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TECHNICAL ASPECTS IN THE DEPLOYMENT OF ENERGY STORAGE SYSTEM IN MICROGRID: A REVIEW

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Abstract

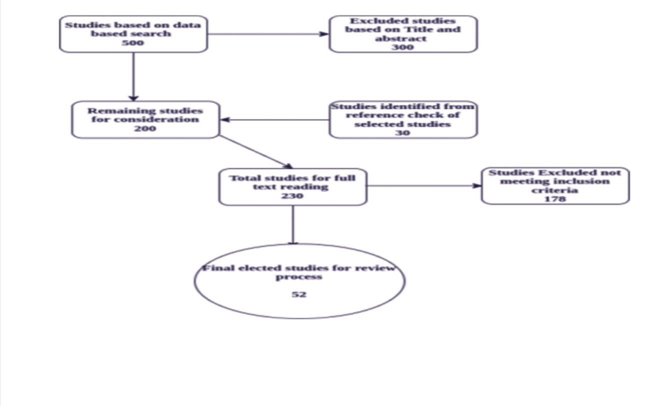
Global needs for energy is increasing day by day. This has promoted increased penetration of renewable energy into the grid. Increasing use of renewable energy systems and its technological advancement has led to the emergence of storage as a crucial element in energy management. This has also changed the traditional way of load balancing. Intermittent nature of these sources introduces errors in the grid. In order to make these sources more reliable, an energy storage system will be the most crucial factor. Electricity storage can be viewed as a key solution to overcome a number of technical and financial issues in the integration of renewable energy sources with the grid due to its unique capacities to store, absorb and later injecting electricity again. The objective of this paper is to compare existing storage technologies and new advancements based on their main performance parameters suitable for the application. The comparison shows that each technology differs from other in terms of ideal system application environment and energy scale of storage. Hence it is very important to study different storage systems for optimum integration with the grid. This article is an overview of recent undertakings that represent storage as a reliable solution for stable and cost effective operation of microgrid. The objective of this article is to stimulate conversation about storage technologies among interested parties and to learn how users feel about various challenges related to the deployment and use of grid level storage technologies.

Keywords: microgrid, energy storage system, BESS, performance of ESS

INTRODUCTION

Electrical energy is a crucial component of any nation's economic activity. The global energy business is about to make a significant new capital investment to replace outdated plants and satisfy rising electricity demand. Major transformations are going on from growing electrification to harnessing energy from renewables. Innovation, increased competitiveness, and regulatory support have propelled renewable energy forward in recent years. As per fig.1 international energy agency, percentage of yearly worldwide electricity generation is predicted to increase from 25% in 2019 to 86% in 2050.[1] In 2020 the contribution of renewable has reached 7468TWh which is up by 7.4% as compared to its previous year [2]

Figure 1. Global Energy Scenario



Integration of renewable energy sources present new challenges as the energy harnessed using these sources is fluctuating and affects power quality and grid stability. Also the energy generated from these sources depends on nature, and peak generation may not coincide with the peak demand. For maximum benefits, when excess energy is produced, it must be stored and then released when electricity generation fall below the required demand. Energy storage technologies are an essential component of a dependable and efficient renewable and distributed generation unit. [2][4][5]

This paper provides an overview of the progress of MG-oriented energy storage technologies. Energy storage-related technologies and principles. The technologies and operating principles for each method differ significantly, diversifying the range of available energy storage products significantly. More particularly, while one storage method may be ideal for smoothing out annual fluctuations, another may be appropriate for meeting short duration high power requirements. Hence basic understanding of each technology becomes essential.

Microgrid is a power system that has been scaled down. It incorporates all of the elements found in a bigger power system, but on a smaller scale. Renewable energy and/or fossil fuel generation are used to power the microgrids.

Microgrids can operate in island mode during a fault or other external disturbances and in normal conditions they can be connected to the utility grid. Thus giving uninterrupted power to the consumers. Customers will benefit from increased efficiency, lower costs, and cleaner. One of the important advantages of microgrids is their ability to store energy. Microgrids may also improve local reliability and give lower costs reduction in investment costs, reduction in emissions, improvement in power quality, and reduction in the distribution network's power losses.[6-8] Furkan Ahmad proposed profit maximization of microgrid aggregator under power environment with optimization algorithm which can be used to integrate microgrid [9] T. Adefarati, R.C. Bansal used optimization tech for finding optimized solution for reliability and economic assessment of a microgrid.[10] Microgrids have a number of advantages, but connecting them to the distribution grid presents considerable challenges. These problems can be categorized into three groups: concerns with consumer engagement, regulatory issues, and technical problems with the control and protection system. [11][12][13] Technical obstacles include issues with main utility grid operation and control, load frequency management, fault detection and isolation of faults, while regulation concerns pertain to regulation laws, the legality of microgrids, and engagement between microgrid enterprises and customers. To deal with protection issues and operation constraints with the renewable integration, several technical and financial issues with the integration of renewables can be addressed by using electricity storage as a key component of the solution. Storage is widely used to balance renewable energy generation and energy demand, and it provides some independence from the main power grid. The remaining sections are arranged as follows:

Section 1 Discuses architecture of microgrid in brief and the storage types available and currently being used

Section 2 Functions of energy storage is discussed in brief.

