World™ Utility Summit

ENERGY STORAGE APPLICATIONS THE UTILITY AND DISCOM PERSPECTIVE

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18-22 JANUARY 2020
INDIA EXPO MART, GREATER NOIDA, NCR, INDIA

THE THEME

The theme of the World Utility Summit, WUS 2020 is "Utility Next". The electricity eco system is undergoing an unprecedented transformation with the proliferation of renewables, distributed generation resources and electric vehicles on one side and consumer activism and regulatory pressures on the other. Developing countries are also facing these challenges in addition to their ongoing activities to provide universal 24x7 power supply. Moreover, as many of the consumers of electricity become prosumers, the electricity eco system would change radically and new market entrants would emerge. There is an immediate need for utilities to evaluate how the provision and consumption of energy services would happen in the future.

This summit would bring in thought leaders across the globe to deliberate the preparedness of utilities to deal with the transformational changes. Regulators, technology providers, consultants, government bodies and utility leaders are expected to share their views on the various challenging and exciting scenarios and help shape the roadmap of the future utilities.

SUMMIT TRACKS

MARKET ENABLERS

Knowledge Partner - USAID in association with KPMG

With the emergence of distributed generation resources and availability of multiple electricity providers in today's era, consumers have a variety of options to meet their changing energy demands. At the same time, future of the electricity ecosystem will include higher penetration of next generation technologies like renewables, energy storage, electric vehicles and digitization.

The role of utilities would need to be repurposed to prepare for the future. What will the customer portfolio of utilities look like? What will be future expectations of the consumers from the utility and how will the utilities need to transform themselves to meet them? How will the utility markets evolve? These are some intriguing questions that will be addressed in this track.

REVENUE SECURITY

Knowledge Partner - CRISIL

Utilities get their revenues primarily via billing the customers for their demand and energy usage. New eco systems, with multiple options for consumers to meet their electricity demand, will pose stiff competition to the utilities. How can the investments made by the utilities be safeguarded? How can utilities ensure they are resilient to the transformational changes in the electricity eco system? What are the key learnings from similar experiences? This track will cover the latest developments on the upkeep of the financial health of the utilities, learning across the globe and develop a strategy for a resilient utility.

GRID TRANSFORMATION

Renewable Energy and Electric Vehicles
Knowledge Partner - GIZ

Renewables and electric vehicles are being promoted across the globe for a variety of reasons. These technologies will transform the power grids in an unprecedented way. Renewables introduce high intermittency in generation capacity. High intermittency leads to underutilized transmission infrastructure, increased impact on grid operations and increased need for flexible generation sources. Increasing penetration of electric vehicles will require major upgradation of infrastructure and new business models. New approaches need to be explored to ensure smooth and effective integration of these technologies with the power grids. This track will cover the case studies globally and deliberate the technology considerations and best practices to manage the network.

ENABLING TECHNOLOGIES

Digitalization and Cyber security
Knowledge Partner - Accenture

With the abundance of critical data in power systems coupled with remote access, operating the system securely without compromising system availability and data privacy is a major concern. Cyber security threats are increasing day-by-day and there is a continued need to develop mitigation technologies and solutions to make the power equipment/devices, control systems, communication and operations more secure. Today, many concepts like user and device authentication, data encryption, communication robustness, defense-in-depth, malware protection, whitelisting, system hardening, monitoring and analytics are used by the stakeholders to address cyber security issues effectively. All the stakeholders including equipment/device vendors, system integrators, owners/operators of system, government agencies and technology experts have a role to play in making the power operation and delivery secure. This track will cover the latest development and share best practices in this space.

POLICY & STANDARDS

Knowledge Partner - National Smart Grid Mission

With the changing dynamics of the electricity ecosystem, policies & standards become extremely critical to ensure the technical, financial and business viability for all the stakeholders. There is a need to have a robust policy, especially in the areas of distributed generation, renewables, electric vehicles and energy storage. Consumers should be made aware of the changing scenarios and engage them in the decision process. It is imperative that all the stake holders in the future utility eco system should support the evolving regulatory standards and ensure seamless transition. Environmental aspects also have to be considered. This track will share the views of various leaders driving policy and standards to ensure that the key interests of all the stakeholders are safeguarded.

ENERGY STORAGE

Knowledge Partner - India Energy Storage Alliance (IESA)

Energy storage has a versatile role in to play in operating grids and providing value to all the stakeholders. This includes balancing demand and supply, regulating frequency, managing renewables and providing autonomy for consumers. Energy storage will also play a very important role in achieving full potential of new and upcoming technologies. This track will cover the latest developments in technologies, new business models, grid dynamics, learnings from pilot demonstrations and operational considerations associated with these technologies.

MESSAGE FROM KNOWLEDGE PARTNER

Dr. Rahul Walawalkar
Executive Director, IESA

India Energy Storage Alliance is honored to partner with Indian Electrical and Electronic Manufacturer's Association and IEEE for authoring the knowledge paper on energy storage on occasion of the World Utility Summit at Elecrama.

For over a century we have designed electric grids around the globe with an underlying premise that energy cannot be stored and we need to produce the electricity where there is a demand. Pumped Hydro, however, has been a notable exception to this belief and around the globe over 80 GW of pumped hydro facilities have been an integral part of the generation mix. Similarly, lead acid and NiCd batteries have been used by utilities as well as consumers back up applications when the grid fails. This situation is rapidly changing with the innovation taking place in technology development as well as the innovation in policy and business model side. Past decade has seen tremendous progress around the world in adoption of advanced energy storage technologies such as advanced lead acid, li-ion, sodium-sulfur as well as thermal storage technologies both on the supply side as well as behind the meter. There are many more promising technologies for longer duration storage such as gravity-based storage, flow batteries, metal-air batteries that are in early stage commercialization now, which can become mainstream in the coming decade.

Utilities are traditionally seen as slow adaptors of technologies, but we are seeing notable exceptions around the globe. With the changing regulatory focus and need for efficient and environmentally sustainable grid, utilities are embracing energy storage technologies as enablers for the transition for the 21st century grid. Energy storage technologies coupled with new paradigms such as microgrids and demand response are creating opportunities for completely redesigning the modern grid and providing a flexible alternative to traditional approach. Growth of renewable energy both on centralized as well as distributed level is accelerating this need.

Regulators and policymakers play a key role of gate-keepers in this area. Conferences such as WUS play a key role in spreading the learnings from global case studies and providing learnings to decision-makers that can accelerate adoption of these emerging technologies in India. This white paper is our effort to bring together such learnings and facilitate the decision making. With support from all the participants, we are sure, we can make India a global hub for not just deployment, but also for R&D and manufacturing of advanced energy storage technologies in the coming decade.

