Battery Energy Storage: Unlocking Potential in India

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Abstract*— India has embarked on an ambitious journey to deploy 175 GW of renewable energy capacity by 2022. The journey aims to address complex set of challenges in Indian power sector like access to electricity, reliable supply and reduce carbon footprint of power sector. This will lead to steep increase in variable renewable energy (VRE) generation capacity in the country as 100 GW solar and 60 GW wind power capacity is expected under the program. The rise in VRE will pose several unforeseen challenges like managing the variability and uncertainty. A combination of technology, regulatory and market design interventions will be needed to find a solution to this challenge. Due to the number and variety of services Energy Storage Systems (ESS) can provide, the energy storage technologies are often seen as holy grail to address large scale renewable integration issue and increase the penetration of renewables in the grid. Countries like the United States, Germany, Japan and South Korea have identified the role ESS will play in future electricity markets and have taken leap into this segment to become world leaders in deploying energy storage resources. India too is witnessing a transition in power market as ESS are becoming a reality with Tata Power Delhi Distribution Limited (TPDDL) commissioning India's first utility scale battery energy storage system (BESS) in February 2019. This paper explores plausible applications of energy storage in the Indian context for an energy storage resource coupled to a wind-solar hybrid generator and assesses its commercial feasibility.

Keywords- *Energy storage, li-ion batteries, battery energy storage system and benefit-cost analysis*

I. INTRODUCTION

Globally past few years have been something of a stage rehearsal for the energy storage to explode into the centre stage of power system and market. International Energy Agency's (IEA) latest research indicates that global energy storage deployment reached a new record level in 2018, nearly doubling from 2017. [1] Although pumped hydro storage has dominated the installed capacity, electrochemical systems have gained traction in past years.

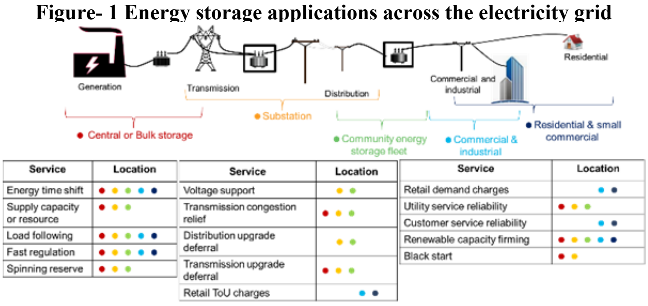
Traditionally new markets have evolved quickly wherever markets have created supportive policy and mechanism. Additionally, declining technology cost, growth of renewable energy markets and smart grids, and stackable business model together could stimulate the global expansion of energy storage in the power sector.

As the top two countries leading the energy storage deployment, China and US have both received extensive market-regulatory support from the governments. In China, the State Gird Corporation has launched several large-scale energy storage pilot projects, more than half of which are targeted for ancillary services, to ensure reliability while integrating massive amounts of wind and solar power being built in the remote western regions. In the US, the Federal Energy Regulatory Commission (FERC) has issued several rulings to establish standards and mandates for fast-responding technologies including energy storage and has removed barriers for energy storage resource participating in all various wholesale markets. The storage deployment in Japan has been accelerated since the 2014 Fourth Strategic Energy policy focused on emphasizing regional flexibility, energy diversification, and improved regional self-sufficiency. Those representative examples indicate a strong dependence on the supportive regulatory mechanism to promote successful energy storage deployment.

II. ENERGY STORAGE APPLICATIONS AND BENEFITS

Although energy storage resources have the technical capability to provide a host of applications, it is their location on the electrical grid that determines application selection. Figure 1 illustrates a sample of services energy storage can provide along the electricity grid. [1]

Figure- 1 Energy storage applications across the electricity grid



The energy storage applications can provide several benefits within three broad categories; revenue stream, cost avoidance and reliability improvement. For the services illustrated in Figure 1, the benefits are shown in Table 2.