Section 3 Presents techno-commercial comparative study of ESS for grid integration

Section 4 Discussion of Cost Components and Performance Metrics of storage systems

Section 5 Discussion of Economic advantages of energy storage systems

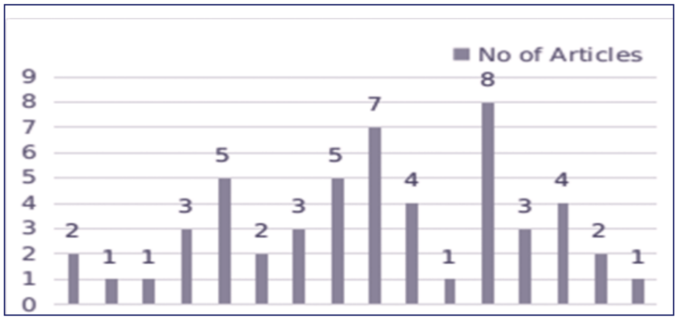
Section 6 conclusion of the study is presented in this section.

1. MICROGRID AND STORAGE

1.1 Architectural Model of Microgrid

A microgrid is a collection of interconnected loads and dispersed energy sources that operates as a single, controllable entity in relation to the grid and is contained within well-defined electrical boundaries. A microgrid can function in both grid-connected and island mode by connecting to and disconnecting from the grid. [14]. A simple microgrid can be seen in fig. 2 where renewable energy sources are connected along with base load plant with the main grid

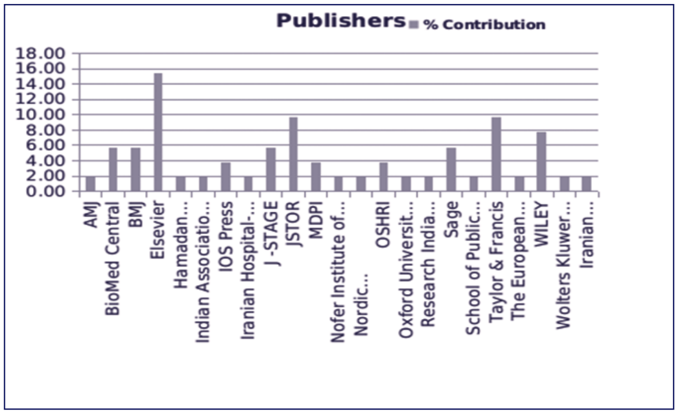
Fig. 2: Architecture of a microgrid



1.2 Storage :

Energy storage systems can be found in almost all kinds of energy, namely mechanical, chemical, and thermal. Fig. 3 gives the classification of these technologies based on their primary source of energy. Literature shows that all of them have been explored, enabling the development of the approaches outlined here. Pumped hydro power plants can be viewed as the oldest storage system .Here excess energy is stored in the form of pumped water. This hydro power is again converted to electrical energy when the energy demand increases. [14] Geographical constraints make the use of this system limited to particular locations only. Compressed air energy storage (CAES) device compresses air into a chamber while charging. This compressed air is used to run the turbines when required. The first CAES system implemented worldwide was the one at Huntorf, in 1978 in Germany, with 220 MW.[15] The revolving kinetic energy of a flywheel is used to store electrical energy. High-capacity flywheels are required in electrical power systems because it uses electrical energy to rotate a rotor at a very high speed for energy storage. Friction losses reduce the efficiency of this system and long term storage is not possible with it. [15]

Fig.3: Energy storage technologies



2. THE FUNCTION OF ENERGY STORAGE IN INTEGRATION OF MICROGRID

Considering that the first half of the 20th century, pumped hydro has been the primary kind of electricity storage utilized to provide a variety of grid services that aid in efficient, dependable, and cost-effective running of power networks. The energy and operational requirements have changed over the past 100 years, as have the technological advancements and the power storage business. Numerous power storage systems have arisen and are now in various phases of development and deployment. These technologies range in price and technical suitability for offering particular services. The improvements in storage technology and decreased storage prices, emergence of liberalized markets for ancillary services and electricity, difficulties of constructing new transmission / distribution networks, the role storage can play in enabling the replacement of peak demand energy generators like gas or diesel with solar and wind energy in off-grid scenarios, are some of the key factors that is encouraging investment in storage systems.[16] ESS technology attributes to the process of energy conversion from one form to storable form and again transform it into electrical energy when needed. Thus Energy storage units function as energy guard or backup to prevent power disparity between the supply and the demand sides.[17]