Contents

Introduction

'Change is the only constant', a well-known phrase has become the way of working in today's world. Innovations and disruptions have made many sectors rethink the way they operate, and the story has been same for the Energy sector. Innovation in this sector has been gradual over the last century, mostly incremental till the last century. With the acceleration and development of Renewables and its penetration into the Grid, challenges have come up which is now making Utilities and DISCOMs (Distribution Companies) to go back to the white board to develop a more agile and dynamic strategy to remain sustainable in the VUCA (Volatile, Uncertain, Complex, Ambiguous) world around.

The world has now well understood the fact that if we want to restrict the annual global temperature increase within 2 degrees (Paris Agreement) by 2050, we have to look for alternate sources of greener energy production. This has led to many Governments making Renewables "Must Run" and thus curtail down generation from conventional plants. Over the last 5 years, the reserve margin in Indian Grid alone has increased to 55% as of November 2019 (CEA). What this also means is that conventional plants are being made to run at very low utilization factors and some of them being even shut down. This is creating a concern for the State DISCOMs who are increasingly raising alarm on the Grid dynamics. MNRE[1] projections show that by 2022, the Indian Grid will have around 100 GWs of Solar generation and more than 175 GW of renewable generation. This means that in early morning hours and late evenings, there will be a substantial ramping challenge that the Grid will face. In early morning to cater to the solar generation and reduce the conventional generation and in evening to cater for the fall in solar generation and increase the other generations. IESA (India Energy Storage Alliance) analysis has demonstrated, the higher solar generation during the day would create challenges for the baseload plants due to "Indian Camel Curve[2]" similar to the California Duck Curve projected by CAISO in 2013. Projections show that ramping rate can increase to around 130% from today's level in 2030. This in figures comes to around 350MW/min. for a longer period of time (4-6 hours).

The 2012 Indian Grid Blackout has also given rise to many strict regulations to improve grid reliability. This includes stricter Deviation Settlement Mechanism (DSM) protocols for both generators and DISCOMs with high penalties for violating schedules, narrower frequency bands and more stringent rules for upgrades and maintenance cycles. Over and above this, the increase in rooftop solar in urban cities can create problems of back feeding and reactive power support at the Distribution Transformer (DT) levels. The question which arises here is that is the existing infrastructure capable of handling this dynamic? One issue with DTs itself is its placement in fast growing Indian cities, which makes upgrades a very exhaustive and expensive task. One should also not forget about the captive power generation, which also ends up relying on the Grid for reliability and in turn increases uncertainty of operations for the Grid. There has been talks of making the load management blocks from 15 minutes at present to 5 minutes, which means the level of load management dynamic will only increase going forward.

Solutions to the above-mentioned concerns are many but ones which are both techno-commercially and environmentally viable are less. Thermal plants for once, are not designed to handle rapid ramping and load switching without significant penalty on heat rate and emissions.

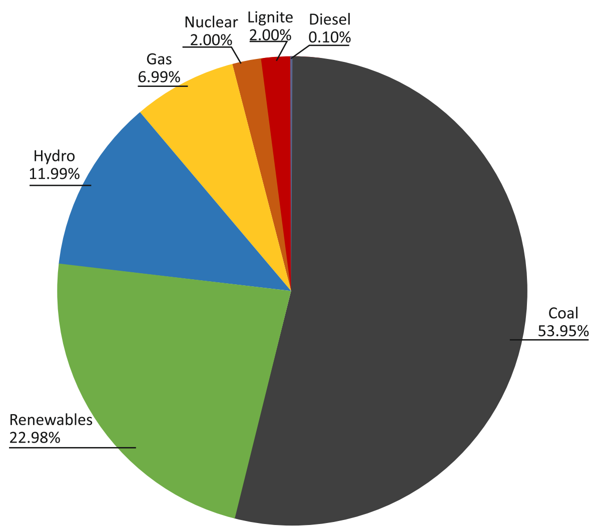
[1] "MNRE Current Notices and Updates", Ministry of New and Renewable Energy. https://mnre.gov.in
[2] "Large Scale Integration of Renewables": Report by POSOCO. 31 August 2015

Gas-based power plants can cater to this, but India suffers from non-availability of cheap domestic gas and these plants are mainly operated only as Peaker plants. One technology which fits is better pumped hydro, but the concern with pumped hydro is its capital cost and environmental viability. One technology which fits in beautifully as a solution to all these concerns is distributed energy storage technologies including electrochemical batteries and thermal storage. With around 85%[3] decrease in costs and continual improvements in technology, batteries are more and more becoming commercially viable. The LCOE (Levelized Cost of Energy) from batteries is now making a competitive bid against that from conventional power plants.

This white paper provides overview of various applications which advanced energy storage technologies can serve to make Grids more reliable, with focus on the Indian Grid. It also showcases examples from around the globe that can guide Indian DISCOMs on how deployment of batteries can manage DSM effectively, reduce penalties, provide efficient ramping, defer distribution transformer upgrades and also capture in curtailments. The paper also discusses on potential business models which can make integration of storage with grid feasible both technically and commercially, with insights into the future developments and predictions.

2. Power Sector – Status Quo and Projections

The[4] Indian power sector's present generating capacity is 366 GW, of which 54% is coal (refer figure 1). But in just 2 years' time, the percentage of coal in the grid has come down from 59% to 54%. Which in itself shows the way the sector is moving. The annual growth percentage of the sector as on date is around 6 – 8%. Renewable capacity as on date is 83 GW which represents around 14% of the total generating capacity. Around 62 GWs of renewable capacity is under execution and bidding as on November 2019.



In 2018 alone, renewables have pumped in 101.83 Billion units into the grid. One sector which is highly unexplored due to infrastructure difficulties and cost is pumped hydro (85% unexplored). Analysis shows that India has potential of 96 GWs of pumped hydro but at present only 4.8 GW is operational and additional 1 GW is under construction. As on Load Balancing Report released by CEA in June 2019, India is 2.5% peak surplus and 4.6% energy surplus. When seen region wise, only South and East India experiences slight power deficits. With increase in demand and rise of urban population, the peaks being experienced across India has also increased considerably. As indicated earlier, in order to cater to the increase in renewable generation, utilities have been bound to curtail generation from conventional plants. This can be inferred from the increase in Reserve margin in the Grid, which has increased considerably from 2011 to around 55%.

2018, was seen as a low investment year for renewables, majorly due to currency fluctuations and anti-dumping duty which was imposed on imported solar panels. India has set a target to have 40% generation capacity through non-fossil fuel sources by 2030. Projections from various reports like

[3] IESA Resources. India Energy Storage Alliance. www.indiaesa.info/resources
[4] Ministry of Power, Government of India "Monthly Generation Report", Nov 2019, www.powermin.nic.in

BNEF show that 75% of India will be powered by Renewables by 2050. This will also lead to considerable reduction in the spinning reserves present today as many of the conventional power plants today are running at below par utilization factors, also due to non-availability of cheap domestic gas, many gas plants are being shut down or run as peaking plants. What this also signals that the ramping rates will be increasing as with massive solar ingress (75 GW by 2025), early morning and late evening ramps will get more steeper and for longer duration. As on date, the ramping rate is 150 MW/min for 40 minutes, this can go up to 340 MW/min for 3 to 4 hours by 2025[5].

