# Central Electricity Regulatory Commission

## New Delhi

Staff Paper

on

Introduction of Electricity Storage System in India

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# Index

## Introduction

1.1 The electrical generators connected to the grid and supplying electricity are categorised based on their operating cost/ pattern of base load, peak load and intermediate load. The electricity demand fluctuates throughout the day. The hydroelectric generating stations with un-priced fuel are traditionally used to meet the peak load or intermediate load; however, most of the time, it is not adequate to meet the gap of peak demand. The peaking generating stations[1], with high variable cost, are intended to bridge the gap between peak and base load. These generating stations are capable to start and stop quickly and operate when high ramping rate is required . The precise balancing of electricity demand and generation is achieved by adjusting output of generating stations such as hydroelectric and gas based generating stations. These generating stations are also called as load following generating stations. The use of gas based generating stations for balancing purpose is uneconomical as it increases the power purchase cost of distribution licensees due to higher price of natural gas in India.

1.2 The increasing share of renewable generations in the grid has impacted the traditional approach of balancing. The renewable sources with un-priced

[1] ***Gas based generating plants are considered as peaking plants in this paper, provides quick start and stop, to meet the demand variation. These stations are uneconomical due to high gas price compared to coal.***

fuel such as Wind, Solar Power are intermittent in nature, that is, their output depends on external conditions, such as sunshine or wind. The value and timing of their output are not controllable. The variability of renewable generation is to be taken into account while adjusting output of load following generating stations for the purpose of balancing. One of the approaches to address the variability of renewable generation is capacity addition of conventional load following generating stations such as hydro electric plants and gas based plants. The use of load following generating stations is not limited to variation of load, but its use is now extended to counter the variability of renewable generation. The higher penetration of renewable generation will require higher capacity of load following generating stations. The balancing through the conventional load following generating stations such as hydroelectric plant and gas based thermal plant would not be adequate. Alternatively, the renewable generation dominated states use coal based thermal generating stations to counter balance the variability of the renewable generation. However, regulating generation output[2] of coal based thermal generation plants, to address the variability of renewable generation is not recommended based on number of consideration including uneconomical cost and challenges involved in practical implementation.

[2]*Generation output refers the ex-bus generation of the grid connected conventional generating station which is being regulated for balancing the variability of renewable generation*.

1.3 The decentralized market structure provides individual market entities to be more responsive in complying with grid discipline rules of balancing their generation and demand. The Commission has mandated volume limits on over-drawal and under-drawal of electricity by any beneficiary or a buyer and under-injection or over-injection of electricity by a generating station or a seller in order to maintain grid frequency between 49.95 Hz and 50.05 Hz. Load serving entities are severely affected due to these grid discipline rules because of variation of flow over the periphery on account of uncontrolled fluctuation of load. Further, the intermittent nature of renewable generation within the periphery of load serving entities will further contribute to variation of power flow over the periphery.

1.4 In the coming decade, the need for modernizing the grid will help the nation to meet the challenge of handling projected energy needs as well as increasing energy from renewable sources while maintaining a robust and resilient electricity delivery system. These challenges warrant a specific energy storage solution to cater to peak demand and to address the variability of intermittent generation. In this context, need is felt for specific Electricity Storage System ("the ESS") that would provide economically feasible Electricity Storage Services to address these challenges. Energy storage can play a significant role in meeting these challenges by improving the operating capabilities of the grid, lowering power purchase cost and ensuring high reliability by maintaining unscheduled interchange as well as deferring and reducing infrastructure investments in new projects. The ESS has a wide range of applications which can be deployed from consumer level, connected to distribution system, to bulk storage system connected to the grid. The ESS in India has long term economic significance. The ESS has a potential to improve industry economics because it connects diverse energy sources to diverse energy uses. It enables some portion of one time's consumptive load to be met from another time's primary generation.

1.5 The most common form of grid energy storage in the India is pump-storage hydroelectricity, in which electrical energy is converted to gravitational potential energy, which is subsequently converted back to electricity by running the water down through a turbine. Pump-storage hydroelectric plants represent about 6.80 GW capacity (under operation and construction) storage capacity and is one of the mature technologies for the bulk electricity storage, However, it's yet to carve a niche for itself in the overall basket of about 309 GW installed capacity as on date in the country. Therefore relying only on the traditional approach for storing electricity through a pump-storage hydroelectric plant would not be adequate and thus, unconventional bulk electricity storage system (ESS) would be required.

1.6 The bulk ESS is specifically useful to address controlling of renewable generation. In India, Renewable potential is concentrated in a few States such as Tamil Nadu, Rajasthan, Gujarat etc. In these States, further growth of renewable generation has been limited due to intermittent nature of these sources. The renewable dominated States are facing specific challenges for maintaining reliability. The ESS can play a vital role in addressing these challenges in renewable dominated States. The application of the ESS is envisaged for the renewable dominated States for time shifting of the renewable generation, optimal utilization of the available generation, shifting of generation at the time when it is required and utilization of the renewable generator for longer period.

1.7 Although, the ESS may initially have various challenges including cost/ commercial reasons, but in the long run, cost of the ESS is expected to decrease due to technological innovations. In this context, it is to be noted that the State of California, USA enacted a Law[3] in October, 2010 requiring the California Public Utilities Commission (CPUC) to establish appropriate energy storage procurement targets for California load serving entities for 2015 and 2020, if cost effective and commercially viable by October, 2013. In June 2013, the CPUC proposed storage procurement targets and mechanisms totaling 1,325 MW of storage which indicates the possible viability in storage technologies. Also to be noted is the Enhanced Frequency Auction results (200 MW of frequency response capacity) starting as early as April 2017 in National

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[3] ***California Governor signed a landmark legislation (first laws on energy storage systems in USA) designed to increase the use of large-scale energy storage systems. Under the bill, AB 2514, utilities will have targets to procure grid-connected energy storage systems as soon as 2015. This bill requires the California Public Utilities Commission ("CPUC") to open a proceeding by March 1, 2012 to determine appropriate investor-owned utility procurement targets for viable and cost effective energy storage systems to be achieved by December 15, 2015 and December 15, 2020. The CPUC is required to adopt the procurement targets by October 1, 2013.***