In accordance with the applications, storage approach can be divided into three categories:

1. Low-power: used in remote locations, primarily to power transducers and emergency connectors

2. Medium-power application: In remote places, (individual electrical systems, and town supply).

3. Application for network connection with peak levelling.

4. Applications for power quality control

The electric grid can benefit from a variety of services that the electricity storage technologies can offer, and they can be positioned according to their performance and price. Pump storage hydropower is the only electricity storage method that has ever been widely used. Unconventional technologies can be used to create storage facilities, such as a electrochemical battery cells, compressed air energy storage,(CAES) superconducting Magnetic Energy Storage (SMES) flywheels. Each technology has unique performance characteristics that make it more or less appropriate for different grid applications and particular grid services.

With the growth of the electricity market, the use of renewable energy sources, and the expansion of regulatory interventions, it is expected that non-traditional storage facilities will play an increasingly important role in addition to traditional assets of generation, transmission, and distribution.

The possible applications of the ESS are as under:-[18][19][20]

a) There is now more renewable energy on the grid as a result of the government's numerous policy initiatives to promote renewable power. By regulating the intermittent nature of the generation, the ESS can increase the value of renewable energy and increase the reliability of the distribution of power produced by wind and solar technologies.

b) The ESS has been utilized to lower peak demand in the worldwide context. Currently, the expensive generation is being deployed to satisfy the peak demand. By adjusting the supply of output from economically generated sources during peak periods, the ESS can be used to address concerns with peak demand.

c) Storage could improve the power system's dependability to keep the frequency at 50 Hz. For automatic frequency control, large flywheel installations in conjunction with frequency-linked automatic control systems may be helpful. A substitute for spinning reserves or ancillary support services could be storage.

d) Storage could be used to reduce greenhouse gas emissions caused by wasteful excess capacity and increase the efficiency of the power system by storing excess generation over and above that required for 50.00 Hz frequency. Energy storage can lessen the need for significant expansion of new transmission grid. Distributed storage can also lessen line loss and congestion by transporting electricity during off-peak hours, which eliminates the need for overall peak-hour generating. Storage can increase the lifespan of current infrastructure by lowering the peak loading (and overloading) of transmission lines.

f) When preparing for emergencies, energy storage might be crucial in black start operations that strengthen the performance of the power system.

2.1 Grid Level Applications of Energy Storage System [18][19][20][21]

Generation Optimization

A storage facility may be used, for example, to switch the output of a generator from one time period to another. The distribution licensees and generating firms may decide to change demand or consumption.

By rerouting off-peak production to more lucrative peak times, generating enterprises can increase the market value of their energy. To efficiently meet customer demand for electricity, storage facility can be adjusted to generator output in response to the load curve.

Controlling Intermittent Generation from Renewable Sources: A storage facility may also be used to commit to providing electricity to customers for a longer length of time by storing generation output from intermittent renewable energy sources. Storage facilities could be used by the generating firms and distribution licensees to maximize the utilization of renewable output.

The distribution licensee could employ a storage facility to store excess renewable energy production to meet consumer demand for electricity. By scheduling the power discharge to the specified period storage facilities can be used to supply the electricity on a solid commitment basis.

Reliable Operation of Power System Operation: A storage facility may also be used to sustain the flow of electricity through a tie-line by storing generation output. To reduce transmission system congestion and ensure the transmission system operates reliably, tie-line flow control is crucial. By controlling unscheduled interchange transfers within the legal bounds, area control error is also maintained.

Minimize the aberration from schedule dispatch: The penalty for going off schedule is severe, especially when it interferes with grid operation. Grid entities now have to account for new unscheduled interchange fees and volume restrictions. The generating businesses or distribution licensees could use storage facilities for efficient and well-managed exchanges with the grid in order to decrease the departure from schedule.

3 TECHNO-COMMERCIAL COMPARISON OF DIFFERENT STORAGE TECHNOLOGIES

In spite of developments in technology storage of electrical energy in large scale is difficult. Electrical energy needs to be stored in several ways, including chemical, thermal, mechanical, gravitational, adiabatic, magnetic, and others. The power and energy density, life cycle, ramp rate, etc. of an energy storage system can be used to classify it. Today, BESS is the most famous ESS worldwide which can satisfy most of the requirements of the power system. It is an electrochemical energy storage system that produces or absorbs electrical power by chemical reaction. Electrical energy is converted from chemical energy and vice versa by an electrochemical reaction. [22][23] The systems can store and release electricity by charging and discharging cycles. The system is free of harmful emission or noise and requires less maintenance several stacks make up each battery. A number of BESSs should be connected in parallel and series in order to attain high power and energy density. There are various types of BESS, including lithium-ion, lead-acid, nickel, sodium-sulfur, and metal-air batteries etc. table 1 shows technical and commercial comparison of large scale storage systems, [24][25] ,some vital parameters for the selection of BESS like C-Rate max and min, DOD, and efficiency is considered under technical category. Whereas commercial aspects like storage Capacity, Energy and power density, life and maturity of technology is considered under commercial category

