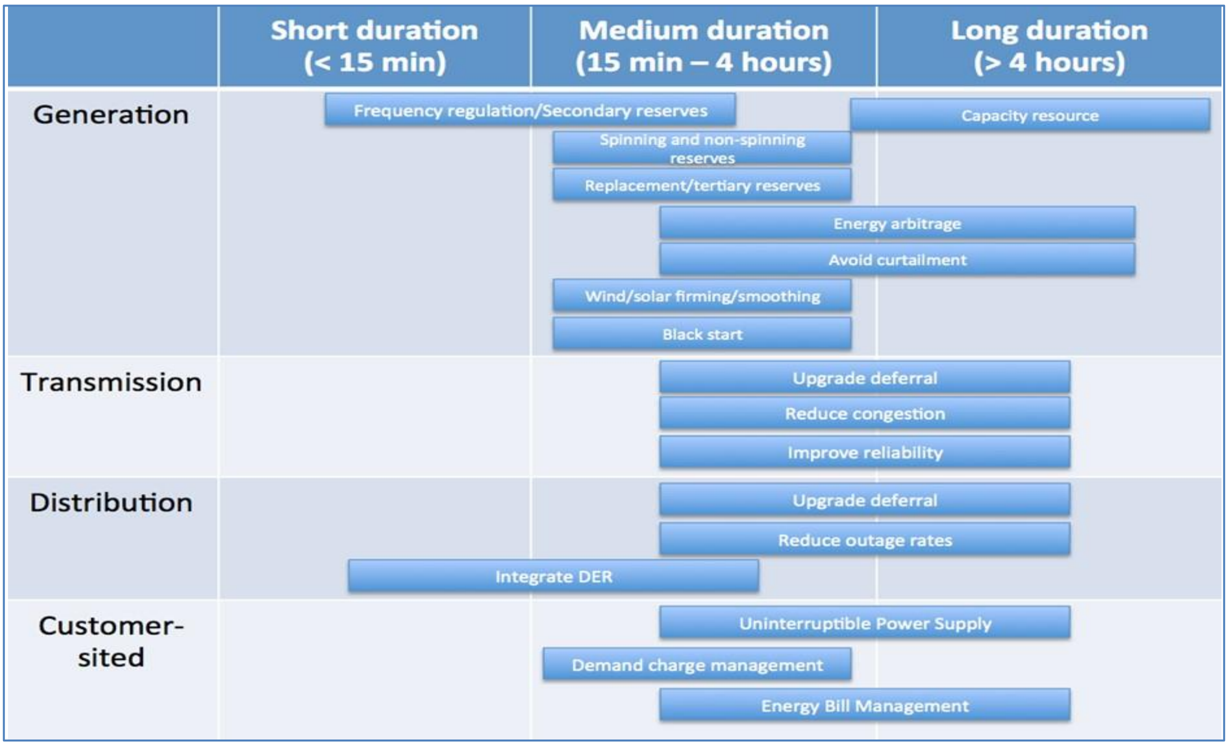


Figure 1

- Unlike in developed countries/states (like Denmark, Germany, Spain, Germany, US, etc.) the Indian electricity market (& grid infrastructure) still does not have the 4 essential sufficient conditions to allow balancing VRE. These are namely (i) Adequate Spinning Reserves (Balance power), (ii) Seamless grid T&D lines, (iii) a vibrant power market with short gates closures and futures/forward market and (iv) a dynamic market based grid ancillary services (for frequency, control, etc.).
- With the threat of inconsistent annual rainfall in the country, there is huge competing demand for the limited water resources bringing stress frequently to power generation (Hydro & coal based power plants). This situation is further exacerbated by the multifold increase in urban cooling (HVAC) loads during summer, when no amount of variable Solar and/or Wind power injection is going to help without having ES option.

- In addition, while the current practice to provide grid stability and balancing by making conventional coal based power plants to operate variably upto 55% PLF is operationally fine to optimally integrate VRE generation, it does saddle the Power System of State DISCOMs and the coal based power plants with hidden unaccounted costs.
  - For the DISCOMS these costs related to either DSM penalties for unscheduled power exchange at their state periphery or the fixed cost of contracted but un-requisitioned conventional power one is obliged to pay or the emergency power that the DISCOM buys at increased cost from the power exchange or from peaking powerplants to maintain grid stability matching the VRE generation. In addition, coal based power plants incur additional operating costs in lieu of the variable PLF operations that leads to higher coal consumption, lower plant efficiency & higher plant operating costs.
  - These hidden costs (DISCOMs & Coal Power Plants), not accounting for the additional economic cost of increased CO2 emissions, for integrating VRE generation amounts to somewhere between Rs 2 to 3.0/kWh, that is the additional to the low Rs ~2.44 to 3.00/kWh bus bar costs discovered at the recently conducted Tariff Based Competitive Bids (TBCB) for Solar and Wind in the country
- IEA's 2014 published report titled 'Energy Technology Perspectives of a 2°C Scenario', clearly finds that ES Technology can be one of the most promising technologies that could give an 80% chance of limiting average global temperature increase to 2°C by 2050 (affecting both the Electricity and transportation sector)
- And rightly so, the GoI's key top electricity sector institutions both from the Technical and Regulatory perspective, understanding the criticality of the Indian power system stability had initiated couple of significant regulatory efforts as listed below.
  - The Central Electricity Authority (CEA) issued draft 2nd Amendment in Dec'16 to the "Technical Standards for Connectivity to the Grid) Regulations, 2007" for Wind & Solar projects, specified the need to control their generation ramps (both up & down) and ability to provide grid stability via use of co-located storage batteries.
  - The Central Electricity Regulatory Commission (CERC) vide its 4th Jan'17 issued staff discussion paper sought public stakeholder comments for evolving due business models for employing Energy Storage batteries, for effecting optimal RE grid integration.