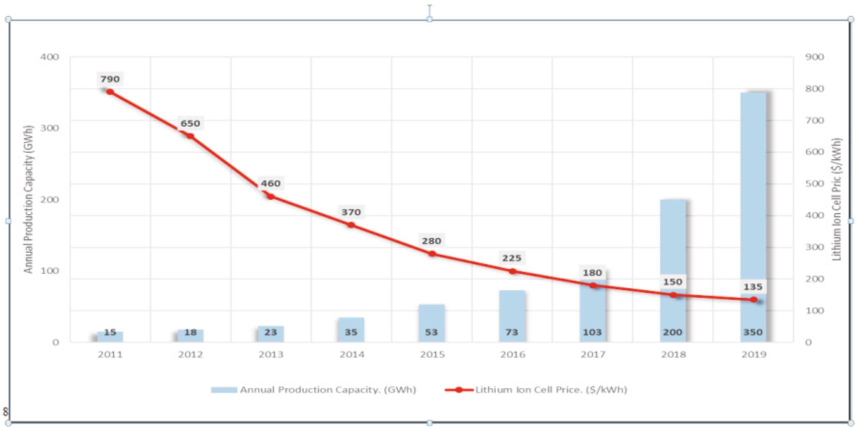
As such, the requirement of grid stability is well understood and appreciated, thus there are various regulations and standards which has been normalized to make the Grid responsible. The Industry has also realized the importance of storage for grid reliability. IESA[6] predicts that the storage market for India can be around 300 GW by 2025. The main markets include Electric Vehicles, UPS, Renewables and Telecom. There has been particularly huge focus on battery storage which has been a decrease of almost 85% at cell level costs (Lithium Ion) over the last 8 years. This has mainly resulted from installations across the world of BESS projects. As on 2018, the total Storage installation in India was 24 GWh[7], this is projected to reach 65 GWh by 2026. NITI Aayog is also about to launch the India Gigafactory document which predicts a 50 GWh domestic manufacturing market for India by 2025. If we look into the application areas, around 68% of the demand comes from Behind the meter applications, followed by Grid applications.

The increasing percentage of renewables in the grid also will increase the ramping rate requirements. Studies done by IESA predict increase in ramping rates from 150MW/min for 40 mins. at present to 340MW/min. for 3-4 hours by 2025.

Potential of the storage market as per IESA's annual Energy Storage report is more than 300GWh by 2030 growing at a CAGR of 21% from 2018 to 2025. The world has seen a steep decline in battery prices, by 85% from 2011 to 2018, at present battery prices are around USD150/ KWh, further 30% reduction expected in 2 years' time, almost reaching USD100/KWh by 2030.

Figure 2 shows how the price has fallen for battery packs from 2011 to 2018. The price drop mainly attributes to the economies of scale for each manufacturer crossing the 5 GWh mark by 2015.

Figure 2: Battery Price and Manufacturing Capacity Trend (CES Analysis)



[5] India Energy Storage Alliance, Internal Load curve analysis report, www.indiaesa.info/resources
[6] "India Stationary Energy Storage Market Overview Report", IESA, June 2019, Accessed on Nov 2019
[7] "India Stationary Energy Storage Market Overview Report", IESA, June 2019, Accessed on Nov 2019
[8] IESA Resources. India Energy Storage Alliance. www.indiaesa.info/resources/Storage101

3.Government Commitments

Government[9] of India has been actively promoting the Greening of Grid revolution. It has placed ambitious targets from time to time from 225 GWs of Renewable capacity by 2022 (including hydro) to 30% of vehicles manufactured as EVs by 2030. India also made a commitment in Paris Agreement to reduce GPD's emission intensity by 33% by 2030 from its level in 2005 and promotion of indigenous manufacturing and development of skills – Make in India. With policy frameworks like FAME I and now FAME II and also encouragement and incentives on local manufacturing, the Government has made clear its intent. All these has given a clear indication to market on the way forward in the power sector. Recently, NITI Aayog has also been discussing upon the Gigafactory plan which is in the final stages of cabinet approval. The plan focuses on domestic manufacturing of batteries in India so that the Country does not have to rely on imports and becomes a market leader in the storage Industry.

4.Concerns for Utilities and DISCOMs

In a renewable heavy grid, the concern for Utilities and DISCOMS is two-fold. One, is the non-reliability of renewables; Over time, forecasting and scheduling has been regularized for renewables but the present forecasting softwares themselves are not that accurate, this results in real time variations which the utilities find hard to manage. These in-turn are subjected to penalties for underdrawals or overdrawals.

The second concern is high solar generation. Unlike wind, solar is only available during day time, thus to cater for solar, the utilities back down other generation sources, but on the contrary, this is generally a low demand region. At a time when the demand actually starts rising, (~5pm) solar generation plummets. Thus, it's a situation where demand increases and supply decreases.

To balance off this mismatch, utilities are faced with steep ramping blocks, and predictions show that such ramping will only become more steeper and longer, going forward. The question arises, who will take care of such high ramping in a high RE Grid. Thermal plants are not designed to cater to frequent ramping, gas plants fit in well, but cheap gas availability is a concern, pumped hydro can, but we do not have enough installations of pumped hydro in India, this is where batteries can play a big role, as they have fast ramping capabilities.

Over and above this, the increase in rooftop solar in urban cities are creating problems of back feeding and reactive power support at the Distribution Transformer levels. The question which arises here is whether the existing infrastructure capable of handling this dynamic? One issue with DTs itself is its placement in fast growing Indian cities, which makes upgrades a very exhaustive and expensive task. One should also not forget about the captive power generation, which also ends up relying on the Grid for reliability and in turn increases uncertainty of operations for the Grid. There has been talks of converting the load management blocks from 15 minutes at present to 5 minutes, which means the level of load management dynamic will only increase going forward.