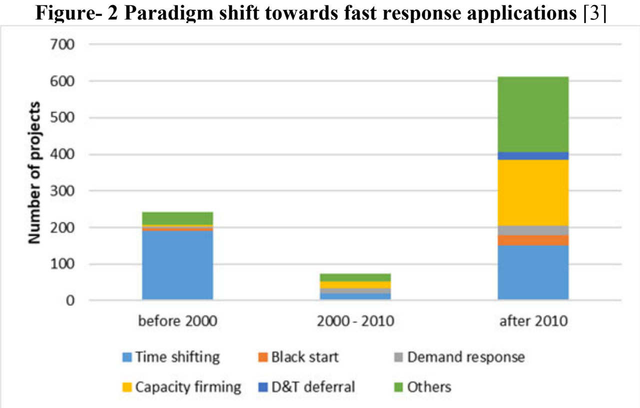
Table- 1 Benefits of energy storage applications

Applications	Revenue stream	Cost avoidance	Reliability improvement
Energy Time Shift	✓	✓	
Supply Capacity	✓		✓
Fast Regulation	✓		
Spinning Reserve	✓		
Black Start	✓		
Voltage Support	✓		✓
Transmission Congestion Support		✓	
Transmission Upgrade Deferral		✓	
Distribution Upgrade Deferral		✓	
Retail ToU Energy charges	✓	✓	
Retail Demand charges		✓	
Service Reliability (Utility Backup)			✓
Service Reliability (Customer Backup)			✓
Renewable Capacity Firming	✓	✓	✓
Demand Response	✓	✓	

III. GLOBAL TRENDS IN ENERGY STORAGE

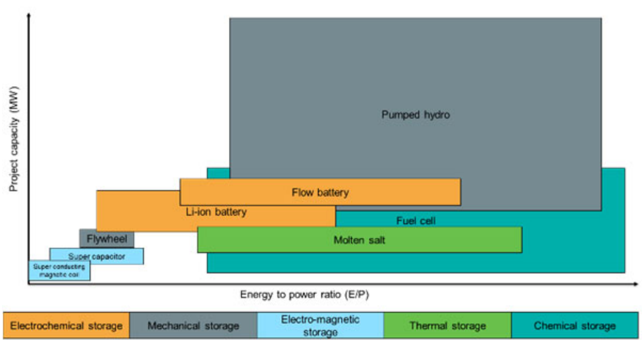
All energy storage resources have the same fundamental role: to absorb energy generated at one time and to discharge it to supply power at another. Traditionally energy storage has found use for long duration 'energy applications' like time shifting. However, in face of growing variable renewable generation and changes in demand profile, short duration 'power applications' like frequency regulation and capacity firming have gained importance (Figure 2).

Figure- 2 Paradigm shift towards fast response applications [3]



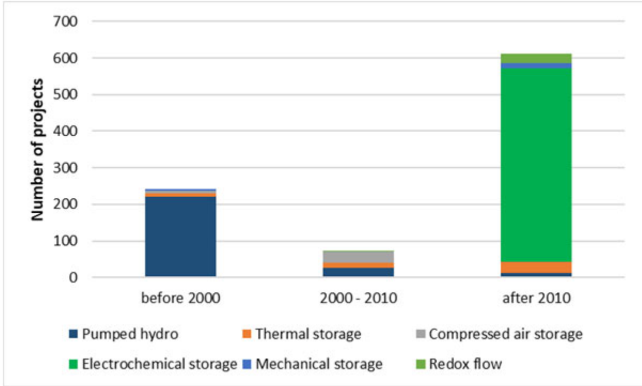
Energy storage projects may range from small domestic photovoltaic installations to large-scale pumped-storage hydropower. Essentially there are five broad energy storage technologies with their own characteristics and performance levels (Figure 3). Each storage technology has an associated energy to power ratio (E/P) range and is best suited to support applications whose E/P requirements overlap with this range.

Figure- 3 Major energy storage technologies



Globally power systems are becoming more volatile in the face of variable renewable generation and changes in demand profile, which is demanding faster response from existing storage resources systems (96% pumped hydro). Since the traditional resources (pumped hydro) are unable to provide necessary response, new fast responding technologies are moving to limelight (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure- 3 Paradigm shift towards fast response technologies [3]



IV. GLOBAL POLICIES AND REGULATIONS

Several countries (Figure 4) having high variable renewable energy penetration in energy mix or home to battery manufacturing giants are leading in energy storage deployment. A summary of energy storage related policies and regulations from these countries is presented in Figure 5.