3. POLICY & REGULATORY CONSIDERATIONS TO SUPPORT UNDERLYING BUSINESS

- Current Electricity Act 2003, needs few changes to enable full benefit of ES deployment. Meaning the Electricity Act needs to be forward looking and broad enough to allow new business models based on modern ES technology- that will bring about efficiency across all sections (Transmission, Distribution, Operation, Generation and load/Demand management) of the power sector (including off-grid applications) - while simultaneously ensuring lower GHG emissions and water consumption (per kWh served).
- Amendment of Electricity act 2003 to duly accord classification of ES is critical for without which policy & regulators have little ability and room to interpret and define the its role and the services it can render objectively.
- Policy & Regulators while developing new rules and conditions must consider the following fundamental moot questions for allowing ES applications

- What are the quantifiable benefits (& cost-offsets) of employing ES over other current options?
- Who Owns the ES batteries?
- Who all are the beneficiaries (it could be multiple) of ES services
- Who pays for which of ES service and how much?
- What is the cost-offset offered by ES and to each of the beneficiaries?

Therefore, ES applications need to be defined by their (a) mode of operation, (b) its location on the grid (before the meter or after the meter), (c) the problem they are designed to address; (d) the benefits it can offer. Refer to the possible application benefits as illustrated above in *Table 1*.

- ES technologies can offer multiple services nearly simultaneously and serve parallely different business applications. As a result, the full value of the ES can be realized in proportion of all the value services it can offer. The advantage then is that impact of ES cost is then not impacting any one service fully and the ES is utilized to its full economic purpose. However, to realize this
    - Due regulatory classification of ES is needed in the Electricity Act 2003
    - Suitable regulatory framework for ES technologies to enable stacking up of the various ES services that could be monetized. "Stacking up" concept is shown below as an illustration (Figure 3).
- In the Indian perspective, where we do not have sufficient fast response reserves (gas or pumped storage or Hydro) or a modern fast responding power market (which is unlikely to be in place even after the 160GW of VRE is on line), to handle large VRE generation variability, it is also important to allow development of Independent Aggregators of ES (IAES) and serve the energy balancing needs of the grid system and also the firming up/dispatching needs of VRE generators.

