Distributed Energy Storage: A Potential Game-changer

- A Detailed Insight

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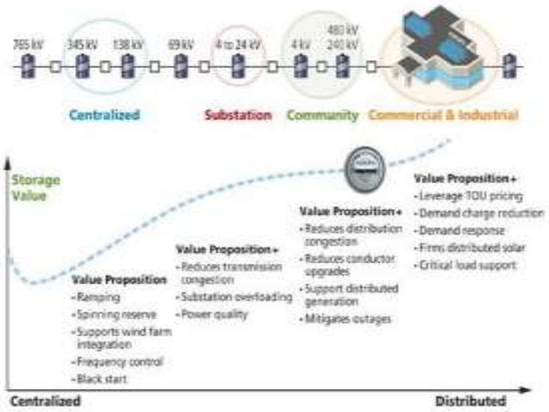
***Abstract**:* The recent developments at COP21 in Paris highlighted the importance of Energy Storage Systems for Renewable Energy in India. India has proposed reducing carbon emissions to a tune of 33% to 35% by the year 2030 as compared to 2005, and specifically mentioning energy storage in its INDC. The increased penetration of Solar PV and wind installations is fundamentally altering the power sector across the world. The shift towards more and more distributed power generation and higher contribution of energy to the grid from variable power sources like solar and wind are creating new challenges in grid integration of renewables. The seasonal fluctuations in solar power generation and the inherent unpredictability of energy from these sources have led to increased adaption of energy storage systems. With such high renewables in the energy mix and constant focus on quality of power, the relevance of storage systems is increasing remarkably. Energy storage has long been recognized as a potential "game changer" allowing the power system to reflexively adjust to the limitations dictated by the laws of physics by adding a new dimension to energy delivery that is not currently available. Though, presently it remains a huge missing link in the entire energy story. A number of key issues for the Indian market like realizing a more modern and resilient grid by incorporating proven and innovative energy storage solutions; assessment of energy storage needs towards power generation and transmission networks; creating an open market leading to decrease in costs for energy storage technologies; need for switching from diesel generators to energy storage systems, etc. need extensive research and development.

There is tremendous opportunity for storage development in India and many leading players are very keen to tap the Indian energy storage space. At the same time, exponential growth of storage systems has been fuelled by proliferation of many modern technologies. This paper focuses on the distributed energy storage (DES) segment of the energy storage systems in contrast to utility-scale energy storage. DES is having one of the highest growth rate in the sector. As incentives for development and deployment are being introduced and costs have fallen, the number of DES projects are increasing globally. The growth of DES is closely linked to the rapid deployment of behind-the-meter solar, high commercial/ industrial tariff demand charges, demand management incentives, and self-generation incentives. Various technical aspects of DES, Benefits, Value streams for customers and grid, Challenges, Necessary Codes and Standards in DES deployment, Its Growth potential and Future path ahead for DES technology are covered in detail in this paper.

I. INTRODUCTION

DES is defined as an energy storage element or system located at the distribution substation, within the distribution system, or customer-sited located either behind the customer's utility revenue meter or customer-sited on the utility side of the revenue meter. While electricity-in-electricity-out storage is emphasized in this review, thermal energy storage is also included in this definition. DES is contrasted to utility-scale energy storage in that it interconnects at, and supports, the bulk electrical power system level, and is usually of a larger unit size (>5MW).

DES has distinct advantages over utility-scale energy storage for size, functionality, location, and value. Many experts believe that the maximum benefits for energy storage are on the distribution system or behind the meter applications. It is depicted in the following figure.



Source: Renewable Energy World Article

Figure 1: Increasing value of Energy Storage

We can see the energy storage's value increases as it approaches the edge of the grid and the customer's load, with economic benefits accruing to both the utility and the end-user.

Presently, the inherent nature of electricity necessitates that the power system constantly balances supply and demand. Storage would provide arbitrage and other opportunities by allowing users to accumulate power at a certain time for use at a later time. This "warehousing" possibility would add value to the power system by enabling increased use of variable resources, enhancing grid reliability, and delivering digital grade power where needed.