Grid of UK has provided necessary impetus in recognising Storage system's potential.(Source: Energy storage in the UK - An overview, 2nd edition, REA publication). On 12th May 2016, the Energy Market Authority (EMA) and Singapore Power (SP) have jointly announced the launch of a Request for Proposal (RFP) to implement a utility-scale Energy Storage System (ESS) Test-bed projected to be of 6 MW capacity with a view to evaluate the performance of different technologies such as lithium ion, flywheels and redox flow batteries taking into consideration Singapore's hot and humid climate and highly urbanised environment. This will enable them establish the standards and guidelines associated with deployment of ESS. This will also enable them prepare policy and regulation framework required to facilitate the introduction of ESS in their electricity market. With the penetration of variable generation expected to increase from its existing level as per the target set by the Government of India the necessity of the ESS in the Indian grid cannot be obviated. In fact , Ministry of New and Renewable Energy (‘MNRE”) has already come out with tender/s considering the renewable generator with ESS for inviting tariff based bid for renewable projects.

1.8 It is envisaged that the ESS can address issues with the shifting of generation, regulating dispatch of electricity, maintaining flow control in transmission system and strengthening reliability of the power system without adding capacity from the traditional and variable sources of power. The possible applications of the ESS are as under:-

a) Various policy interventions of the Government to encourage renewable generation has resulted in penetration of renewable energy on the grid. The ESS can enhance the reliability of delivery of power generated from wind and solar technologies by controlling the intermittent nature of the generation and in effect, increasing the value of renewable power;

b) In the global scenario, the ESS has been used for reducing peak demand. Today, to meet the peak demand, the costly generation is being dispatched. The ESS can be deployed to address the issues of peak demand by shifting delivery of economical generation output during peak period;

c) Storage could address reliability of power system for ensuring frequency at 50.00 Hz. Large flywheel installations combining with frequency linked automatic control system could be useful for automatic controlling of frequency. Storage could be an alternative method of providing spinning reserves or ancillary support services.

d) Storage could be used to improve the efficiency of power system through storage of excess generation over and above required generation for 50.00 Hz frequency and reduce greenhouse gas emissions caused by wasteful excess capacity;

e) Energy storage can reduce the need for major augmentation of new transmission grid. Additionally, distributed storage can reduce line-congestion and line-loss by moving electricity at off-peak times, reducing the need for overall generation during peak times. By reducing peak loading (and overloading) of transmission lines, storage can extend the life of existing infrastructure;

f) Energy storage can play an important role in black start operation during emergency preparedness which provides robustness to the power system operation.

1.9 At present, there are various uncertainties on practical use of storage technology, performance of new storage technologies in the Indian environment, its applications and the governing market rules for operating storage technologies in the grid. These uncertainties may inhibit the interest and acceptance in storage technologies for investment and utilization by the stakeholders.

1.10 This paper is intended to generate discussion among the stakeholders about storage technologies and to know the users perceptions about the various issues on deployment and operations of grid level storage technologies. We believe that well established policy and regulatory framework for the ESS at this infancy stage may channelize the investment in this segment of the power sector. This paper covers the probable uses of storage technologies, probable operational framework, tariff and other related aspects.

## 2. Overview of Storage Technology:

2.1 The electricity storage technologies can provide a range of services to the electric grid and can be positioned based on their cost and performance. The only electricity storage technology that has been traditionally adopted is pump-storage hydropower. The pump-storage hydropower stations were generally built prior to the enactment of Electricity Act, 2003. The storage services by pump-storage hydropower were recognized as a part of the generation obligation. The list of hydropower project having pump-storage facility is given in **Appendix A**.

2.2 Storage facilities can be designed with non-traditional technologies such as large number of Electrochemical Battery Cells, Flywheels and Compressed Air Energy Storage (CAES). The technology of Superconducting Magnetic Energy Storage (SMES) is useful for low discharge capacity. Each technology has its own performance characteristics that makes it optimally suitable for certain grid services and less so for other grid applications. The developed countries have set up a pilot projects of the ESS based on these technologies. In India, at present, there is no project based on non-traditional storage technologies. However, the role of non-traditional storage facility along with traditional assets of generation, transmission and distribution would be expected to increase with the development of electricity market, renewable generation and increasing regulatory interventions.

2.3 The generic technical parameters about various storage technologies based on the form in which the electricity is stored before converting into electricity, is given in following table:

Table-2

| Type of Storage | Net Energy Yield | Discharge Capacity | Range of Capacity |
|---|---|---|---|
| Pumped Storage | 75-80% | 6-10 hours | 250-1000 MW |
| Electrochemical Battery Cell | 60-75% | 4-5 hours | 100-200 MW |
| Flywheel | 80-90% | ¼ hours | 10-20 MW |
| Compressed Air (u/g[4]) | 73-80% | 8-20 hours | 0-180 MW |

The cost and performance characteristic of Electrochemical battery cells varies depending on the type of chemical used in it. The different types of chemical batteries are given below:

Table-3[5]

| Sr No | Type of Chemical Battery |
|---|---|
| 1 | Sodium-Sulfur battery storage |
| 2 | Sodium-Nickel-Chloride Batteries |
| 3 | Vanadium Redox Batteries |

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[4] ***This refers the underground compressed air technology.***

[5] ***Source of data in Table-2 & 3 : EPRI Report " DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA" from www.epri.org***

| | |
|---|---|
| 4 | Iron-Chromium Batteries |
| 5 | Zinc-bromine Batteries |
| 6 | Zinc-air Batteries |
| 7 | Lead-acid Batteries |

## 3. Grid Level Applications of Electricity Storage System:-

**3.1 Optimization of Generation:** One of the possible uses of a storage facility is to shift generation output from one period to another. The generating companies and distribution licensees could opt to shift demand or consumption. Generating companies could use storage facility to enhance the market value of its generation by shifting off-peak generation to more lucrative peak periods. Distribution licensees could use the storage facility to shift generation output following load curve to effectively serve the electricity requirements of consumers.