3.1 Comparison of Energy Storage Technologies: This section compares and analyses energy storage systems from technical and business standpoint for electrochemical batteries, a comparable review has been conducted and are represented in tabular form as shown in table 2. [24][25][26][27][28][29][30] Based on the available of information the most pertinent technical features are chosen, such as energy and power density, efficiency, lifetime, dispatch duration, self-discharge, and technology maturity level etc are selected for comparison. Observations from the available data are summarized below. Energy and Power Density: It is observed that electrochemical batteries have higher energy density than other storage systems. The power density of Flywheel System, and SMES, is higher. Among electrochemical energy storage, Lithium-ion, Na-S, and NaNiCl2 batteries have higher energy density than other types of batteries. The comparison is shown graphically in Figure 1 shows that PHS has lower power and energy density whereas it has highest power range. SMES and SCES has lower energy density but higher power density.

Power Rating: It is found that, PHS, CAES and electrochemical battery are available with higher power range and discharge time.

Self-Discharge Time: In comparison to other types of ESS, PHS, CAES, and VRFB have a very low daily self-discharge ratio. Na-S and NaNiCl2 electrochemical energy storage systems have a high rate of daily self-discharge. Like SMES and SCES, electrical energy storage systems have high daily self-discharge rates.

Graph 1: Technical Comparison of different storage technologies

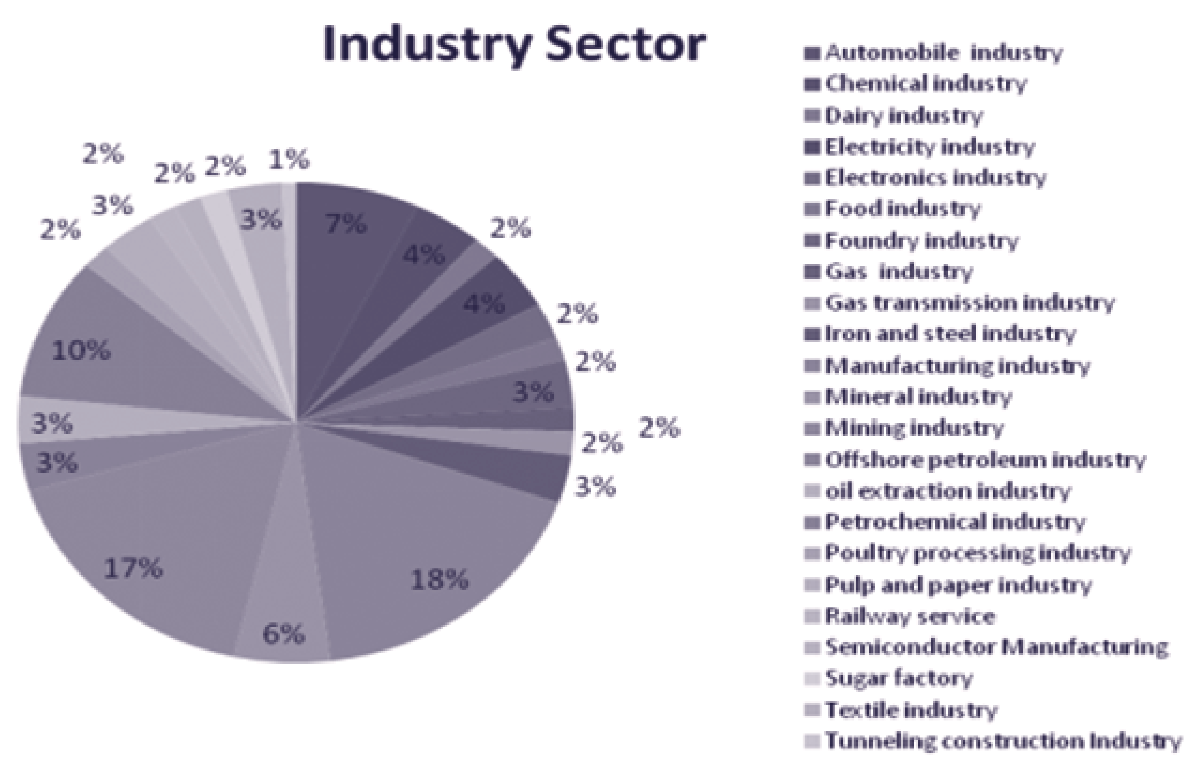


Table 1” Technical and commercial comparison of storage technologies

Technology	Technical							commercial									
	Efficiency	Response Time	C-rate min	C-rate max	DOD%	Max. operating temperature	Safety (Thermal stability)	Storage Capacity($ /kWh)	Development & construction (years)	Operating Cost ($/kWh)	Energy Density (Wh/L)	Power Density (W/L)	Discharge Duration	Power Rating (MW)	Lifetime (years)	Life (full cycles)	*Maturity of Technology*
Lead-acid	81	<1/4 cycle	C/10	2C	50	50	High	226	0.25	3	75	355	1min -8hours	<50	03-Dec	500	M