There are several types of DES, including: electrochemical (e.g., batteries); thermal (e.g., hot or cold water, ice, eutectic salts); chemical (e.g., hydrogen); or kinetic (e.g., compressed air, hydro.)

II. BENEFITS OF DES

Distributed, grid-connected energy storage can improve the reliability and resiliency of the power delivery system—in addition to reducing overall costs—if developed, designed, and deployed appropriately. Further, storage can make the grid more flexible by providing a buffer between generation and loads so as to reduce the strain on grid assets and allow the grid to accommodate more variable renewable energy and many new consumer loads. In this way, storage provides valuable flexible capacity, and DES can provide local flexible capacity closer to load centres. In some cases, it can do so more cost effectively than traditional status quo solutions such as gas-fired peak plants. Storage can also make the grid more resilient by supplying ancillary services such as frequency regulation, and temporary local power source or sink, thereby augmenting transmission and distribution architecture and operations. Accordingly, it can reduce overall costs by deferring the need for investments in grid upgrades, and provide an innovative element for operational optimization.

Because of the increasing demand for clean, reliable, and low-cost electricity provided by otherwise variable resources, the value of grid storage is greater than it has ever been. Energy storage may provide fast response to second-to-second ramps in the supply or demand of electricity, as well as shifting larger amounts of energy through time to balance generation and load. Energy storage may increase the reliability and resiliency of the grid by providing temporary local sources of electricity that augment the transmission and distribution network. Energy storage may also reduce the potential for future rate increases by allowing deferral of grid upgrades and increasing asset utilization on the grid. However, grid storage still faces significant technical, economic, and regulatory challenges, which may be surmounted by a coordinated effort between industry, government, and other stakeholders.

Ultimately, distributed, grid-connected storage may change the dynamic of utility operation and business model by allowing electricity to be "warehoused." Similar to how refrigeration completely transformed the food industry by introducing inventory at every stage in the supply chain, so too can storage impact the utility industry by acting as an inventory of electric energy on the grid, adding a buffer to what is otherwise perhaps the ultimate just-in-time production and delivery system.

III. CRITICAL ASPECTS OF DES

There are still numerous challenges posed by DES, as well as challenges to DES market development. To fully realize the benefits of DES and effectively address the challenges, several key locational and technical aspects of DES must be taken into consideration. These specifics are discussed below.

A. Locational Aspects

DES provides some important locational differences compared to utility-scale storage. By its nature, DES tends to be deployed closer to the electricity consumer. Due to this locational reality and the smaller scale of DES (having capacities in the kW or single-digit MW range verses utility-scale with unit capacities at a MW or GW scale), there are important considerations regarding the physical characteristics of DES. The tendency to deploy DES close to the end customer makes some technologies less practical for such applications. For instance, most current pumped hydroelectric and compressed-air energy storage technology concepts could not be practically deployed in the DES setting due to their geological requirements.

B. Technical Aspects

DES also has some important technical necessities based on the possible applications that a deployment could be used for. Some of the most important technical requirements are summarized below.

1. *Energy and Power Capacity:* The different potential applications of DES have varying capacity needs. Generation shifting and capacity deferral services, for instance, tend to require high energy capacities. Some ancillary services (e.g., frequency regulation) are more dependent on having high power capacities that can be sustained for short charging and discharging durations.

2. *Efficiency:* The roundtrip efficiency of a DES system is of course important for most applications. Moreover, some DES applications (for instance, generation shifting and emergency uses) also can be sensitive to the self-discharge rate of the technology. These types of applications may require energy to be stored for a prolonged duration of time, for which technologies with high self-discharge rates are not well suited.

3. *Cycle life:* The ability of a DES technology to cycle its state of charge frequently many times is important for some applications. Frequency regulation requires relatively constant charging and discharging, and technologies with limited cycling lifetime ability are not well suited to this type of application. Generation shifting, as a counter example, typically only entails one charging/discharging cycle per day. Another important consideration is how well a technology adapt to deep cycling. Emergency uses may require infrequent deep discharges of the DES. Some technologies suffer extreme degradation with this type of duty cycle.