**3.2 Controlling Intermittent Generation from Renewable Sources:** Another possible use of a storage facility is to store generation output from renewable sources of intermittent nature for commitment of serving the electricity to the buyers over a longer period. The generating companies and distribution licensees could use storage facility to optimize use of renewable generation. The generation companies could use storage facility to supply the electricity on firm commitment basis by shifting renewable generation to the period agreed in contract. The distribution licensee could use storage facility for storage of surplus renewable generation output to serve the electricity requirements of consumers.

**3.3 Reliable Operation of Power System Operation:** Further possible use of a storage facility is to store generation output for maintaining flow of power over tie-line. The flow control of tie-line is important to address the congestion in the transmission system and for reliable operation of the transmission system. It also helps to maintain area control error by managing unscheduled interchange transfer within the regulatory limit;

**3.4 Minimize the deviation from schedule dispatch or drawl:** The deviation from schedule has been regulated through CERC (Deviation Settlement and other related matters) Regulations, 2014. The deviation from schedule attract huge penalty particularly the deviation which is detrimental to the grid operation. The introduction of additional unscheduled interchange charges and volume limits has made grid entities more accountable. In order to reduce the deviation from schedule, the generating companies or distribution licensees could use storage facilities for effective and well controlled exchanges with the grid.

**3.5 Storage of Excess Generation of Grid:** The standard frequency of electrical system is 50.00 Hz which can be achieved at equilibrium level of load (including network losses and auxiliary consumptions) and generation in the grid. The average frequency of more than 50.20 Hz has been observed during number of blocks. If frequency of power system would sustain at 50.20 Hz (0.20

HZ higher) for two hours in a day, there will be wastage of natural resources in terms coal and natural gas. Thus ESS could be used to arrest the high frequency operation above standard frequency and contribute for optimal utilization of the national resources of country.

**3.6 Ancillary Service:** The storage service will be useful for providing the regulation service to the system operator at the rates of ancillary service decided by the Commission.

## 4. Potential Owners of Electricity Storage Facilities:

**4.1 Transmission licensees:** The transmission licensees may own the storage facility as a facilitator and provides storage services as supplemental to the transmission services based on the supplemental service rates. The transmission licensee is not allowed to undertake the business of trading of electricity under the Act. The transmission licensee undertakes wire business involved into the power transmission. These transmission licensees might provide storage service as a facilitator and may own the infrastructure of storage facility without claiming the title of the stored energy.

**4.2 Generating Companies:** Generating companies may own the storage facility and provide bulk sale of power as part of generation obligation or provide storage services to the others. These generating companies may supply the electricity from ESS by bundling it with conventional sources. The generating companies can creates storage facility as part of their generation business. The generation business is a de-licensed business under the Act and hence the storage facility created by the generator would not require a license for such storage facility. The storage facility can be used by the generating companies to meet their generation obligation under the firm contract at the rates agreed under the contract. They may provide storage services to other generators at the rates agreed mutually by them.

**4.3 Distribution Licensees:** The distribution licensees that own distribution system may own a storage facilities to flatten the demand curve or to provide reliability support or sale of power as part of distribution obligation or provide storage services to others. The utilities that own distribution system may own the storage facilities as part of their distribution business. They may provide storage services to other generators at the rates agreed mutually by them.

**4.4 Merchant power plant (including Captive Power Plant):** The merchant power plant may own storage facilities for sale of power in the open market when the market offers attractive prices.

**4.5 Bulk Consumers:** The bulk consumers may install storage facilities at their end-use locations to ensure that their electric-powered uses can continue to run notwithstanding disturbances or outages in the upstream bulk electric system or distribution system. This type of storage facility has strategic importance because it provides them independent power . The end users value power the most and can give storage technology vendors a starting point, from which they can scale up their offerings and achieve lower costs per stored MW or MWh.

## 5. Operational Framework:

In order to ensure well directed investment in the area of electricity storage in the country, it is important to have the business models that fits with the present legal and regulatory framework. The business model of Electricity Storage System can be different based on the consideration of whether the owner of the storage facility can take title to the stored energy or whether the energy stored in the storage facility is legally owned by others. Apart from the ownership, the other relevant aspects are purpose, use of storage facility and its tariff recovery from the users. Prior to discussing the appropriate business model for storage facilities, the relevant aspects involved in multiple ownership and multiple uses have been discussed in subsequent paragraph.

### Multiple Uses

5.1 The business model for storage services will be more complex when there are multiple uses. Under certain circumstances, the storage can act like any of the traditional generation categories, and also like load. When the storage facilities are owned by the transmission line owner, it may be operated as per directions of the system operator and profit may not be a driver in that case. However, when it is owned by the generator, it may be operated on their own to optimize the profit margin. This will be even more challenging when the storage facilities are used in part by generator and transmission owners. Given that storage facilities can be physically capable of providing multiple services, it may be reasonable to contemplate some appropriate sharing mechanism of cost among users.

A transmission licensee may own storage facilities as a facilitator to address issues related to variable or renewable energy resource integration, to relieve congestions and shifting of conventional generation to meet peak demand. The storage facilities could be owned for the purpose of grid operation similar to the capacitor bank owned by the transmission licensee. The capacitor bank is owned and used by the transmission licensee as a compensation device to reactive load and provides support to voltage stability in the transmission grid. The storage facilities may also be owned and used by the transmission licensee as compensation to intermittent generation variation provides support to frequency stability to the grid. Being a transmission service provider, it could use the storage facility as a transmission asset to provide voltage support or as a virtual replacement transmission circuit. On that basis, the transmission provider may seek to recover the asset's costs through transmission charges. The transmission provider also may be able to use the storage facility to firm up output from variable energy resources used to serve retail load. This latter function would be equivalent to shifting variable generation from one period to another in order to maintain deliverability to retail customers, impacting cost recovery under retail rates. If the same storage facility is used to store energy of conventional generator, the recovery of storage costs is to be addressed in this case. As discussed above, the recovery of storage cost would be more complex when the single storage facility is used for multipurpose.