[9]"MNRE Current Notices and Updates", Ministry of New and Renewable Energy. Mnre.gov.in

5. Storage as an enabler: Focus - Utilities and DISCOMS

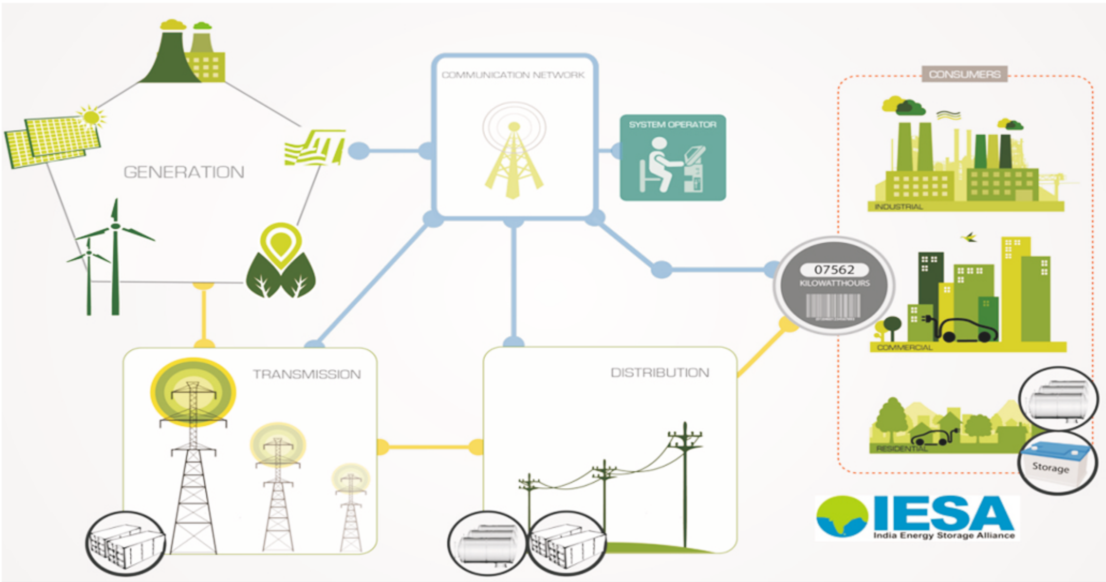


Figure 3: An illustration of the connected Eco-System

As illustrated in Figure 3, there are many solutions, but not many which makes technical and commercial viability. Energy storage is one solution which therefore is becoming more and more prominent for addressing these concerns. The following section discusses on some of the potential applications of battery storage to address the current concerns being faced by Utilities and DISCOMs.

Table 1 shows the various applications that battery storage can play a role in across the energy value chain.

Table 1: ESS Applications across the energy value chain

Transmission	National Grid	RLDC/SLDC/IPP
Investment deferral	Delivering ramp rates	Frequency regulation
Voltage support	Output shifting	Firming of output
Congestion management	Acting as flexible reserve	Smoothing and deviation control
Reduction in losses	Saving investments in peakers and additional system capacity	

[10]

Some of the value proposition of Energy Storage mentioned can be served by central level assets such as pumped hydro storage and compressed air storage. But these assets have limitations over the advanced storage technologies (Refer Appendix 1), which are their long gestation period in a scale of ten to twelve years and their inability to serve local transmission and integration issues.

[10] "India Stationary Energy Storage Market Overview Report", IESA, June 2019, Accessed on Nov 2019

In India, there is a huge unexplored potential of pumped hydro which is available, but not much has been tapped in that sector till now. This is mainly because of location constraints and also availability of resource. For bulk power management, pumped hydro and compressed air storage are very well suited (refer appendix), as they can serve for a storage capacity of as high as 100 MW to 1 GW. A draft report by CEA on Optimal Generation Capacity Mix for 2029-30 discusses about 5 MW of pumped hydro storage capacity in the same. Storage technologies like high energy capacitors, flywheels, super capacitors on the other hand are well suited for power applications as they have the capability to discharge a large amount of power in a very short time. Flow batteries too are very well designed for load shifting operations and the biggest advantage with them is that they can be expanded without much of an investment. Batteries, specially lithium ion has gained prominence mainly due to having a good balance between energy and power density and also the cost of it is far more economic than the other technologies as on date. There exist certain problems which are being addressed like fire hazards, life cycle, efficiency and above all, recyclability. But as on date, it has gained the most wide spread acceptance in the energy storage sector. Also, not all applications are suitable for equal duration of storage. Table 2 shows the optimum duration of storage based on present cost for various applications.

A Report on Forecasting, Concept of Renewable Energy Management Centers and Grid Balancing by GIZ, states that from a long-term perspective, energy storage becomes a viable option. But the report recommends integration of RE through energy storage only after considering less costly balancing options like demand side management, flexible operations of conventional power plants and regional balancing.

Energy Storage assets can handle multiple applications and also lead to multiple cost benefits. However, co-owning and multi-use would require the regulations to evolve with a holistic view of benefits of energy storage.

Table 2: Best Case application of Storage for various sectors

Application	Grid/Local	Hours
Avoiding of investments in new intermediate load plants through RE firming	Grid	4-8
Replacement of Peaker plants	Grid	4-6
Ramping at grid scale level	Grid	0.5-1
Avoiding of Wind & Solar Curtailment due to excess generation at off-peak hours	local	2-6
Frequency Regulation	Grid	0.25-1
T&D Congestion relief / upgrade investment deferral	Local	1 – 4
Deviation settlement for both inter and intra state	Local	0.5 - 2
Firming of output of wind and solar PV plants	Local	2-4[11]

[11] "India Stationary Energy Storage Market Overview Report", IESA, June 2019, Accessed on Nov 2019

Table 3 shows the various grid level storage projects which have been proposed in India between 2017 and 2019.

Table 3: Proposed list of BESS projects in India from 2017 to 2019

Project	Capacity	Location	Expected Year of Commissioning
PGCIL	2 x 500 kW, 250 kWh BESS (Lead acid + Li Ion)	Puducherry	2017
NLC	2x10MW Solar PV 8MWh/16MW BESS	Port Blair, Andaman & Nicobar Islands	2019
NTPC	2MWh BESS	Port Blair, Andaman & Nicobar Islands	2019
NTPC	17MW Solar PV 6.8MWh/6.8MW BESS	South Andaman, Andaman & Nicobar Islands	2019
NTPC	8MW Solar PV 3.2MWh/3.2MW BESS	South Andaman, Andaman & Nicobar Islands	2019
AES-Tata Power	10MWh BESS	Sub-station, Delhi	2019
SECI	10 MW/20 MWh BESS for 160 MW Wind + Solar Hybrid	Andhra Pradesh	2019
SECI	2 MW Solar PV Project/ 1 MWh BESS	Kaza, Himachal Pradesh	2019
SECI	2 x 1.5 MW Solar PV/ 2 x 2.5 MWh BESS	Leh District, Union Territory of Ladakh	2019
AP State Electric Utility	5 MW Solar PV Project/ 4MWh BESS	Makkuva, Andhra Pradesh	2019[12]

[12]SECI Tenders and Press Releases: Solar Energy Corporation of India. www.seci.co.in

5.1 Case for ESS for Transmission investment deferral

The[13] RE addition into the Indian Power grid is expected to cross 175GW by 2022, of which 160 GW comes from Solar and wind energy resources and 120GW is of utility scale projects that are connected directly to the transmission grid network. These two sources of power are variable in nature, and the typical total peak energy from solar+wind crosses 100GW only for 29 days a year for 4 hours per day. This constitutes 1.3% of the total time during the year, the transmission line connected to the project is utilized for 120GW. Energy storage can be used for deferring transmission capacity investments. Based on system modelling studies, optimum location for the addition of energy storage can be decided and integrated. This results in delivering the RE power to the consumer sat the cheapest cost.