4. *Power and energy density:* The power and energy density of a storage technology is important exactly because of the siting of DES near the end customer. Extremely low-density technologies may not be suitable for uses as DES, due to physical space restrictions in an end customer building or attached to a pad-mounted distribution transformer.

IV. VALUE STREAMS FOR THE GRID AND CONSUMERS

A selection of ownership structures could be used for DES, a very important consideration in making DES economically viable. The ability to capture the value associated with different DES applications are dependent on a number of factors. These include the presence of restructured wholesale electricity markets (as opposed to a DES deployment in the service territory of a vertically integrated utility), retail price structures, and the ability to design contract or incentive mechanisms for some DES applications. If the correct combinations of restructured electricity markets (and the associated price signals), appropriate retail pricing, and innovative contract design are not available, the issue of capturing the value of DES applications can be surmounted through ownership structure. For instance, generation shifting by a DES system owned by an end customer is only economically viable if the customer is exposed to time-variant retail prices or rates.

Depending on its use, DES offers a number of value streams. These benefits can accrue to the bulk power system, the end consumer, or to society at large. The uses that a DES deployment provides may also depend on who makes operational decisions. It should be noted that the value does not necessarily accrue directly (or only) to the device owner. For instance, an electric utility may install DES systems that are used primarily to the benefit of end consumers. In other instances, an end consumer may install a DES system that provides power system services, for which it is remunerated through retail prices or other contracting arrangements. These potential services are classified into six broad categories and summarized in the following section.

A. Generation and Load Shifting

Generation and load shifting was and remains the primary use of large-scale energy storage deployments. Although conceptually the same, the actual operational practice of this application differs slightly between restructured electric power systems and those that are served by a vertically integrated utility. In the vertically integrated paradigm, the utility stores excess energy during periods in which the marginal cost of producing energy is low and later discharges the stored energy when the marginal cost is high. In doing so, there is a cost savings to the power system and a benefit to society at large because high-cost generation is displaced by lower-cost generation. These benefits translate into cost savings for consumers as well.

In a restructured market, storage is used in the same manner, except that charging and discharging decisions are made on the basis of market energy prices. In a restructured market, this application is occasionally referred to as energy arbitrage, as the storage plant is arbitraging differences between on- and off-peak prices. If market energy prices reflect marginal costs, these two paradigms should result in similar (ideally identical) operational decisions.

The energy arbitrage concept can be extended to DES, although doing so depends heavily on market and contract design.

B. Capacity Deferral

Another application is to use energy storage to defer a generation, transmission, or distribution capacity investment. These three forms of capacity deferral are functionally similar. In the case of generation capacity deferral, storage is charged when there is excess generating capacity available and discharged when generating capacity is scarce. If sufficient capacity is available, this use of storage alleviates the need to add generating capacity to the system, reducing the system's capital cost. This use of storage is typically an ancillary benefit of generation shifting. This is because marginal generation costs or energy prices tend to be low when the system has excess capacity available, and high when generating capacity is scarce. Thus, this use of storage can also reduce system operation costs (in addition to its capital-cost benefit).

Because this use of storage is closely related to generation shifting, the models discussed above, in the section on Generation and Load Shifting, allow for generation shifting in the vertically integrated or restructured paradigm and could be used to provide this benefit.

Properly located storage can also provide benefits in deferring transmission or distribution capacity investments. Transmission capacity deferral could potentially be incentivized using the same methods discussed for generation capacity deferral.

C. Ancillary Services

A third set of applications is to use energy storage to provide ancillary services. Indeed, much of the recent “merchant” storage development globally has been batteries and flywheels built to provide frequency regulation in restructured electricity markets, including in the New York. This is evidence that restructured electricity markets are providing price signals for competitive energy storage to enter the market and provide high-value services.