Nickel cadmium	60-70	NA	C/10	C/1	90	50	High	470-823		7.5	50-150		1min -8hours	<50	15-20	1000-5000	
NaS	81	NA	C/8	C/6	100	NA	Medium	436	0.5	8	220	140	<8h	<350	5	5000	C
VRB	72	NA	C/8	C/4	100	50	High	268	1	11	42.5	2	<10h	<3	10	10000	EC
ZBB	72	<1/4 cycle	C/8	C/4	100	50	Medium	696	1	15	45	13	<4h	<1		4000	EC
Flywheels	85	<1 cycle	1C	4C	85	NA	NA	2656	1	80	110	7500	3-120s	<1.65	20	>100000	EC
Pumped hydro	80	In minutes	C/20	C/6	90	NA	NA	21	5	2	1	NA	4-12 h	100-4000	30-50	20000	M
CAES	64	In minutes	C/10	C/4	40	NA	NA	48	3	1	4	NA	6-20 h	100-300	30	20000	C

Table 2 : Comparison of electrochemical batteries used for energy storage

specification	Type of battery					
	Lead acid	NiCd	NiMH	Li-ion		
				Cobalt	Manganese	Phosphate
Specific Energy Density(Wh/kg)	30-50	45-80	60-120	150-190	100-135	90-120
Peak Load Current Best Result	5C 0.2C	20C 1C	5C 0.5C	>3C <1C	>30C <10C	>30C <10C
Charge time	8-16h	1h typical	2-4h	2-4h	1h or less	1h or less
Cell Voltage	2V	1.2V	1.2V	3.6V	3.8V	3.3V
Internal Resistance (mΩ)	<100 12 V pack	100-200 6V pack	200-300 6V pack	150-300 7.2V	25-75 Per cell	25-50 Per cell
Overcharge Tolerance	High	Moderate	Low	Low. Cannot tolerate trickle charge		
Self-Discharge/month (room temp)	5%	20%	30%	<10%		
Life Cycle with 80% discharge)	200-300	1000	300-500	500-1000	500-1000	1000-2000
Charge Cutoff Voltage (V/cell)	2.40 Float 2.25	Full charge detection by voltage signature		4.20		3.60
Discharge Cutoff Voltage (V/cell, 1C)	1.75	1.00		2.50-3.00		2.80
Charge Temperature	-20 to 50°C	0 to 45°C	0 to 45°C			
Discharge Temperature	-20 to 50°C	-20 to 65°C		-20 to 60°C		
Maintenance Requirement	3-6 Months (topping charge)	30-60 days (discharge)	60-90 days (discharge)	Not required		
Safety Requirements	Thermally stable	Thermally stable, fuse protection common		Protection circuit mandatory		
In Use Since	Late 1800s	1950	1990	1991	1996	1999
Toxicity	Very High	Very High	Low	Low		

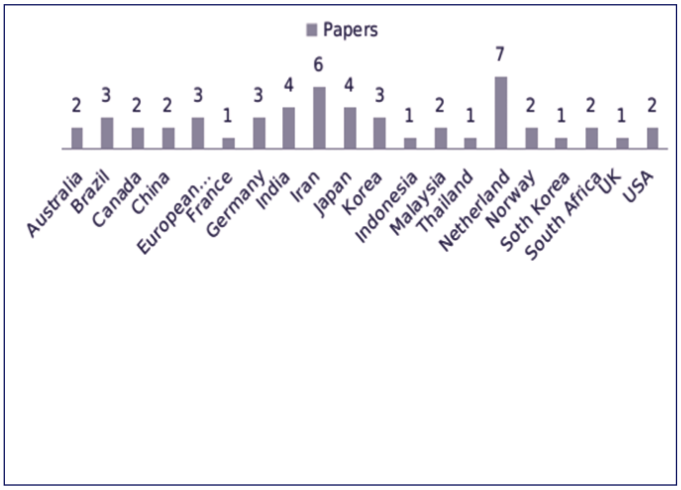
Life span: Electrochemical energy storage devices have a lifespan of between 7.5 and 15 years, whereas PHS has the longest life of 50 years.

Technological Maturity: When compared to other ESS, electrochemical batteries like lead-acid and Ni-Cd batteries, PHS, are the most mature and commercialized technologies.