In order to derive a pragmatic and suitable business model for the above the model of natural gas storage facilities has been examined. The natural gas storage facilities are operated by pipeline owner (transporter) and offer open access storage services to customers who contract for that service. The storage facility operator may not buy and sell the gas commodity at that location. Contract storage service is offered as decided by gas regulator or at contract rates for the service of storing customers' gas and only those storage customers buy and sell the gas commodity itself (storage customers hold ''title'' to the gas held in storage). Generally, the customer pays a reservation fee and a storage fee based on usage with take or pay liability (for under scheduling) though this may not always be the case with negotiated rates. Either way, the time arbitrage gains on the stored gas are the profit or loss for the customer, not the gas storage operator. This model has not yet been adopted for electric storage facilities but may provide an attractive alternative business model for some electricity storage operators. In this model, the storage operator would operate and maintain the electricity storage facility at its customers' direction and never take title to the energy stored at the facility. Thus, each storage customer would decide how to use its purchased storage capacity. If similar model is to be considered in the electricity, a transmission licensee would be the owner of storage facilities and needs to sign an agreement with long term electricity customers or the grid operator. This model appears to be simple and practical, however, the only issue is recovery of cost. If customers avail of a storage facilities service, the cost recovery of storage facilities would be difficult.

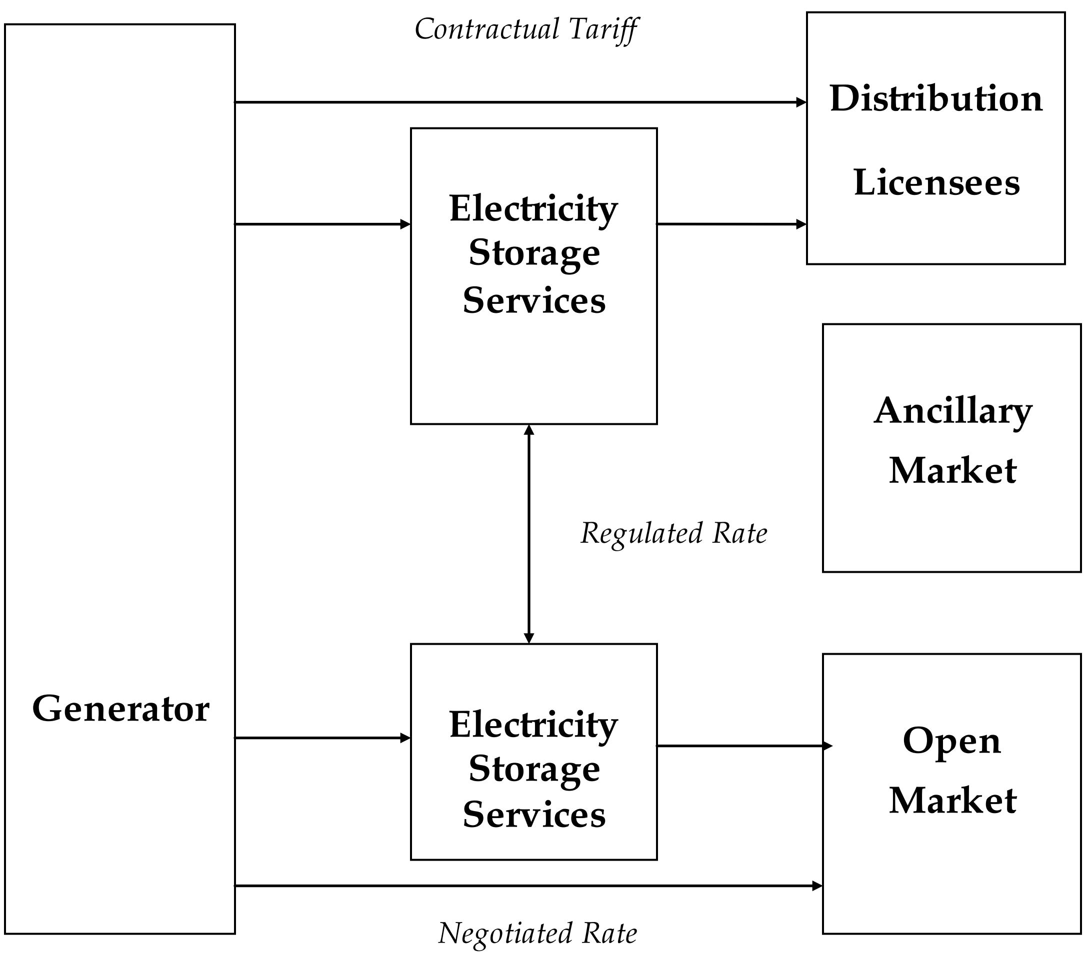
**Multiple Ownership**

5.2 Electricity is a uniform product and it does not differ with the developer or resources unlike goods which when produced by one manufacturer differ from when it is manufactured by another. This character of electricity provides an opportunity for creation of storage facilities to store the electricity of multiple suppliers together even at large scale without any difficulties. Further, the investment for setting up of the storage facilities is higher, equivalent to the production of electricity and single owner engaged in the generation of electricity or load serving or transmission business, may not opt for the storage business. One of the options could be to set up storage facilities jointly by all State entities by creating special purpose vehicles or joint ventures. There are certain advantages to creation of such multi owner company. For example: Special purpose vehicle company may be created for setting up of storage plants and used for the purpose of storage of electricity to flatten the load curve or to reduce deviation across tie lines as per the directions of the System

Operator. Another is to create a special purpose vehicle or joint venture for setting up of storage plants to take care of variability of renewable generation. In this case, the cost recovery mechanism of storage facilities may not be a difficult.

**Probable Operational Framework**

5.3 The Operational framework for Electricity Storage Services is envisaged separately based on ownership i.e. if the service is owned by a generator or transmission licensees. The storage services owned by the distribution licensee may not fall under the jurisdiction of the Central Commission.