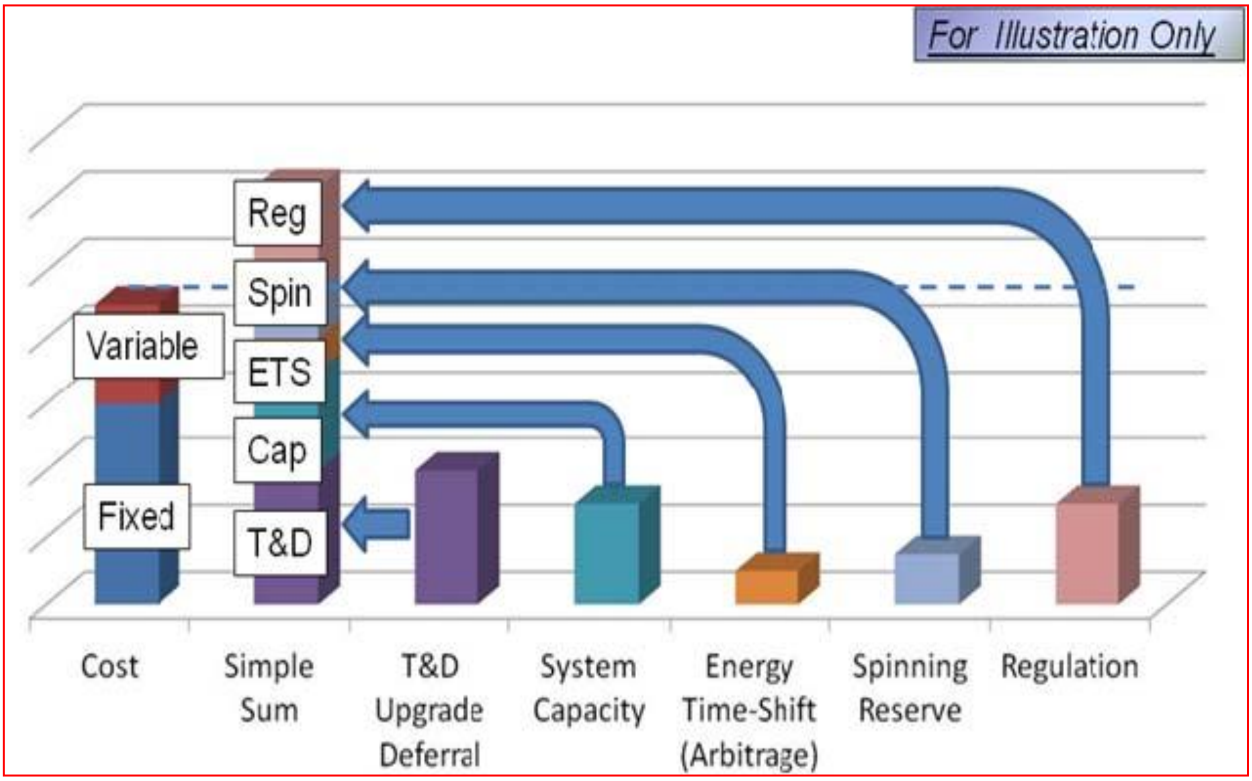


Figure 3

- Spurring storage demand is a key requirement for investors & manufacturers to set up large (GW) scale manufacturing units that further may need
- Encouraging ES manufacturing with specially tailored incentives with assured demand off-take, just at least matching the benefits being offered for promoting Solar PV (Cell & Module) manufacturing in India

- Assisting with assured long term supply of critical raw materials (possibly securing mining leases in India & abroad for cobalt, Lithium, specific rare-earths, etc.) and specialized manufacturing capital equipment technologies
- Detailed market studies to estimate the base demand with matching Long-Term consistent policies
- Estimating the off-setting (hidden) system cost by ES towards grid balancing costs and for each specific business application, for it allows to price the ES services.

4. CONCLUSION

ES will be one of the crucial component of India's energy infrastructure strategy especially when there is a sustained thrust to add 430 GW of Solar PV & Wind by 2030 ahead of the 160GW by 2022- as part of the Nation's effort to meet its energy security and climate change objectives (COP 21 commitments).

ES technologies can allow both firming up and time shifting VRE generation dispatch (to offer in a co-located position with RE project either 'Peaking Power' or "Flexi Firm Power'), apart from addressing the crucial grid integration/stability issues.

In addition, ES can provide multiple other important services to the power sector like:

- Decongesting T&D system constraints and often delaying upgrading T&D lines
- Allowing coal power plants to address fast ramp rates (up & down) and improve their operational efficiencies
- Raising self-consumption of solar roof-top and/or off-grid applications
- Improving operational efficiencies of captive DGs

Modern ES batteries are fast evolving with a year-on-year technology cost curve reduction >17% that can broadly be classified for power applications (like a Sprinter) or for energy applications (Marathon runner). Traditionally, Lithium-ion (Li) batteries have been more for power applications (<1 hour duration), but on the back of massive commercialization driven by the Electric Vehicle industry, chemistries like the Lithium Nickel Manganese Cobalt oxide (LNMC), Lithium Nickel Cobalt Aluminum oxide (LNCA), Lithium Titanate Oxide (LTO) and Lithium Iron Phosphate (LFP) have made huge improvements both in terms of technology and cost, and able to extend upto 4 hours of discharge. Lately, newer technologies like Vanadium redox, Zinc-bromine, etc are presenting nearly 3 to 4 times more life-cycles than Li batteries and are expected to be more suitable for stationary power applications from 2023 onwards.

Current regulatory framework (EA 2003) does not allow due classification of the ES, largely on account of its dual role that it can act (near) simultaneously both as a load and as a generator for applications both for the behind-the-meter and in-front-the-meter applications. An appropriate regulatory treatment allowing stacking up the multiple services that an ES technology can serve (often to multiple end users' benefit), will allow due economic benefits to be offered. This is far more important than the just cost reduction of ES technologies. A very important element as part of the business development for ES in India, is to value the 'total' cost of all other alternatives to use ES for the defined underlying business application, in an effort to price ES services.

- With the upcoming National Energy Storage Mission (NESM), India can look to leap-frog across manufacturing, deployment and applications and be a Global leader by year 2024
- Commercially driven ES demonstration projects (with good performance monitoring for feedback learning) can greatly help streamline the match between business model and application across in each of the 3 ES market segments (i) T&D, (ii) Bulk distributive RE generation (Solar, Wind & Hybrid Projects) & (ii) Customer end Distributive generation (Solar Roof-tops & Diesels)
- Local manufacturing of ES technologies & associated BoP, can bring about cost advantage (~20-30%)
- Estimating the off-setting (hidden) system cost by ES towards grid balancing costs and for each specific business application, for it allows to price the ES services.