Using storage for ancillary services reduces the need to reserve capacity from a conventional generator, which often results in the generators operating less efficiently. Moreover, using conventional generators for ancillary services increases wear and tear, due to the need to cycle their output up and down. An additional benefit of using storage for ancillary services is that many storage technologies provide a much faster response than conventional generators. In sum, these benefits of using storage for ancillary services result in reduced generation costs (from operating generating facilities more efficiently) and reduced capital and maintenance costs (from reduced cycling of conventional generators).

In case of Indian power industry scenario, there is no reserve provision for contingency conditions due to generation deficiency and the balance between demand and generation in real time has been achieved by a frequency linked self-dispatch regulatory method known as unscheduled interchange (UI) mechanism. The UI mechanism is embedded with the availability based tariff (ABT) mechanism for determining the tariffs of electricity suppliers. There is provision of monitory incentives for both buyers and sellers for frequency regulation and contingency reserves. These extra prices provide incentives for storage to enter the market and provide these services. Storage typically has a better response to the ancillary service signal compared to many conventional generation technologies which bolsters the incentives for storage.

A major advantage of DES, compared to utility-scale storage, is the ability to locate the systems at key locations to support loads and provide critical volt-ampere reactive (VAR) support and improve power quality. Most DES systems are capable of delivering both real and reactive power. Reactive power is essential in voltage regulation and/or in supporting a large load, such as motors and compressors. Voltage regulation and VAR support is needed on a localized basis both in locale and time frame. By providing localized voltage regulation, the bulk system can focus on delivering power in the most efficient manner possible.

Similar to voltage regulation, power quality is also very difficult to obtain from the bulk system. Excellent power quality on the bulk system does not guarantee good power quality at the distribution system. Many factors affect power quality and many of those factors occur at the distribution level. DES may be uniquely qualified to improve power quality on the distribution system and therefore to the loads being served. Most power quality issues are related to over and under voltage events which can be addressed through localized voltage regulation provided by DES. Another power quality factor is signal distortion and signal interruption (losing a cycle or two). DES can provide methods to actively filter the power signature to minimize the effects of signal distortion and interruption.

D. Reduced Transmission and Distribution Losses

Storage can also provide benefits in reducing transmission and distribution losses; these losses are proportional to the square of the current flowing over the line. When storage is used for transmission or distribution capacity deferral purposes, it reduces the line loading during peak-load periods and increases loading during off peak-load periods. Because the losses are proportional to the square of the line loading, the decreasing in winding losses during the peak period tends to outweigh the increased losses during the off-peak period. Thus, in net, this leveling of load between on- and off-peak periods tends to reduce overall losses.

E. Phase Balancing

Phase balancing is an important factor in the efficient transmission and delivery of power but it is also a critical element for power quality. In distribution systems, it is relatively common to see an uncontrolled third phase or leg. Sometimes this is also described as the “wild” leg or phase. This is a symptom of a lack of phase balancing. DES systems are capable of providing real or reactive power by phase, meaning that DES is capable of providing different support to different phases. This capability allows DES to balance phases both in regards to load sharing as well as voltage regulation. This one capability may increase the power transfer at a substation by more than 30% because as substations get more and more loaded, phase balancing or lack thereof becomes more and more amplified. DES may be uniquely qualified to solve this important issue and phase balancing may be one of the most valuable benefits provided by DES.

F. Emergency Uses

‘Hudhud’ cyclone, among others, and ‘2012 India blackout’ have shown the vulnerability of our electrical grid system. DES offers the possibility of supporting critical load segments even when the main grid is down. Also, DES can accelerate the restart of the grid system by testing and supporting the load circuits while the main grid is brought back to operation. DES can provide unique capabilities to resync a distribution system with the bulk system without significant load transfer and other synching issues, such as frequency and phase matching. The ability to test a distribution system without tying it to the bulk system is a major advantage of DES and also a major value even if it is difficult to access and quantify. Future distribution systems may have significant DER and those resources can best be utilized if DES is a core asset of the respective distribution system.