5.4 **Combine with generating station:** The Electricity Storage System may be owned by the generator (including generator or group of renewable generator)[6] and used by that generator to enhance the supply of power to distribution licensee, ancillary market or open market, as the case may be, by shifting of generation when demand is higher at the discretion of the generator. This kind of ESS may be integrated with the conventional generator or renewable generators. This model is for the dedicated use i.e. only used by the developer for their own use. However, at present, it will be difficult to envisage the dedicated nature of ESS till viability is achieved. Thus, in order to optimize the services of ESS, the use of ESS may be kept as non-dedicated so that same can be used for system reliability by the System Operator or Central Transmission Utility or availed by any other grid connected entities.

It may not be viable to establish the ESS equivalent to the generating capacity, due to high capital cost and corresponding fixed charges of the ESS. Further, the evacuation of transmission system will limit the injection beyond the installed capacity. Thus a storage capacity to the extent of 10% or 15% may be considered as dedicated to the generating station to enhance the availability during peak hours which obviate the requirement of costly peaking power.

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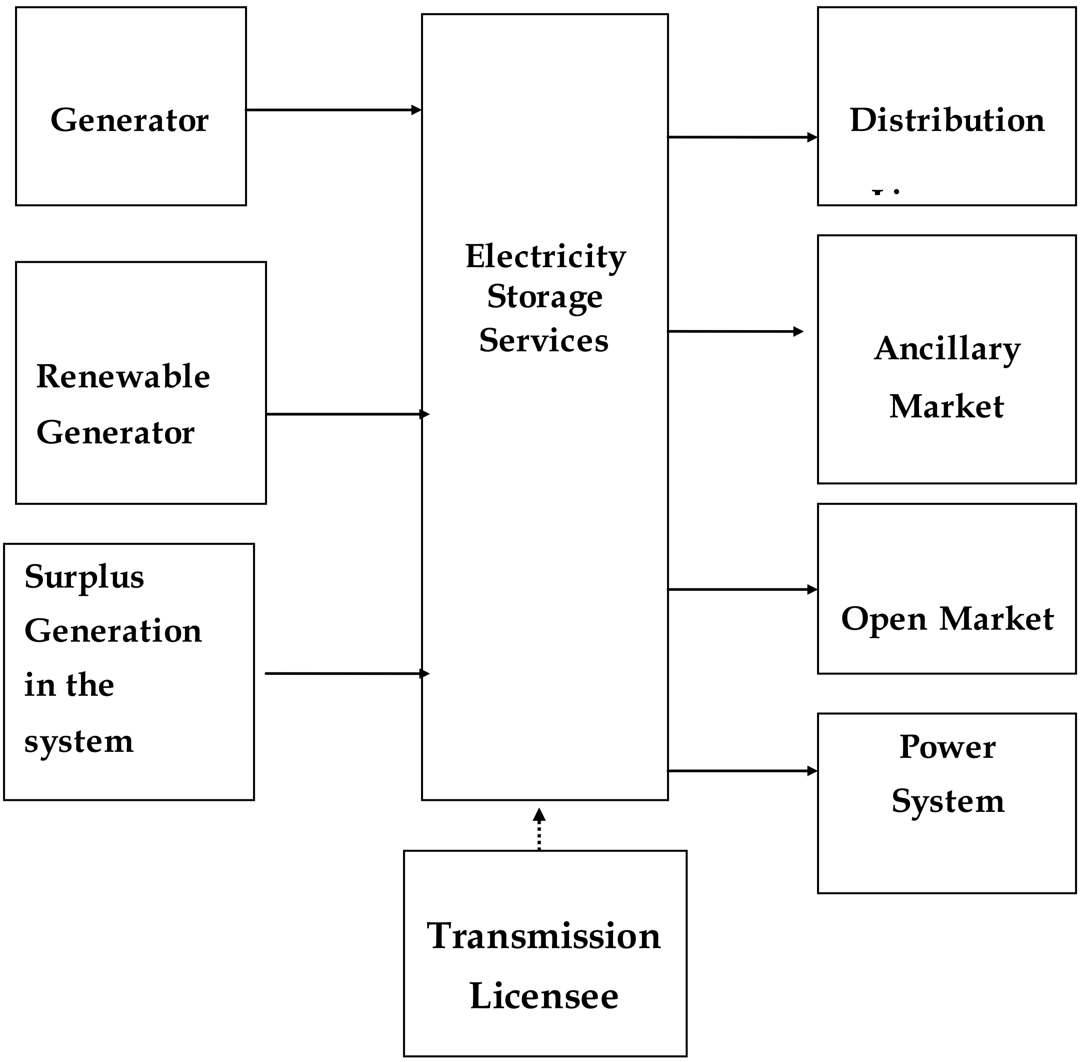
[6] ***It is not envisaged the transmission licensee owned storage facilities for their own use due to limited applicability***

5.5 **Combine with transmission business:** In this case, the Electricity Storage System may be owned by the transmission licensee[7] and storage services may be provided to generators (including renewable generators), distribution licensees and any other grid connected entity. The transmission licensees may also provide the storage services to absorb the excess generation in the system and dispatched when it is required as per the instruction of the System Operator.




[7] *This may be the case for distribution licensee. However, due to jurisdiction of the CERC, such models have not been covered under discussion.*

The use of this type of storage services may not be limited to the developer who owns it. Therefore, this ESS may be used by generator, distribution licensee for generation, transmission licensee to relieve congestion and power system operator for the purpose of economic and reliable operation.

## 6. Recovery of Electricity Storage Services

The cost of the ESS is to be recovered by pricing of the Electricity storage services. The price of the electricity storage services may be differentiated on the basis of the purpose for which it is used. The following salient aspects are relevant for fixation of tariff to compensate storage services:

**Recovery of Electricity Storage Services for dedicated use:**

6.1 In case the dedicated use of the electricity storage services by generating station or transmission licensee, separate charges for electricity storage services may not be required and it may be considered as a part of the generation or transmission business, as the case may be. The cost of such ESS is to be considered in the tariff determination of generation or transmission licensee, as the case may be. The recovery of the ESS may be through Rs per Unit charges in case of part of generation and Rs per MW in case of part of transmission.