Conversely, commercializing technologies include, Li-ion, Na-S, NaNiCl2, SMES, CAES and FES.

Round-Trip Efficiency : The highest cycle efficiency among ESS is found in, Li-ion SMES, SCES and FES, which all have cycle efficiencies above 90%.Figure 2 shows the comparison of all technologies and their round trip efficiency. The characteristics of batteries and other energy storage technologies discussed above help to define the suitability of those technologies for certain grid-connected applications.

Graph 2: RTE of different storage technologies



3.2 Technical Role and Functions Of Energy Storage Systems

Storage system plays an important role in many grid parameters. Research has been done to study and evaluate the performance of grid for different applications.

1. Voltage Support to the Grid: This refers to the power provided to the electrical distribution grid so that the grid voltage is maintained within the acceptable range. This entails maintaining the frequencies while staying under the acceptable tolerance for up to 30 minutes.

2. Grid frequency support: Grid Frequency Support refers to the provision of active power to the distribution grid in order to minimize any abrupt, significant load generating mismatch and maintain grid power over a given period of time that has not been committed yet to energy generation during this period. [49]

3. Transient stability: Grid Transient Stability is the process of injecting and absorbing real power to lessen power fluctuations.[49]

4. Load levelling: Load levelling is the practice of rescheduling specific loads in order to reduce the demand for electricity, or the generation of energy during off-peak hours for storage and usage during peak hours. Peak shaving is the process of curtailing or shifting electric usage from peak demand to off-peak hours.

Power quality improvement: Change in shape and magnitude of voltage and current gives rise to different issues like harmonics, transients, swag and swell flicker, power factor etc. These issues can be handled successfully with the help of ESS.

Unbalanced load compensation: Unbalanced loads can be compensated for by injecting or absorbing power separately at each phase.

4. COST COMPONENTS AND PERFORMANCE METRICS OF STORAGE SYSTEMS[18][50][51][52][53][54]

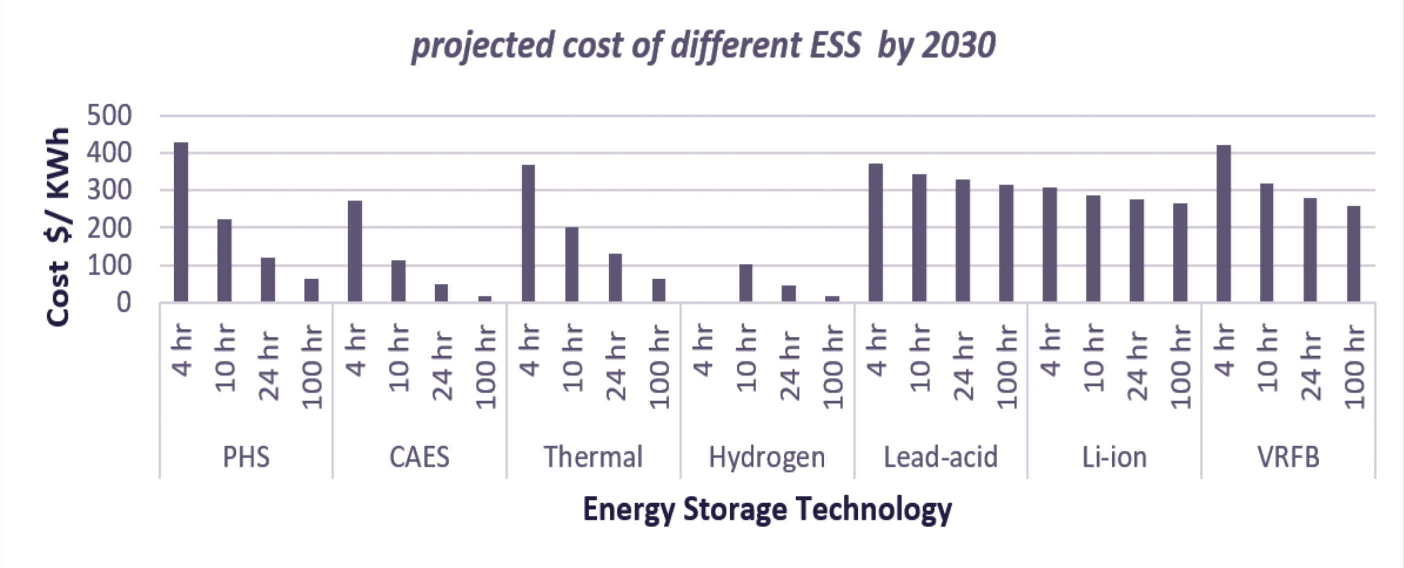
Grid-scale energy storage paves the way for a wide range of storage technologies to compete for the opportunity to offer both established and new grid flexibility services. Examining the various technologies and fairly comparing their costs and performances becomes more crucial as the grid storage sector continues to expand and evolve. Information of various components affecting cost of ESS can be broken into different categories like

1. Capital cost of ESS
2. Operation and Maintenance cost of ESS
3. Decommissioning cost

These parameters must be defined effectively to avoid any misunderstanding while estimating the system cost.