V. NEW POLICY AND MARKET PRACTICE IMPLICATIONS

As the transformation in the power sector unfolds, it is vital that regulatory policies at the state and central level be aligned to recognize the value of storage by providing appropriate compensation and non-discriminatory access to the grid. Ideally, regulatory policies that advance market-based solutions would promote the greatest economic efficiency over the long-term by the deployment of storage technologies should be encouraged and formulated. Various storage technologies including DES can be an effective solution for balancing power flows and voltage levels. In order for this to happen, the owners of storage assets will require compensation for achieving a number of system benefits, such as: Energy reserves including system balancing by either discharging or absorbing energy, Capacity for meeting peak demand to the extent resources qualify as a capacity supply resource, Deferment of transmission and distribution investments, Reduction of customer outages, Ancillary services, including ones such as power quality and electricity customer energy management.

The predictability and dispatch ability of a resource, with particular emphasis on a resource's ability to meet the peak demand requirements of the system, are now key ingredients to the market design. These market rule changes should provide storage greater economic opportunity to compete against other resources in future capacity auctions. Centre should put efforts emphasizing on the reliability characteristics of a resource—regardless of whether the resource is supply-side or demand-side, to compete against conventional supply-side resources

The tariff revisions enhance the ability of limited-energy resources, such as storage, to participate in the frequency regulation market to the fullest extent possible. States should also consider market-based or tariff structures that appropriately compensate storage resources for balancing system loads, maintaining adequate power quality, facilitating higher penetration of distributed renewable resources, reducing customer outages, and deferring the need for distribution capacity investments. For instance, realizing the importance of off-grid PV systems with storage, the Ministry of New and Renewable Energy (MNRE), through the Jawaharlal Nehru National Solar Mission (JNNSM) is offering a higher capital subsidy for PV systems with energy storage, than those without storage. At a state level, Kerala is offering an additional subsidy to encourage off-grid systems with energy storage. The state provides an additional capital subsidy of Rupees 39,000/kW in additional to the 30% capital subsidy by MNRE.

Lastly, state regulators need to ensure that interconnection policies are fair and not unduly burdensome. Interconnection policies for storage should provide transparent procedures and criteria to customers and market participants, such as metering, site control, interconnection cost allocation, electric code consistency, and payment structures. Regarding payment structures, compensation can be in the form of a contract or tariff-based program, and should consider the option of bill credits (including net-negative metering). Technical assistance that will help states evaluate these policies is essential to the deployment of storage technologies, and MNRE can play an important role in the development of best practices that could assist states in implementing regulatory mechanisms that will facilitate deployment of storage technologies in a manner that promotes economic efficiency and reliability.

VI. CODES AND STANDARDS

As the demand and opportunity for DES grows, the development of codes and standards will be critical in ensuring; the development of a uniform language for product subcomponents, that fundamental materials are developed in a streamlined fashion so manufacturers can capitalize on economies of scale to decrease costs, and that different storage devices are interoperable with each other and the grid as a whole. Most importantly, codes and standards development will help ensure the safety of these products during their lifetime, subsequently encouraging consumer confidence and mass adoption. They will also ensure that responsible end-of-life plans are in place, and that interconnecting these devices with the greater bulk grid is as seamless as possible. These three components of codes and standards development—safety, disposal plans, and interconnection

A. Safety Considerations

Safety of any new technology can be broadly viewed as having three intimately linked components: 1) a system must be engineered and validated to the highest level of safety possible; 2) techniques and processes must be developed for responding to incidences if they do occur; and 3) the best practices and system requirements must then be reflected in standardized safety determinations in the form of codes, standards and regulations (CSR) so that there is uniform, written guidance for the community to follow when designing, building, testing and deploying the system.