Most of these wind or solar farms require transmission capacity additions or Transmission line expansions. As per the National Electricity Plan Vol II - Transmission, 47 GVA of transmission addition is necessary by 2022 with RE target hitting 175 GW. From IESA analysis, it is observed that if the peak RE generation crosses 100GW, only 1.3% of the time (in 2022) for which transmission investment can be saved with the installation of a BESS for 5GW/15GWh. While several wind and solar farms are farther than 50kms away from the existing transmission structure, nearly 50% of the projects are well within this range (of 50kms). By installing an ESS to store the peak generation, there can be significant savings on the transmission line investments. Hence by reducing 1.3% of the power from being transmitted across the lines, there can be savings on the transmission cost of constructing about 6 GVA of substations and transmission line capacities. These energy storage units can be also utilized for alternate applications such as RE firming and RE output smoothening, thus the overall benefit is multiplied.

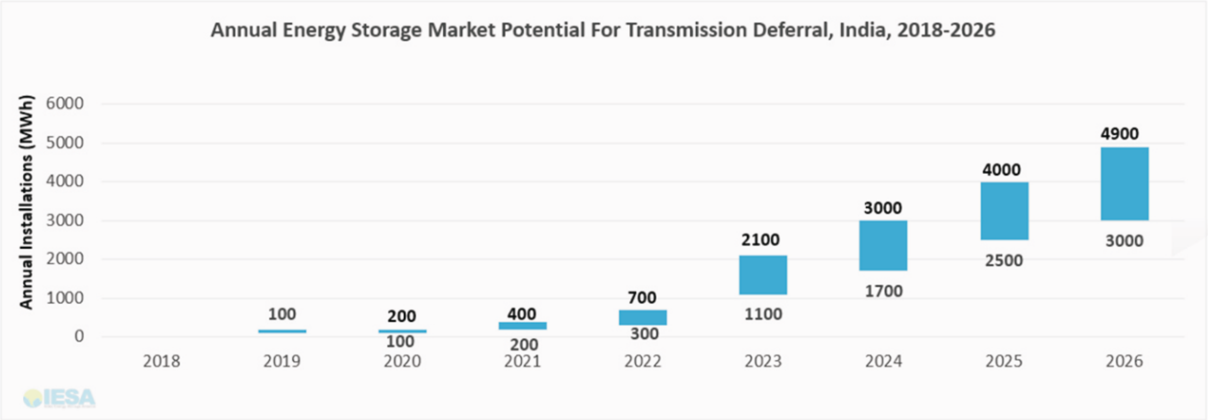


Figure 4: Annual Energy Storage Potential for Transmission Deferral

The total potential capacity of ESS for green corridor investment deferral is around 5GW/15GWh as per IESA analysis Figure 4 shows the expected potentials. The market becomes more attractive with the promotion of locally manufactured products which brings down the CAPEX. In India, RE curtailment is a major issue due to power evacuation challenges. Besides, the CAPEX involved in transmission capacity enhancement, obtaining right of way, land clearances for substations are all key challenges faced by developers. ESS is an immediate remedy for such cases, with a smaller

[13] "Energy Storage System – Roadmap for India 2019-2032" – ISGF, IESA. 6 August 2019. Accessed on Nov 2019

gestation time. When analyzed at an operational windfarm in Rajasthan, it was noticed that during the high wind months due to evacuation constraints, the IPP was losing on generation as the windfarms were being operated in a curtailed mode which resulted in lower generation and thus revenue loss. Such losses can be addressed too by installation of storage. Investment to address curtailment loss through storage makes much more business sense than a total transmission network revamp.

5.2 Case for Storage at Distribution Side

Distribution grids are having a lot of issues in India, like low network reliability, power quality issues like low power factor and harmonics and high technical and commercial losses. 415 V and 11 kV networks are considered not flexible for voltage and power quality fluctuations, as interventions like automated Online Tap Changers (OLTC) are used mostly at 33 kV network and above. In such a scenario, higher penetration of rooftop solar PV (as detailed in Figure 5), integration of EV chargers and rising commercial loads can create a lot of difficulties for the operators in maintaining the network. ESS, as witnessed across the world, can provide a lot of flexibility in low and medium voltage electricity networks.

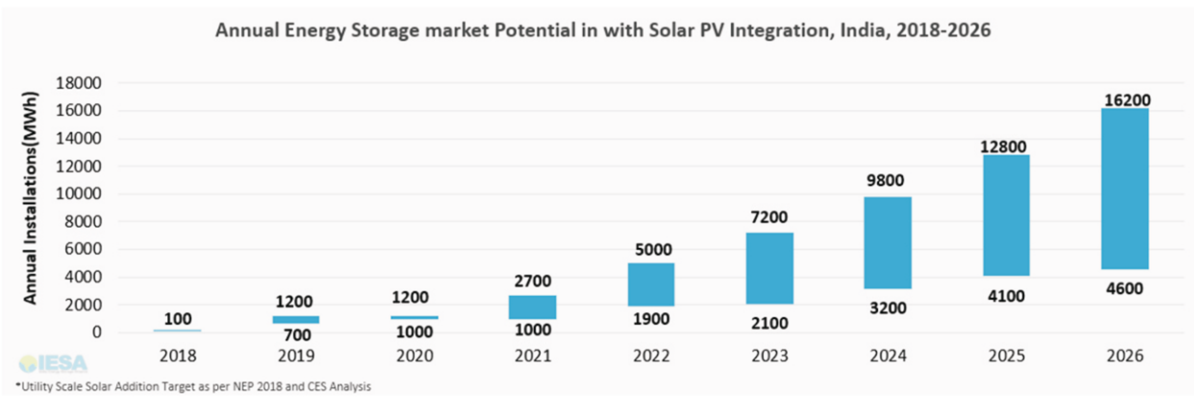
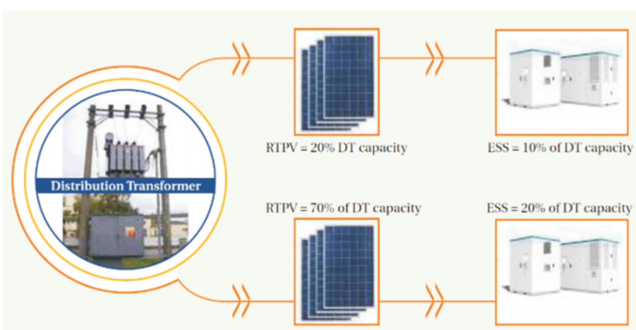