Cost of storage systems depends on factors like, power capacity and time duration for which it is designed to operate. Cost comparison of ESS for 100 MW power capacity in 2030 with different dispatch duration is shown in the graph Figure 3. It can be seen that cost of ESS is lesser if it is designed to operate for longer duration.

Graph 3: Cost of storage technology for different discharge hours



Capital Cost of ESS

Parameters affecting the capital cost of storage systems can be categorized as follows

Storage Block– Cost of battery module, battery management system and rack, is included in this component.

Power Equipment– Cost For power conversion equipment's, and software is considered here.

Storage - Balance of System– Cost of supporting components for the Storage Block with container, flow battery pumps, switchgear, and heating, ventilation, cabling, and air conditioning is included in this component.

Storage System– This cost is the sum of the Storage Block and Storage Balance of System costs is the right degree of detail for some investigations.

Communication & Controls– The cost of energy management system responsible for ESS operation is included here

System Integration - This price includes the system integrator's fee for integrating the BESS's component parts into a single functional system.

Engineering, Procurement, and Construction - includes the shipping, siting, installation, and commissioning of the ESS, as well as one- time charges for engineering and construction tools. Based on the E/P ratio, this expense is weighted.

Project Development– costs related to various permits required, like, power purchase agreements, site control, interconnection agreements, and financing are considered in this component.

Grid Integration– Costs directly related to equipment used in integrating ESS to grid, such as transformer, metering, and isolation breakers.

Fixed Operations & Maintenance cost

This comprises all the costs that are necessary to maintain the storage system's functionality over the course of its economic life and are not affected by energy throughput, planned maintenance, components, labor, and employee benefits. Additionally, substantial overhaul-related maintenance that depends on throughput is included in this.

Basic Variable O&M– includes usage-related expenses for non-fuel consumables required to run the system for the span of its useful life

Losses due to RTE– The percentage of energy sent to the grid and received from the grid to get the ESS to the same level of charge is known as round trip efficiency. Different losses like thermal management, electrochemistry, power conversion, energy conversion, powertrain-related losses, evaporation, or gas/air leakage, reduce RTE to less than 1. The price of additional fuel or electricity needed for every kWh of energy lost as a result of those losses indicated is used to determine this value for RTE losses.

iii) Warranty and Insurance– Fees paid for manufacturability and performance assurance of the components for designated lifetime is included in expenditure towards warranty. Whereas insurance fees is paid to cover unpredicted risks occurring in the system

Decommissioning Costs ($/kw)

This cost includes the cost for disassembly, site recovery, Disconnection and recycling of the parts at the time of decommissioning the system

Performance Metrics

Response Time - The response is time taken by system to go from no discharge to full discharge, and from no charge to fully charged

Round Trip Efficiency (%) – It is the percentage of electricity put into storage that is later retrieved. Less energy is lost in the storage process if RTE is high

Ramp Rate - Ramp rate is how quickly the output can be changed. It is calculated in watts /min. It is important to mitigate the power fluctuations of grid.

Calendar Life (years) – Performance of the batteries deteriorate with time irrespective of their usage. Calendar life is the time elapsed before the battery becomes unusable. For electrochemical batteries, calendar life bank on the SoC of battery and ambient temperature.

Cycle Life – The cycle life for an ESS is the number of charging and discharging cycles it can perform before it becomes useless. It gets affected by DoD of battery.

5. ADVANTAGES AND CHALLENGES IN DEPLOYMENT OF ENERGY STORAGE SYSTEMS

5.1 Advantages

Reliability Analysis of a power system has become very essential in power sector for both utility grid and consumer as demand of reliable power supply has increased. Battery storage system (BSS) can be seen as an effective solution for enhancing the reliability of the existing system and reducing the energy cost and annualized cost of the system [9][10][11][18]

Some of the benefits of ESS are discussed below.

Arbitrage: Arbitrage entails buying cheap electricity during times of lesser demand to charge the storage facility, then using or selling the cheap energy in future when the price of electricity is high. Furkan Ahmad et.al has introduced a model of reputation score to market partakers. Using proper algorithms a profitable approach can be used for surplus/deficit energy trading by switching from one marketplace to another. He concludes that using bilateral trading profit can be increased up to 9.25% [10][11]

Increase in Central Generation Capacity Revenue: In the areas where electricity generation is less, ESS can eliminate the need to install new Generation and "Hire" generation capacity from electricity market

Increase in Revenue with ancillary services: Energy storage yields various ancillary services. Some of these are load following and spinning reserve.