Ministry of New and Renewable Energy ('MNRE") has already considered inviting renewable generators with ESS for developing projects through tariff based bid for renewable projects. This type of the ESS will fall in this category and the recovery of storage service will be a part of electricity tariff of the generating station.

A separate contract for storage services is not required in this case of dedicated use of the storage facilities. However, the ESS may be included in the scope for supply of the generating station or transmission licensee and the operational modalities may be agreed with the users in respective Power Purchase Agreement or Transmission Service Agreement, as the case may be. Separate scheduling, dispatch and energy accounting will not be required in this case.

**In case of conventional generating station:**

6.2 The tariff of the ESS will comprise only a Fixed Charge component. If the use of ESS is dedicated to the generating station, the tariff of such ESS may be pooled with the annual fixed charges of the generating station. Alternatively, the cost of ESS may be recovered through supplemental charges for the period during which it is mandated to use. The tariff of the dedicated capacity may be governed in terms of **Rs per Unit (where Unit = Electricity Sent out of generating station**) corresponding to fixed charges in line with the dedicated type ESS.

Since this storage capacity is used for the generation shift, the recovery of the tariff of those generating stations will be considered with reference to the prevailing operational norms. The ESS is expected to inject the electricity during peak hours. Accordingly, the tariff structure is to be decided separately to the extent of the incremental generation injected by the generating station.

In case of the use of the ESS for the purpose of generation shift, the cost of electricity production is nullified. Therefore the recovery of the ESS will be to the extent of the supplemental charges which includes fixed cost of the ESS and loss of energy during charging, holding and discharging cycles. The rate of supplemental charges can be determined on the basis of the supplemental cost of the ESS corresponding to the net quantity of generation shifted.

The cash flow of the generating station will remain neutral, however, the benefit of the shifting of the generation will be available to the procurer as they can avoid the purchase of costlier power from the open market or burning costlier fuel during peak hours. The ramping rate of the generating station will also undergo a change. Therefore, the procurer has an additional advantage to meet the ramping of the generation or to counter the variability of renewable generation.

The tariff structure as discussed above will attempt to address the issue of recovery of cost of the ESS. Issue of scheduling may not arises if the ESS is connected to the common bus of the generating station. However, if the ESS is located at different network location, the scheduling of the generating station and ESS may be clubbed for the purpose of schedule generation.

**In case of renewable generating station:**

6.3 Since the tariff of the ESS and renewable generation both comprises only a Fixed Charge component, it is appropriate to club the cost of both in case of use of the ESS as dedicated to the generating station. Alternatively, the cost of ESS may be recovered through supplemental charges for the period during which it is mandated to use.

The scheduling and dispatch of the renewable generation may be combined together irrespective of location. The ESS will be a reserved capacity for the renewable generator to smoothen ramping of the output to the grid. The renewable generator will be able to predict the output to the grid in advance (say to 2 to 8 hours). Therefore, the ESS will allow the renewable generator to forecast the output to the grid and to supply the electricity to the procurer through scheduling. The intermittent nature of the natural sources will be addressed with the help of the ESS.

The recovery of the ESS through supplemental charges may be more transparent, appropriate and acceptable to the beneficiaries. It reflects the cost of the additional value that has been provided by the ESS. The supplemental charges are to be recovered based on incremental generation or generation shifted. The appropriate metering and energy accounting system is to be designed to separate out the incremental generation.

**Non-dedicated use of the ESS**

6.4 If, use of the electricity storage services is not limited to the self use by the developer, separate service charges are to be specified for the utilization of storage facilities. The developer of the electricity storage services have to enter into agreement with the multiple users specifying the storage capacity and storage period. The storage capacity may be part of the total storage capacity and storage period may be fixed.

The developer will aggregate the storage capacity and storage period for each 15 minute basis for the purpose of scheduling. In case of multiple contract, there will be a complexity in scheduling and dispatch because the capacity and period of charging and discharging will be different.

- <u>For Generation Shift</u>: If the storage facilities are used by other generator (convention or renewable) or distribution licensee, the storage service charges are to be recovered from that generator or distribution licensee with mark up price. These charges will be recovered in terms of the Rs per KWh per hour for the storage period *inter-alia* comprises period of charging, holding and discharging. A separate scheduling, dispatch and energy accounting is to be required during charging, holding and discharging period;

- Controlling intermittent nature of renewable Generation: If the storage facilities are used for controlling intermittent nature of renewable generation output, it would be difficult to pre-fix period of discharge. The contract documents shall have to address the operational modalities for scheduling the generation. A separate scheduling, dispatch and energy accounting is to be required during charging, holding and discharging period. Alternatively, the renewable generator may opt to dispatch their generation output through storage facilities specifying delivery point. The storage service charges are to be recovered with mark up price. This charges will be recovered in terms of the Rs per KWh per hour for the period corresponding to charging, holding and discharging;
- Voltage Control or Congestion Purpose: In the event of utilization of storage facilities by system operator for voltage control or congestion purpose, the service charges, in terms of Rs per KWh per hours, will be recovered based on actual storage capacity and storage period. The beneficiaries would be regional entities. The service charges may be first met from the reactive pool account or reliability charges. The unrecovered service charges will have to be recovered as additional component of transmission charges in proportion to utilization of transmission system;

- Deviation Control: The service charges of storage facilities for using tie line flow control or deviation control of the control area, the beneficiaries of the deviation control will be the regional entities. There will be a savings of additional UI charges.
- Balancing Control or storage of excess generation: The system operator may use storage facilities for storage of excess generation and dispatched when it is required. In this case, the storage services may be recovered from over injecting or under-drawing entity. The use for storage of excess generation will require specific consideration for scheduling, dispatch and energy accounting. There will be a difference in UI charges because of time differentiation at the time of storage and discharge. This issue is to be addressed by the Commission by devising specific methodology.

If the ESS is owned by the generating station but entire capacity of the ESS is not dedicated to the generating station, the cost of the ESS will be bifurcated corresponding to the dedicated capacity and non-dedicated capacity. The tariff of the non dedicated capacity may be governed in terms of Rs per MW per hour.