Figure 5: Annual Energy Storage Market Potential (PV Integration)

Major benefits of ESS at Feeder/DT level with solar PV penetration:

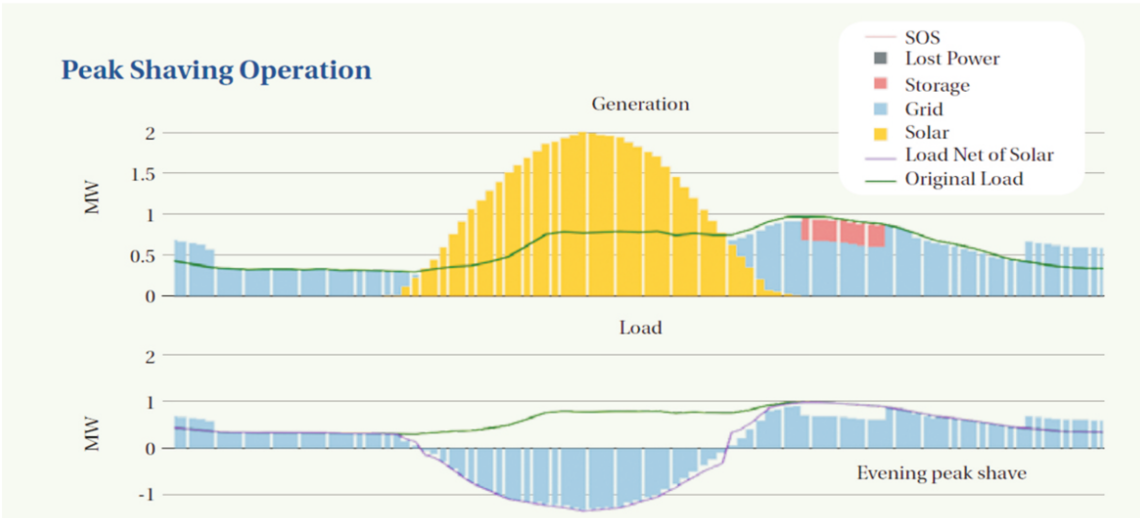
1. Distribution Upgrade Deferral:

ESS can help to defer the distribution upgrades for few years based on load and distributed generation growth rates. Benefits are calculated considering savings on interest payments on upgradation costs for cables and substation equipment due to deferral. The deferral case works really well when afternoon load on network is low and/or load growth on the network is low. Hence, saturated areas like metros with day off peak will be the ideal case to put storage. Also, cities where substation upgrades are not possible due to space constraints are ideal candidates for such deployment.



2. System Peak Shavings benefits:

System wide peak shaving benefits can be captured through storage. ESS (Energy Storage System) is deployed to reduce Utility loads during system peaks (Mostly, evening time). During the low demand hours, storage can be used to capture the excess solar production and the same can be used during non-solar hours.



[14]

Figure 7: Storage benefits as a Peaker Resource

3. Power Quality Savings - Voltage Regulation Perspective:

Even a 40-50% penetration of Distribution Utility Energy storage solution at feeder/DT level can cause a sharp decline in PF and influence voltage fluctuation. ESS can help capturing power losses in the network due to low power factor. As per the data, feeder level load is having 0.9PF but when solar comes into the grid, then PF reduces to around 0.8. Reduction in PF happens because solar is majorly giving active power instead active and reactive power, thus ratio of apparent power to active power (i.e. PF) get reduced. With the help of storage that ratio gets increased and back to its actual PF.

In the study conducted by CES for ISGF funded by MacArthur Foundation to develop an ESS Roadmap for Distribution Grid for Calcutta Electric Supply Corporation, few load centers in Kolkata were analyzed, where annual peak load growth has been 3% for the past 5 years. Introduction of Li ion BESS at varying capacities was studied for 2020, 2022 and 2025. IRR was determined for each of these cases and it was found that ESS capacities in the range of 10% to 20% of the Distribution Transformer capacity in these load centers was found to defer the distribution investment by up to 4 years at +IRR. Deferral apart from energy shifting and power factor improvement was one of the key applications. However, on case to case basis, different applications were found to drive the need for storage at distribution utility level. The same is shown below in Figure 9.

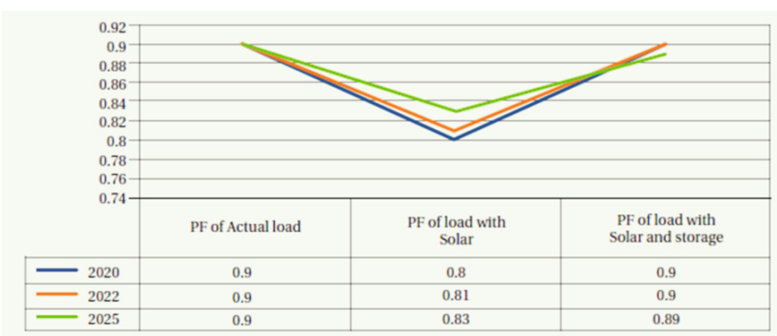


Figure 8: PF Improvements with Storage

[14] "Energy Storage System – Roadmap for India 2019-2032" – ISGF, IESA. 6 August 2019. Accessed on Nov 2019

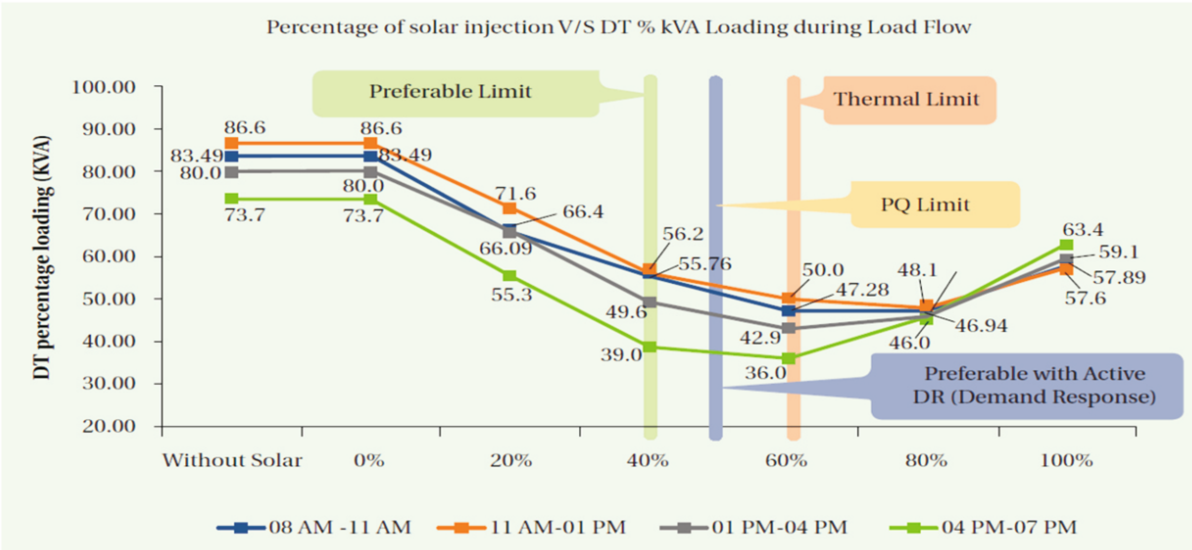


Figure 9: CESC Feeder Load Flow Analysis (CES)