Transmission and Distribution deferral: Congestion on T &D networks is an important problems encountered by system operators while ensuring system security and reliability. With high penetration of RE risk of congestion in T & D increases and threaten the reliability of the system because of the intermittent nature of the renewable resources. A solution to address some of the challenges introduced by RE integration to T&D systems is energy storage. Along with congestion management ESS contributes in voltage regulation, reactive power control, and can increase the distribution feeders' hosting capacity, thus saving the expenses on distribution equipment

Peaking plant capital saving: For a secure and reliable power system, generation and demand should match all time. Enough generation capacity to meet future increase in demand has to be ensured. ESS can effectively replace the peaking plants. Proper scheduling of ESS will help in meeting demand in short time. Renewable energy sources and storage in combination can increase savings by reducing peaking plant investment. For instance, Florida Power & Light will develop a 409 MW/900 MWh battery by 2021 to replace two natural gas facilities [1]

Decreased Reliability-associated Economical Losses: Storage mitigates economic losses caused by power disruption. This convenience is very consumer-specific and applies to industrial and commercial customers, basically to the particular customer who suffer modest to consequential losses due to power outages. From the researches it has been found that reliability of the power system can be strengthened with the introduction of ESS thus reducing the losses related to it.[1][11]

Reduced Power Quality-related Financial Losses: Research has shown that power quality can be improved with the help of ESS It reduces the losses associated with power quality abnormalities that result in loads being taken offline and/or which can damage the equipment. This adverse effect is overcome with use of storage systems [32]

Increase in Rewards from Renewable Energy Sources: Energy Storage system can store energy generated by renewable energy sources during low demand period and sell it during peak energy demand period. This time shifting of storage system can increase revenue from renewable energy sources. This also reduces the negative effect of intermittency shown by these sources.[50]

Increase in Rewards from Renewable Energy Sources: Energy Storage system can store energy generated by renewable energy sources during low demand period and sell it during peak energy demand period. This time shifting of storage system can increase revenue from renewable energy sources. This also reduces the negative effect of intermittency shown by these sources.

Challenges in the deployment of ESS:[56][57][58]

Energy storage solutions with low costs: Extensive engineering research and development will be needed to create novel storage concepts and the materials that will be used in them in order to reduce costs. The cost also includes elements like operational uncertainty management, early deployment uncertainty control, technological risk mitigation, etc. The cost of storage technology is anticipated to decrease as a result of advanced international research.

Environmental issues related to storage technologies: Although storage technologies do not release greenhouse gases into the atmosphere, they do utilize chemicals. The regular replacement of this chemical will be necessary due to the extended battery life cycle. Concerns for the environment may arise during this chemical's disposal. There are currently no policies in place to handle the environmental issues brought on by the deployment of storage facilities.

Regulation of storage technologies: There isn't currently a policy or regulatory framework in place in the nation. There is currently no legislative or regulatory framework in place in the nation because grid storage implementation and acceptance are still in their infancy. A framework for policy would be required if the industry accepted it. However, it is obvious that storage solutions are needed in areas like frequency regulation, renewable energy, generation shift, etc. Lack of well-defined policies and regulatory framework may hinder investment in the power sector.

Battery storage technology safety considerations: Facilities for storing electro chemicals may be dangerous from a number of angles, so they must be handled with particular safety precautions. Grid-based storage technology costs and business plans will be influenced by safety standards. The adoption of big storage systems in metropolitan areas or close to other grid resources, such substations, will be hindered by safety concerns, which are also a worry. In order to properly deploy the various storage systems, safety standards and procedures must be devised.

Stakeholder's Acceptance of technology and cost: The adoption of stakeholders is essential for the deployment of storage technologies. The planning criteria for the current situation do not call for the deployment of grid level storage facilities. Awareness about deployment and functioning of storage technologies integrated with grid will enhance the interest of stakeholders. They may become more interested in and willing to invest in and use storage solutions. Pilot-based projects can be used to increase stakeholder confidence by providing them with real-world storage experience.

6. CONCLUSION

The assessment of available energy storage methods that are suitable for electrical power systems is the major component of this review. With the proliferation of decentralized and renewable energy sources which enter electricity grids, storage is a significant problem.

According to the findings of this study and a comprehensive assessment of the stakes, we discover that:

By preventing load shedding during periods of excess production, it serves as both a technological answer for network management and a way to better utilize renewable resources.

Decentralized storage, when combined with local renewable energy production, could increase the stability of the power network by feeding a particular demand zone through a energy farm network.

There are numerous options for enhancing system security, but it is challenging to compare them because of their vastly varying requirements. To help enhance the efficacy and expenses projections for storage systems, we made an effort to identify and compare the group of technical and economic features.

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