- The tariff of the non-dedicated capacity of the ESS may be recovered through Storage Charges corresponding to storage period and Mark up price.

- o Capacity charges of these stations will be increased due to increase in capital cost, working capital, operation and maintenance expenses and due to increase in auxiliary consumption.
- o Variable Charges of these stations are expected to be constant due to shifting of generation as the resultant scheduled energy will remain unchanged over a day. There may be single storage service contract for entire storage capacity or multiple storage service contract for multiple use from single storage facility.

The tariff of dedicated and non dedicated portion may be fixed as discussed above. This will be the most likely business model as the generating station may like to use the ESS for its own purpose and also for the purpose of providing storage service to others.

**Open Access to the inter-State Transmission:**

6.5 Where the storage facilities is located at different location from generation sources, the transmission network will be used which will attract the transmission charges and losses. Further, the storage facilities is expected to be used for drawl of electricity as well as dispatch of electricity resulting into export or import of power. The transmission network is to be planned by considering this aspect. As regards the transmission charges and losses, it may be linked with the users of storage facilities. The scheduling and energy accounting mechanism will require specific consideration especially when multiples transaction of multiples uses are scheduled simultaneously at common dispatch points.

## 7. Regulatory Jurisdiction

7.1 Energy storage systems and its services can be used in regulated and deregulated markets. Currently, policy and regulatory framework for energy storage systems does not exist in the country. In the absence of a policy and regulatory framework, it is not possible to establish the revenue generation model for energy storage system developers and the case for investment will remain muted. While there is an established need of storage system in areas such as frequency regulation, renewable generation, generation shift etc., there are uncertainties in regard to their applications in the industry as well as jurisdiction of the Appropriate Commission. A well established regulatory oversight may direct the investment in the area of storage technologies. Various issues such as planning criteria, cost structure including depreciation rates, grid connectivity of storage services, tariff structure and recovery methods, cost-effectiveness criteria, standardization of operational norms, incentives, and rebates etc. are to be addressed.

7.2 The Central Electricity Regulatory Commission (CERC) regulates interstate transactions, while State entities such as State Electricity Regulatory Commissions (SERCs) regulate distribution licensees, State transmission and state level generation. Further, Regional Load Dispatch Centres (RLDCs) oversees operations of regional transmission and generation and State Load

Dispatch Centres (SLDCs) oversees operations of State transmission and generation. The issue of jurisdiction of storage facilities, if created, is important to address for the proper development of storage technologies.

7.3 The Electricity Act, 2003 ('the Act') covers the generation, transmission and distribution of electricity but it does not specifically cover the "holding" of electricity. As per the Act, the word "transmit" means conveyance of electricity by means of transmission lines for transmitting electricity output from a generating station to another generating station or substation and the definition of "inter-State transmission system"[8] covers the conveyance of electricity between states, across intervening State and conveyance within the State which is incidental to such inter-State\transmission of electricity. The bulk storage facility has similar characters of transmission because the storage facility is meant for storage of generation output through charging, holding, and discharging and conveying it to the other substation. In this scenario, the bulk storage facilities can reasonably be considered as a form of transmission, for jurisdictional purposes. The Central Commission has jurisdiction over the inter-state transmission of electricity under Section 79 (c) of the Act" thus the storage

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*[8] As per Section 2 (36) of the Electricity Act, 2003 " inter-State transmission system" includes - (i) any system for the conveyance of electricity by means of main transmission line from the territory of one State to another State; (ii) the conveyance of electricity across the territory of an intervening State as well as conveyance within the State which is incidental to such inter-State transmission of electricity; (iii) the transmission of electricity within the territory of a State on a system built, owned, operated, maintained or controlled by a Central Transmission Utility.*

facility meant for conveying electricity over inter-state are to be regulated by the Commission as a part of inter-State transmission[9].

7.4 On the other hand, a storage facility or ESS can be considered as one that enables the primary generator to sell at wholesale, either directly or through intermediaries, to the load-serving entities (distribution licensees) who receive the energy discharged from the storage facility. Under this character, the storage facility is akin to a generating station. The Central Commission has jurisdiction over the generating companies under Section 79 (a) and (b) of the Act.

7.5 Thus, different types of storage facilities are likely to warrant different regulatory classifications and treatments. If the storage facility was owned by a different owner (transmission or generator or others) then what would be the economic consequences and what regulatory treatment would be necessary are the relevant questions to be answered. It should not simply be assumed that the same mode of regulation will be well-suited to all of them. It is expected that a range of regulatory modes should be employed for addressing regulatory requirements of storage facilities.

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***9** Under this context, the bulk ESS can be a part of inter-state transmission or generation, depends upon its character and uses. This discussion is only to indicate jurisdictional aspects of the regulatory Commission.*

7.6 The development of the bulk ESS will be required to address the issues related with planning criteria and grid connectivity which may be dealt in operational and planning code specified by the Commission in CERC (Indian Electricity Grid Code) Regulations, 2010 after obtaining the advise of Central Electricity Authority. Other regulatory aspects such as depreciation rates, tariff structure and recovery methods, cost-effectiveness criteria, incentives, and rebates etc. are to be addressed by the Commission.

## 8. Challenges to the deployment of Energy Storage System:

**8.1 Cost competitive energy storage technologies**: A reduction of costs will requires extensive engineering research and development for new storage concepts and materials used for it. The cost also involves the factors such as technical risk mitigation, controlling the uncertainties at the early stage of deployment, operational uncertainties etc. Advanced research at international level is expected to reduce the cost of storage technologies. Recognizing the potential to reduce the cost of storage facilities, California enacted a Law in October, 2010 requiring the California Public Utilities Commission (CPUC) to establish by October 2013 appropriate energy storage procurement targets for 2015 and 2020 for California load serving entities, which arecost effective and commercially viable . In June 2013, the CPUC proposed storage procurement targets and mechanisms totaling 1325 MW of storage which indicates the possible cost reduction in storage technologies.