Also, a scientific testing of systems is needed to validate the safety of DES devices, with particular attention paid to the chemistries and "mechanistic responses" of each new storage system. Further, a streamlined process for researching, testing, and certifying the DES products that come to market—with transparent standards—must be solidified, especially as an increasing variety of devices are created and the industry becomes more crowded. A key component of this will be identifying the most likely areas for system failure when these devices are installed outside the testing environment, so that oversight can be applied and threats can be mitigated. Standards must then be implemented to ensure that the safest and most reliable devices and materials are promulgated, and that inherently risky devices are updated to reflect the safety codes.

B. Fire Safety Codes and Standards

DES systems add an additional level of electrical complexity, and therefore potential hazard, to the homes, businesses, and commercial sites at which they are installed. Support is needed for testing and simulating the fire risk potential of these devices. These efforts should seek to identify which components, if any, pose the greatest fire hazards and how best to manage those risks. Subsequently, work is needed to determine the most effective response measures, keeping in mind that the typical fire response approaches and common suppressants may not interact as expected with the chemicals used in DES devices. These potential issue areas should be identified, tested, and translated into effective protocols before mass market penetration of DES.

C. Site-specific Codes and Standards

Attention must also be given to how the location of a DES system—for example inside a residential basement vs. outside at a commercial entity or business—affects the particular set of codes and standards to which the system is subjected. Work is needed to establish permitting and siting standards that are appropriate for the particular location, ownership type and size of the system. For systems that are co-located with generation facilities or in close proximity to sensitive areas (e.g., protected lands), consideration should be given to what additional permits or actions should be required. To facilitate greater adoption of DES, these permitting and siting processes should be established in a streamlined and user-friendly manner.

D. End-Of-Life Considerations

When developing the set of codes and standards needed to ensure that DES systems are safe, reliable, and economically feasible, it is important to consider the entire life cycle of the product. This consideration should include the "end-of-life" stage: the disposal, recycling, and/or decommissioning options that are available for the device, as well as the advantages and disadvantages of each alternative. For example, several ISOs are now requiring end-of-life disposal costs and safety to be considered in their procurement requirements.

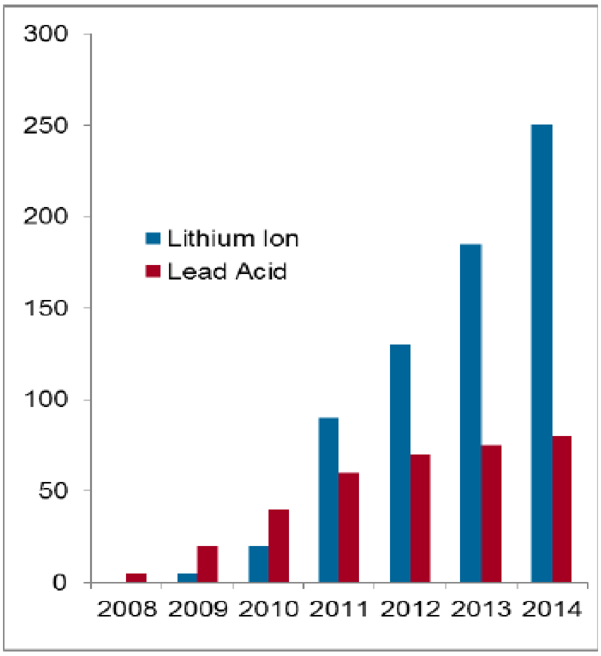
E. Interconnection

Effectively incorporating a growing number of DES systems onto the grid requires a systematic, transparent approach with clearly defined codes and standards. Coordinating and developing the technical aspect of these processes is a critical part of ensuring that interconnection is feasible, non-discriminatory, safe, and cost-effective. Opportunities also exist to standardize and improve systems communications protocols, frequency smoothing, automatic generation control, advanced inverter functions, and a host of other functions. There should exist DES-relevant interconnection codes and standards.

VII. POTENTIAL FOR FUTURE GROWTH

IESA has estimated over 70 GW and 200 GWh of Energy Storage opportunity in India by 2022, which is one of the highest in the world. Out of 70 GW, over 35 GW of demand is expected from newer applications like wind and solar integration, frequency regulation, peak management, T&D deferral, diesel usage optimisation and electric vehicles. Hence there is a sizable opportunity for advanced storage technologies in the new applications itself apart from opportunity for existing technologies to improve their performance for traditional applications.