The study yielded the following findings:

1. 20% of DT capacity storage option is suitable for 2022 and 2025 to get maximum IRR. This storage option is also suitable for 2020 at a cost of negative IRR. But still there is high deferral benefit.
2. Solar penetration in the year 2022 and 2025 helps to reduce the original load curve, which may defer the transformer replacement up to a certain year.
3. Maximum IRR is driven by low storage cost.
4. For higher penetration (year 2025 with 70% solar penetration) storage still provides economically viable results given appropriate size and technology.
5. The top metro cities in the country have peak load growth was between 2-7% during 2018. During 2019-2026, various factors such as adoption of energy efficiency practices by residential, and C&I customers in the metro cities and space saturation can lead to lower peak demand growth in these cities
6. The peak load growth of key cities such as Delhi, Mumbai, Kolkata, Bengaluru are expected to be 3-4% annually during 2019-2026. Within such cities, with a high concentration of Commercial activities (assumed to be 10-20% of the total city load), the growth can be even lesser at 1-2% annually have peak load centers, with loads connected to it growing at a slow pace of 2-3% annually. In these cities, there would be 10-20% of load centers.
7. DISCOMs will be discouraged from investing in distribution grid upgrade or expansions, in this case due to low returns and longer ROI. So ESS makes a good case for this case, as when needed the ESS unit can be disassembled and shifted to another location, if the peak load remains flat after a few years of operation.

5.3 Case for Storage for Distribution Utilities

To[15] make Grid more reliable and attain energy security, Deviation Settlement Mechanism was introduced in 2014. The same has been amended 5 times till date. Over time penalties for not adhering to schedule has been made strict. Average price of electricity transacted through DSM is around Rs. 3/unit but the maximum DSM rate is Rs.8 /unit. With new vector, the DSM penalty can go up to Rs.16/unit in case of violation of the band. The cost of DSM is unavoidable, but it can be optimized with Smart Grid solution.

As per the experts, zero deviation is in fact coincidence rather than expectation. Battery Energy Storage Solution is an outstanding alternative for short-term balancing in order to reduce the cost of prediction uncertainties.

In its present form, the operational frequency band has been tightened to 49.85 – 50.05Hz. The step size has been reduced to 0.01Hz, maximum allowable deviation is restricted to 12% of schedule and the penalties have been made much more defined. As such with more renewables penetrating the Grid, it becomes more difficult for DISCOMs and Utilities to adhere to schedules.

This is where storage can help in a big way, in such time blocks where the utilities are drawing energy more than the Overdrawal limit, based on whether the penalties incurred are more than the cost of power from battery, the overdrawn amount can be met by discharging the batteries, similarly when the utilities are under drawing more than the allowable limit, the difference can be used to charge the batteries. This way, the Utilities can save on paying penalties due to over or Underdrwal of energy blocks.

One more application where storage can work well for Distribution Utilities is Demand Response services. The market for the same is still not that pronounced in India but in coming days. it is expected to develop a significant market in India.

[15]"India Stationary Energy Storage Market Overview Report", IESA, June 2019, Accessed on Nov 2019

6. Conclusion

Energy storage is the way forward, even the toughest of critics have now acknowledged this fact. It is no longer an option but has become a necessity for the energy sector to remain sustainable going forward. Real on ground projects have further proved the fact that storage projects are viable not only technically but also on commercial grounds. The way forward will further see the main streaming of this technology for applications across the value chain in a more efficient and economic manner.

Looking[16] across the world, there are many examples today, starting from the ESS for frequency response project in Chile (4MWh) and Alamitos (400 MWh), the 129 MWh Hornsdale Tesla project, 10 MWh Hyundai Electric projects in Korea to manage energy shifts and the world's biggest BESS project of 800 MWh in Rongke.

Overall, the future of technology looks promising with many options congregating in the power sector. It's a challenging and competing environment where the technology which remains agile, compatible, trailable, convenient and customer oriented will lead and maintain the sustainability edge going forward. Figure 10 illustrates a similar set-up for the EU Grid.