**8.2 Environment issues of storage technologies:** Though storage technologies will not pollute the environment by emission of greenhouse gases but it involves the use of chemicals. The enhanced life cycle of battery will require the periodical replacement of this chemical. The disposal of this chemical may involve the environment concerns. Presently, no policies are existing to address the environment concerns arising out of deployment of storage facilities.

**8.3 Policy framework for storage technologies:** Currently, a policy and regulatory framework does not exist in the country. Since the deployment and acceptance of grid storage are in their infancy, presently there is no policy and regulatory framework in the country. Industry acceptance would create a need for policy framework. However, the need of storage solutions in areas such as frequency regulation, renewable generation, generation shift etc., is self evident. A lack of well established policy and regulatory framework may inhibit the investment in the Power sector.

**8.4 Safety aspects of battery storage technologies:** The electro chemical storage facilities may be hazardous from various aspects and have to be treated with specific safety considerations. The safety norms for grid based storage technologies will have an impact on cost and business plan. Safety of large storage systems is a concern and will be a barrier in their deployment in urban areas or in proximity of other grid resources such as substations. The safety standards and procedures for the different storage technologies need to be developed for proper deployment.

**8.5 Stakeholder's Acceptance of technology and cost:** Stakeholder's acceptance is a key to deployment of storage technology. There is no clarity on how storage technology will be used in practice and how new storage technologies will perform over time in applications. What will be the market rules for operating storage technologies in the grid? In the present scenario, the planning criteria do not envisage deployment of the grid level storage facilities. Addressing these questions could boost interest and acceptance in storage technologies for investment and utilization by the stakeholders. Practical experience of storage will boost the confidence of stakeholders which can be achieved through pilot based projects.

**9. Comments from the Stakeholders**

9.1 The Central Commission has been regulating the tariff of the generation and inter-state transmission in accordance with CERC (Terms and Conditions of Tariff) Regulations, 2014 based on capital cost. The operational and planning code for transmission network has been specified by the Commission through CERC (Grid Code and Related matter) Regulations, 2010. However, there are no specific regulations which address the tariff and operational code associated with new storage technologies.

Consequently, through this Staff paper, comments of the stakeholders are solicited on the following issues:

i) Whether Electricity storage facility is required in the Indian Power System to address the various challenges discussed in the paper? Or can these issues be addressed through alternative solutions?

ii) How the requirements of storage facilities is to be assessed in the grid? What can be the specific criteria to be considered for development of storage facilities and associated transmission system?

iii) What are the perceived policy changes required to deploy the bulk storage facilities in the Indian Power System?

iv) Whether Electricity storage technology is expected to achieve commercial viability as believed in the international market?

v) What could be the appropriate model for fixation of tariff for multiple uses of storage facilities? Can the tariff of the ESS be determined under cost plus or competitive bidding basis as a part of augmentation of generation or transmission assets? What can be the operational or performance parameters for recovery of the cost?.

vi) What type of financial and nonfinancial data, if any, and what level of detail need to be reported to CERC for the storage technologies for fixation of cost based tariff ?

vii) How scheduling, energy accounting and open access issues will be dealt when the generation output and energy storage output are measured at two different grid points ?

viii) What would be the role of system operators and Central Transmission Utility in operations and planning of the Electricity Storage System ?

ix) Any other issues for development and market acceptance of storage technologies.

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**-// Appendix A //-**

Table-1

| Sr. No. | Project Name | Location | Technology Type | Rated Power(MW) |
|---|---|---|---|---|
| 1 | Sardar Sarovar Pumped Storage Power Station | Navagam , Gujarat | Open Loop Pumped Hydro Storage | 1450.0 |
| 2 | Bhira Pumped Storage Hydro Plant | Bhira , Maharashitra | Open Loop Pumped Hydro Storage | 150.0 |
| 3 | Ghatghar Pumped Storage Hydroelectric Power Plant | Ghatghar , Maharashitra | Open Loop Pumped Hydro Storage | 250.0 |
| 4 | Kadamparai Hydroelectric Pumped Storage Power Plant | Coimbature , Tamil Nadu | Open Loop Pumped Hydro Storage | 400.0 |
| 5 | Purulia Pumped Storage Hydroelectric Power Plant | Purulia , West Bengal | Open Loop Pumped Hydro Storage | 900.0 |
| 6 | Tehri Pumped Storage Hydroelectric Power Plant | Tehri , Uttarakhand | Open Loop Pumped Hydro Storage | 1000.0 |
| 7 | India One Solar Thermal Plant | Talheti , Rajasthan | Thermal Storage | 1.0 |
| 8 | Clique Solar Solar Thermal HVAC System | Greater Noida , Uttar Pradesh | Chilled Water Thermal Storage | 0.175 |
| 9 | Sun-carrier Omega Net Zero Building in Bhopal | Bhopal , Madhya Pradesh | Vanadium Redox flow battery | 0.045 |
| 10 | Khareda Lakshmipura Microgrid | Khareda Lakshmipura , Rajasthan | Lead Acid Battery | 0.040 |
| 11* | KVK Energy Solar Project | Askandra, Rajasthan | Molten Salt Storage | - |
| 12 * | Gujarat Solar One | Kutch , Gujarat | Molten Salt Storage | - |
| 13 * | Diwikar | Askandra , Rajasthan | Sodium and Potassium Nitrate Molten Salt Thermal Storage | - |
| 14* | Nagarjuna Sagar Pumped Hydro Station Tail Pond Project | Satrasala, Andhra Pradesh | Open Loop Pumped Hydro Storage | 700.0 |
| 15 | Srisailam Pumped Hydro Storage | Srisailam, Andhra Pradesh | Open Loop Pumped Hydro Storage | 1670.0 |
| 16 | Kadana Hydroelectric Power Station | Kadana, Gujarat | Open Loop Pumped Hydro Storage | 240.0 |
| 17 | Poithan (Jayakwadi Dam) Hydro Station | Jayakwadi, Maharashtra | Open Loop Pumped Hydro Storage | 12.0 |
| 18* | GigaCapacitor Hyperadad Test Project | Hyderabad, Andhra Pradesh | GigaCapacitor | 15.0 |
| **Total** | | | | **6788.26** |

(*These projects are under construction stage. )