The grid today operates without a substantial amount of energy storage. Worldwide, only a minimal percent of generated electricity is stored. Most of this storage capacity is interconnected at the bulk grid level.



Source: EPRI and USDOE Estimates

Figure2: Lithium ion and lead-acid-based storage systems installed worldwide (MW).

Figure 2 illustrates the total deployed grid storage worldwide as of July 2014, based on total MW installations in each respective year for two technologies (lithium ion and lead-acid based storage systems). Total current market size for lead acid batteries is around INR 27,000 Crore (USD $4.2 billion) out of which stationary and motive applications in India takes the share of INR 12,650 Crore. The stationary and motive application segments are likely to grow by 14% CAGR until 2020 and the forecasted market will be INR 25,000 Crore (USD $4 billion).

These percentages could change dramatically in the coming years. Storage technologies are improving, while costs are falling. Researchers have applied technological advances in materials, control systems, and power conversion to improve all storage technologies. Historical challenges of technical performance, life-spans, and efficiency are increasingly being overcome. Similarly, the economics of energy storage are improving as are value streams. The industry is beginning to address regulatory challenges by clarifying definitions and developing a framework for evaluating storage on today's grid while tools for understanding the value and grid impacts of storage are still in development.

Additionally, deployment of grid-connected storage continues. There has been an expansion in installations for frequency regulation and other ancillary services. The customer-side of the meter installations is also expanding, as storage companies aggressively market products to end-users. Lack of reliable grid power, growth in sales of electric rickshaws, reduction in use of diesel gen-sets and integration of solar PV with the grid at both ground level, roof-top level and at micro-grids likely to boost the sales of battery based energy storage through-out the country.

VIII. CHALLENGES

Grid deployment, integration, operations, maintenance, and disposal are still major unknowns. Deployment of storage and Distributed Generation technology outside of an integrated grid framework can result in substantial additional costs and have limited benefits. Fortunately, the consumer electronics and automobile industries have invested significant capital and effort into developing and manufacturing better batteries for their products. These investments will carry forward to improve grid-connected technologies.

While some storage technologies are mature, turn-key storage solutions are still nascent. Many storage technologies have relatively short useful lives. Battery lifetimes are measured in years, while traditionally grid equipment is expected to have decades-long life expectancies. As with most every other energy technology, energy storage experiences efficiency losses during operation, often referred to as its ‘round trip efficiency’. Such round trip efficiency losses can be considered the “cost of doing business”, and are factored into specific applications. In addition, many of today’s grid analysis tools are not well suited to analyse storage.

Monetizing storage can be difficult, as benefits accrue to many entities in multiple ways, and not just to the owner. Some of the economic benefits flow from certain regulatory challenges. Existing regulations are built around the just-in-time delivery framework of today’s grid and do not account for many of the values of storage**.** Storage does not fit neatly into the existing categories of generation, transmission, distribution, or load asset. A separate asset class for energy storage is recommended to make it easier to monetize all of the value streams.