Figure- 4 Countries leading energy storage deployment

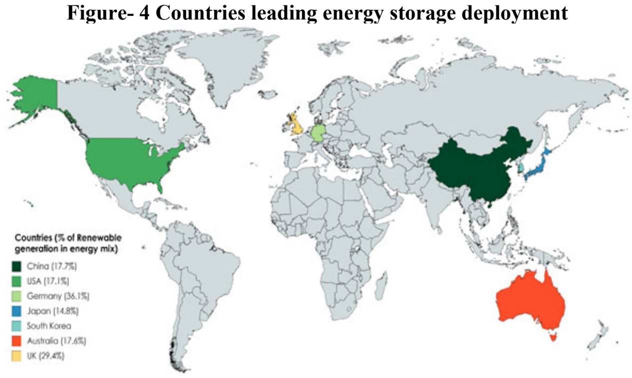


Figure- 5 Summary of energy storage related policies and regulations

Policies focused on			China	USA	Germany	Japan	South Korea	Australia	United Kingdom
Early Development Phase	Financial support	Funding for research and development	✓	✓	✓	✓		✓	
		Funding for demonstrations	✓	✓				✓	
	General support	Supporting manufacturing	✓			✓	✓		
		Stakeholder outreach	✓	✓					
Deployment Phase	Direct support	Storage targets		✓			✓		
		Preferential rates for storage/renewables		✓	✓	✓	✓		
	Creating need/ opportunity	Ancillary services payment on accuracy and capacity		✓					✓
		Energy storage systems participation in ancillary services markets		✓					
		Grid modernization plans		✓	✓				
	Financial support	Subsidy			✓	✓		✓	
		Tax benefits		✓	✓				

V. INDIAN POLICIES AND REGULATIONS

The staff paper on 'Introduction of Electricity Storage Systems in India, 2017' by Central Electricity Regulatory Authority (CERC) highlights the absence of policy and regulatory framework to support energy storage deployment. In absence of peak pricing and arbitrage framework, there are no clear revenue streams for energy storage systems. [4] A summary of regulations which could potentially support energy storage deployment is presented in Figure 6.

Figure- 6 Policies and regulations

Authority	Regulation	Relevance to storage	Status
State Electricity Regulatory Commissions	Forecasting, Scheduling and Deviation Settlement of Solar and Wind generators Regulation	Deviation penalty	Exists
Central Electricity Authority (CEA)	Technical Standards for Connectivity to the Grid (draft for amendment)	- Ramp rate <10% per minute - 10% storage for RE plants >50 MW installed capacity	Needs notification
Central Electricity Regulatory Commission	Ancillary Services Operations Regulations	Frequency Controlled Ancillary Services	Needs deepening and broadening

VI. STORAGE APPLICATIONS (INDIAN CONTEXT)

The energy storage service selection process is dependent on three parameters; technical viability, regulatory requirement and benefits. While the technical viability has been determined through research, pilot projects and deployments around the globe, it is virtually the non-existence of revenue streams and guiding policies and regulations that make service selection process a difficult task. In the present framework, for an energy storage system connected at the generator end following two applications are identified:

1. Deviation Settlement Mechanism (DSM) penalty avoidance (power application)
2. Curtailment avoidance (energy application)

The technical requirements for these applications are shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**, and lithium-ion (li-ion) technology is best suited for these applications.

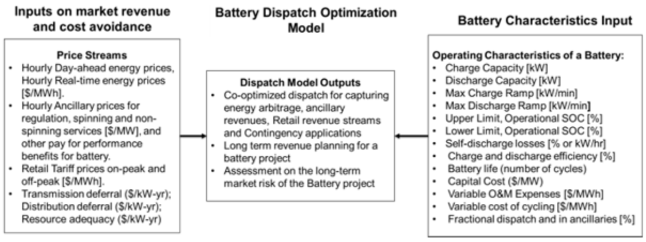
Figure- 7 Technical requirements for identified applications

Application	Type of application	Response time	Discharge duration
DSM penalty avoidance	Power	Seconds	minutes-hours
Curtailment avoidance	Energy	minutes	2-6 hours

VII. STORAGE SIZING

The general parameters needed for storage sizing are illustrated in **Fehler! Verweisquelle konnte nicht gefunden werden.**. In addition, sizing is also affected by the level of performance required. For example, how many frequency deviation events are to be corrected.