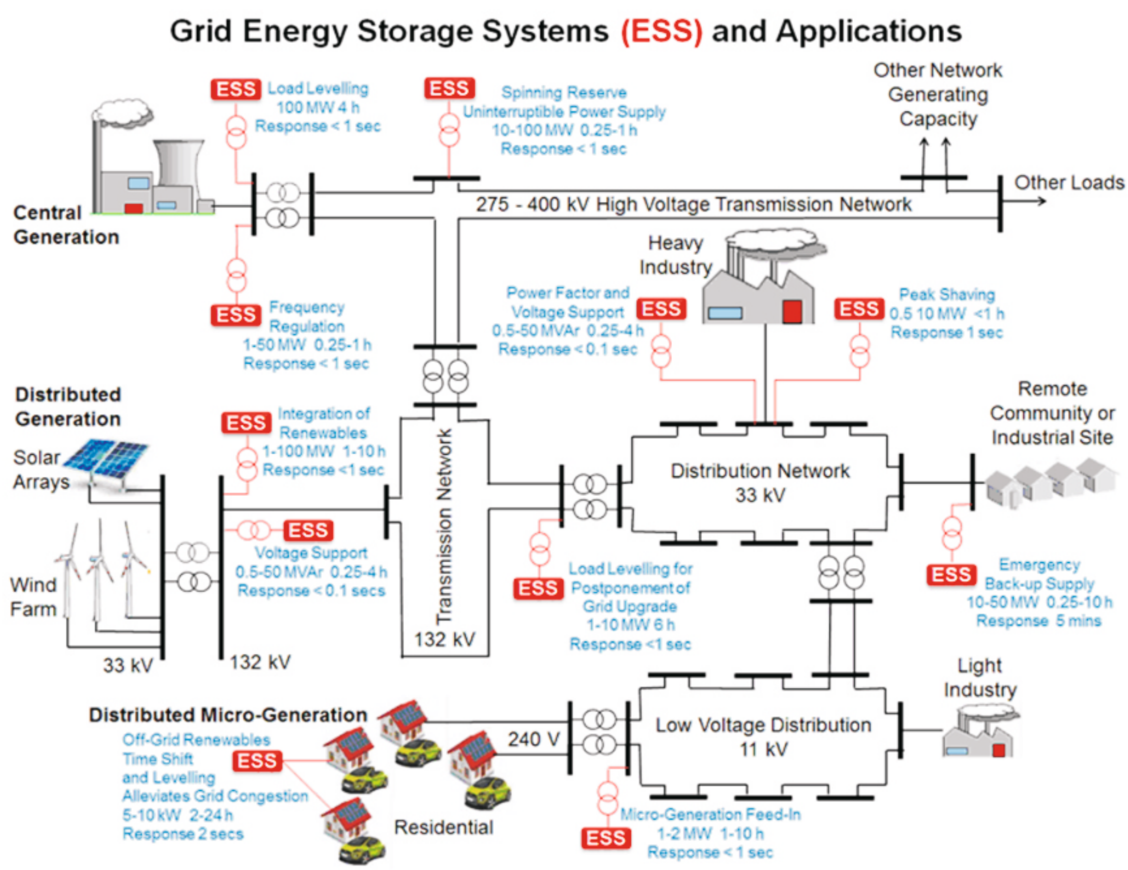
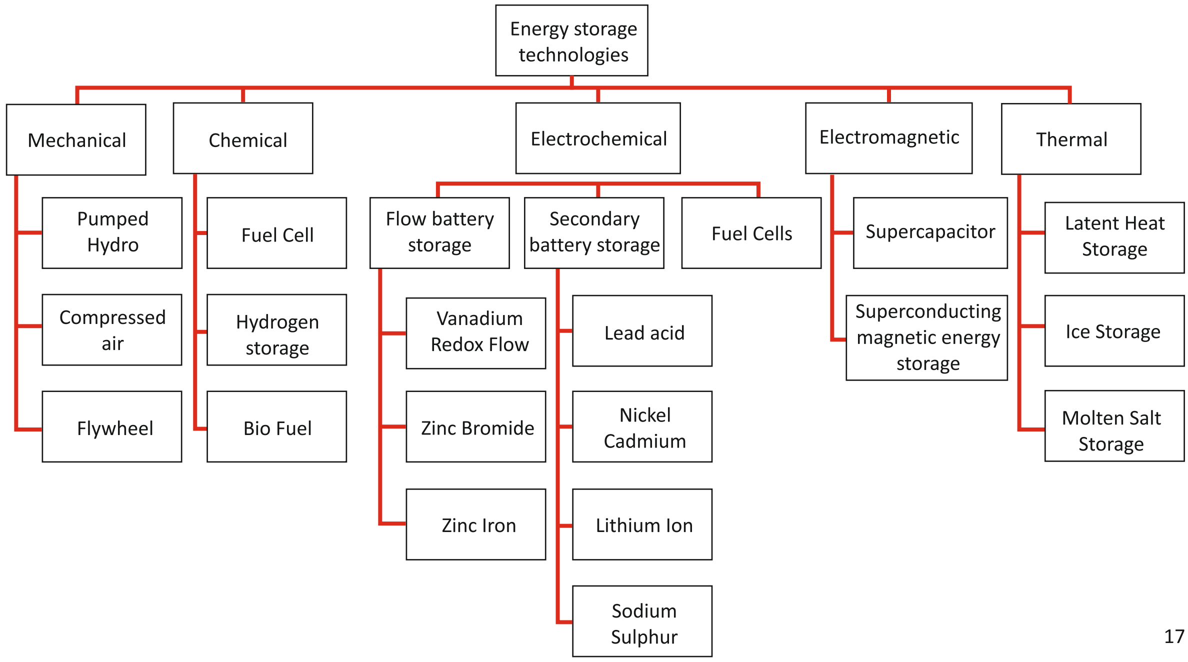


Figure 10: Illustration of deployment of Storage in the EU Grid

[16] "Solving Challenges in Energy Storage". Department of Energy. Storage success stories. August 2018. Accessed on October 2019

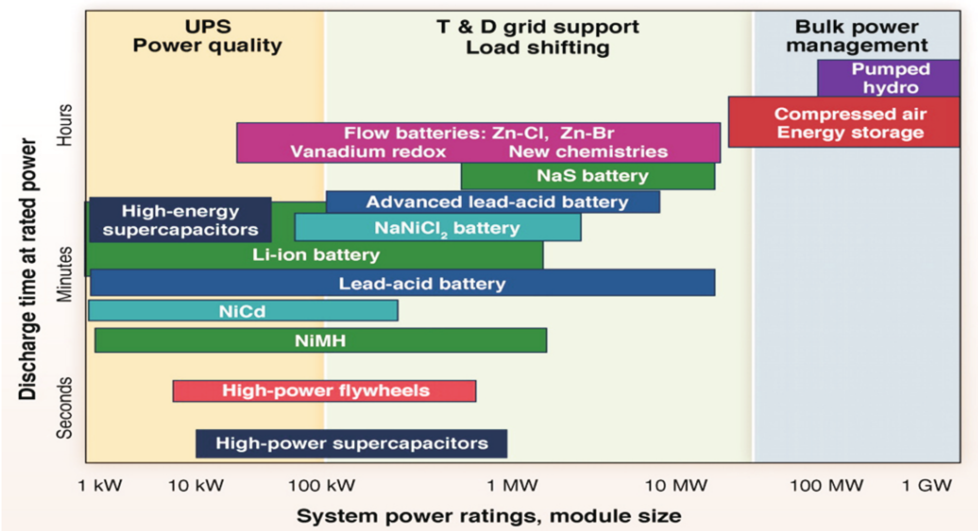
Appendix

1. Storage Technologies Classification:



[17]

2. Classification based on Energy and Power Density of various Technologies



3. Lithium Ion Technology Classification:

Battery Chemistry	Name	Major Cathode Material	Power Density (W/kg)	Energy Density (Wh/kg)	High Temperature Tolerance (deg C)	Main Application	Positives	Limitations
LCO	Lithium Cobalt Oxide	Cobalt	150	150	150	Consumer Electronics	High Energy Density	Limited cycle life Low upper temp tolerance
LMO	Lithium Manganese Oxide	Manganese	450	140	250	High Power Applications	High temp stability Fast Charging Time Low cost	Low cycle life Low energy density
LFP	Lithium iron Phosphate	Iron, Phosphate	300	120	270	Electric Buses and Stationary Applications	High decomposition temp High cycle life High power capability	Low energy density
NMC	Lithium Nickel Manganese Cobalt Oxide	Nickle, Manganese, Cobalt	400	150	210	Transportation and Stationary Storage	Improved cycle Life Fast discharge capability Good battery life	Low energy density
NCA	Lithium Nickel Cobalt Aluminium Oxide	Nickle, Manganese, Cobalt	210	180	150	Satellites, EVs	High energy density	High Cost

[17] IESA Resources. India Energy Storage Alliance. www.indiaesa.info/resources/Storage101

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