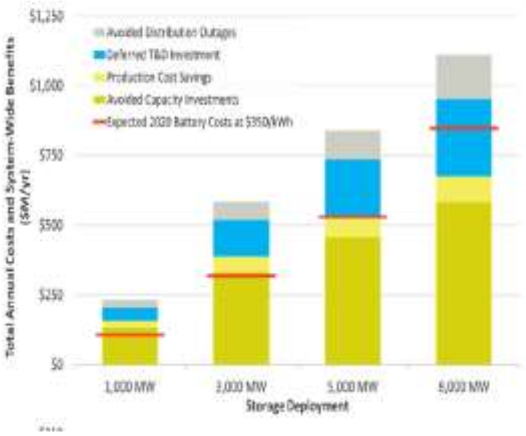
IX. RESEARCH DRIVING THE DEVELOPMENT

The key research question dominating the storage industry is “How can we create better, longer-lasting, and more cost-effective storage technologies?”. Commercialization strategies for these technologies are also important; however, at present, most commercialization is occurring overseas. MNRE can assist by developing a more accurate understanding of when and how storage can best bring value. Better grid analysis tools can determine sizing, deployment, and use of storage for maximum value. Tools are in development by a number of organizations, and results are now being observed with interest by regulators. Additional research is needed to determine what the best practices are for installing and operating storage on the grid. Improvement in storage hardware is possible only through more experience with deployment and operation of storage systems. Many governments are funding many initial deployments, which are highly leveraged through investment from utilities, storage developers, and research organizations.

Just as we have National Laboratory testing wind turbine components (and completed turbines) provided by manufacturers for performance, longevity, generation capacity, and other factors, and solar equipment performances, so too we should have a MNRE Laboratory develop similar testing protocols and devices for energy storage.

Case Example

A study carried out in Texas state, USA reveals that battery storage investment cost per kWh expected in year 2020 is less than savings gained by Avoided capacity investments, Production cost savings, Avoided distribution outages and Deferred T&D investments for various capacities put togather.



Source: The Value of DES in Texas Report

Figure 3: System wide annual benefits compared to expected 2020 storage costs

Also, the grid is a valuable resource and with the combination of storage and DG there is now the possibility for customers to participate directly in wholesale markets and/or enter into long term contracts with their local distribution utility to monetize more of the benefits that customer-sited storage can provide. For example, this is already being done in California in the form of Local Capacity Requirement Procurement. Storage presents a unique opportunity for utilities to deploy an amazingly flexible asset in partnership with their customers and third parties to increase reliability and lower the cost of grid operations for all ratepayers.

X. PATH AHEAD

The recent developments at COP21 in Paris highlighted the importance of Energy Storage Systems for Renewable Energy in India. India has proposed reducing carbon emissions to a tune of 33% to 35% by the year 2030 as compared to 2005, and specifically mentioning energy storage in its INDC. Key government initiatives such as the Government's 175 GW Renewable target, National Electric Mobility Mission (FAME India Initiative), National Smart Grid Mission, 'Make in India' and India's Smart Cities mission are happening with an active thrust. This will be the way ahead to achieve the storage technology in the future. There is a strong push for renewables especially for Solar PV from the Government of India & if it really works the way they are aiming, there will be a huge explosion in demand and with that we will need storage, otherwise targets will not be feasible. Grid balancing on one hand and envisaged huge renewable capacity on the other is a challenge looking at the intermittent nature of renewable energy and its solution is none other than energy storage. Top bureaucrats from Ministry of New & Renewable Energy (MNRE), Government of India are currently in process of gathering inputs from various stakeholders to introduce specific policies to fast track adoption of storage technologies in India. It is a need of an hour that government should think of “Energy Storage Mission” on the lines of National Missions. DES presence will surely increase leaps and folds in coming years globally. More importantly, it will be instrumental in realising India’s future energy targets.

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Major Workplace Projects:

- Gas and Steam Turbine: Renovation and Modernization (R&M) (2014)

Undergraduate Project:

- CFD Analysis of 3D ONERA M6 Wing (2011)

- Project objective was to find the Lift and Drag coefficients, and plotting the pressure coefficient along the length of ONERA wing.
- Created geometry and domain mesh of ONERA wing using ICEM CFD.
- Performed transonic flow analysis with air taken as a viscid and compressible, using FLUENT 12.1 solver.
- Achieved results very much in concordance with the wind tunnel experimental results available with AGARD report, 1979 by Volker Schmitt and François Charpin, scientists at ONERA.

Technical Expertise:

- Six-week certificate course in ANSYS ICEM CFD and FLUENT 12.1
- Control system design using MATLAB R2013a and SIMULINK
- Certificate course in CATIA V5 R18, AutoCAD
- Programming in C, C++, JAVA