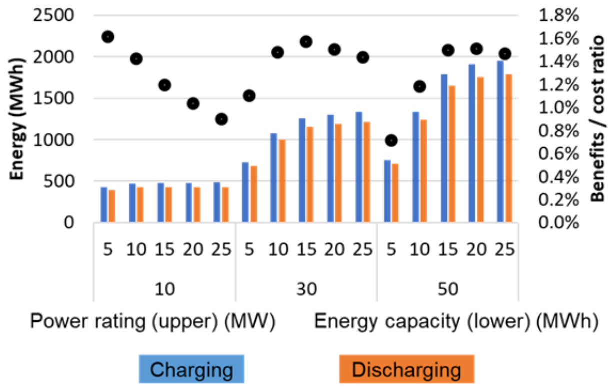
Figure- 8 Factors affecting energy storage sizing



This approach is used for sizing li-ion based battery energy storage system for a wind-solar hybrid power plant in South India. Based on historic trends, around 3.2 % of annual generation is expected to be curtailed along with an annual DSM penalty of around 40 lakh INR. Although ramp-rate constraints are not enforced, a ±10% per minute limit is used without provision for any penalty. The results of parametric analysis for different battery energy capacity and power rating are presented here.

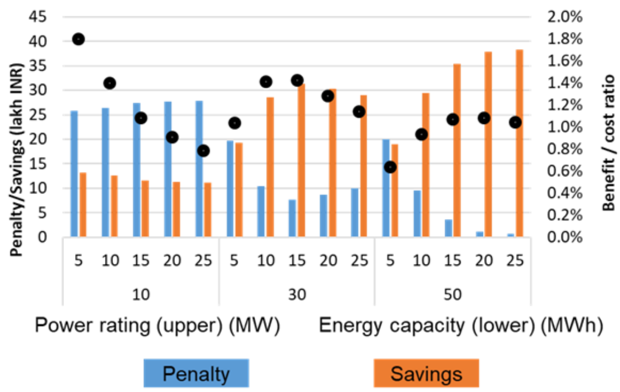
Benefit-cost analysis for curtailment avoidance application is maximum for an E/P ratio between 2h and 3h and is well below 1.8% (Figure 9).

Figure- 9 Benefit / cost ratio for curtailment avoidance



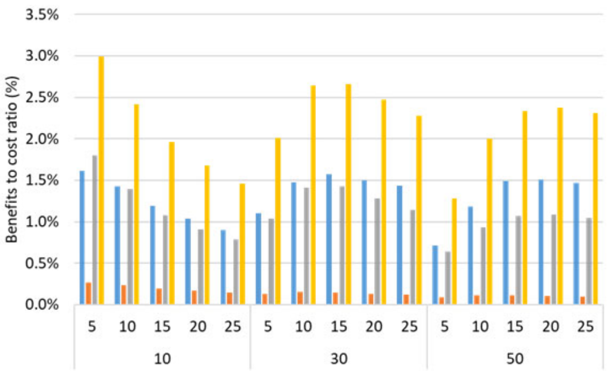
Benefit-cost analysis for DSM penalty avoidance application is maximum for an E/P ratio between 2h and 3h and is well below 1.5% (Figure 10).

Figure- 10 Benefit / cost ratio for DSM penalty avoidance



Since the E/P ratio requirements for both the applications is similar, these two applications can be stacked. Although stacking improves benefits to cost ratio, the gain is not significant.

Figure- 10 Benefit / cost ratio comparison for individual and stacked applications



VIII. Conclusion

Deployment of energy storage resources at generator end is not economically feasible in the present market and regulatory framework. Following steps may be undertaken to change the landscape:

1. The assumptions on curtailment level and DSM penalty as well as levels of absolute error are dependent on geographic location. Thus, Policy makers, utilities and developers need to be prudent in storage site selection.
2. Wind and solar are natural complimentary resources, the penalties on wind and solar generators in isolation will be higher. Thus, energy storage will realize higher benefits in isolated wind and solar projects.
3. Energy storage is modelled as a regulated asset tied by long term PPA. Thus, there is a case to focus on improving its utilization as well. This is possible through 'stacking' of applications. Regulators, utilities and developers should work towards identifying 'Stacking' opportunities.
4. Time of delivery or Dynamic pricing will enable storage to realize more benefits.
5. Policy makers have to acknowledge benefits of same storage resource to multiple stakeholders.

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