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A Review on Energy Storage Systems in Distributed Generation for Generation Expansion Planning Study

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Abstract

handled by the ESS which will improve energy utilization and reliability and hence the total cost of the GEP is minimized.Power System planning is an economic problem wherein the primary objective is to determine the minimum cost strategy for long term expansion of Generation, transmission and distribution systems while satisfying technical and environmental constraints. Generation Expansion Planning (GEP) is one of the important planning activities for the electric utilities. GEP is the problem of identifying the most adequate technology, expansion size, siting, and timing for the construction of new plants considering economic criteria while ensuring that the installed capacity adequately meet the expected demand growth. GEP has many objectives such as minimization of costs, minimization of pollutants/emissions and maximization of profit and maximization of system reliability. Distributed Generation (DG) helps the power system to minimize the cost, complexity and improve the efficiency in transmission and distribution. Renewable DG systems are becoming popular and it can be operated in grid-connected mode. Energy Storage System (ESS) is a key tool to smooth out the intermittent nature of the renewable DG especially for Wind and Solar energy. ESS plays a vital role in micro grid as well as smart grid. In this paper, a review of ESS is done on the basis of several types. The integration of ESS will minimize the investment cost and emission of Green House Gases (GHG) to atmosphere in the system. The intermittent nature of the renewable sources is effectively

Keywords: *Generation Expansion Planning, Energy Storage Systems, Distributed Generation, Renewable Energy Sources*

1. Introduction

Electrical energy is a predominant one and inevitable for the operation of many devices which are being used in our day to day life. Providentially, the production of electrical energy is done with the help of burning fossil fuels, using nuclear materials and other (oil and gas based generation units) poor eco-friendly techniques. Certainly, renewable energy is the foremost component now-a-days to reduce several factors in power system such as reduction of cost of production due to absence of fuel, emission levels of hazardous things and limitation in availability resources [2]. Though reliability of renewable energy particularly on wind energy and solar energy is poor owing to non-availability at entire day/month/year, independency and sizing are the key factors intended for consideration of setting up of more renewable energy resources [5, 25, 26, 28]. Operational flexibility resulting in prominent advantages with renewable energy [10] like:

- Isolated house hold level generation (Solar)
- Stand-alone facilities
- Medium scale generation can be incorporated with industry or institution
- Distributed ownership at large generator side as well as smaller load side

DG denotes a generation that is using many sources of energy through that electricity is generated at load side by means of wind mill, solar PV panel, combined heat and power and many others [16]. Economically, DG is used in domestic and commercial places. Losses due to transmission of the electrical energy can be remarkably reduced by using it [40]. Having DG in the Grid could effect the operation of a power system in both advantageous and disadvantageous

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ways as well. DG can support the system for voltage stability, reducing line losses and many others but it can also affect the coordination of protective relays and dynamic stability of the system [33]. Characteristics of different DGs are shown in Figure 1.

Pumped hydro type of DG can generate more amount of power than other three DGs, thus it has maximum energy level which is shown if Fig. 1. Pumped hydro plant can generate more than 100 MW nowadays, so the power and energy levels are even higher. It is also observed that, the response time is also quicker in the pumped hydro plant. In spite of power and energy level, maximum efficiency of super conducting magnetic energy and advanced capacitors is higher [42]. Since DG is incapable to support the power system in both peak demand as well as off peak demand, there is a necessity to find an alternative way for its effective use [38,39].

The conventional (non-renewable) power plants like coal fired, oil fired etc., are not pollutant free; thus, it is necessary to include carbon capture storage system [37] in all the plants to make them pollutant free. Hence, the investment cost of all the conventional plants may get increased. Energy storage system is one of the key tool, to achieve cost effective and pollution free operation in power system [40]. Electric Energy storage system (EES) supports the power system during the period of peak demand. Generally, EES gets stored when power system experiences off peak demand, the same will be given to the grid once peak demand occurs. Thus, it acts as a bridge between utilities and loads during the critical time of operation. Thereby, EES can transfer the power consumption from higher tariff period during peak demand to lower tariff periods during off peak demand. EES can also increase the adoption of renewable energy sources to the wider level [1]. Interconnected EES and solar PV system creates pollution free environment at many places. Grid Scale EES/batteries has the potential of reducing the peak demand cost of an industry and it is also possible to plan as backup power supply [3].

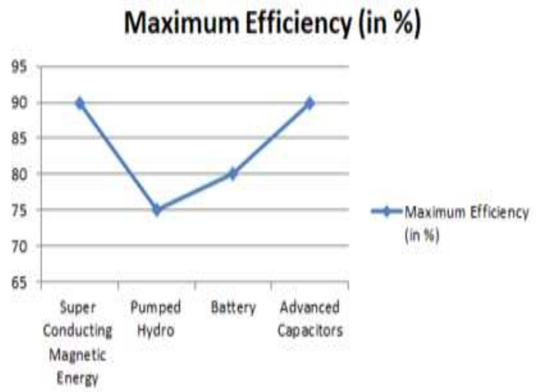

Fig. 1 (a)

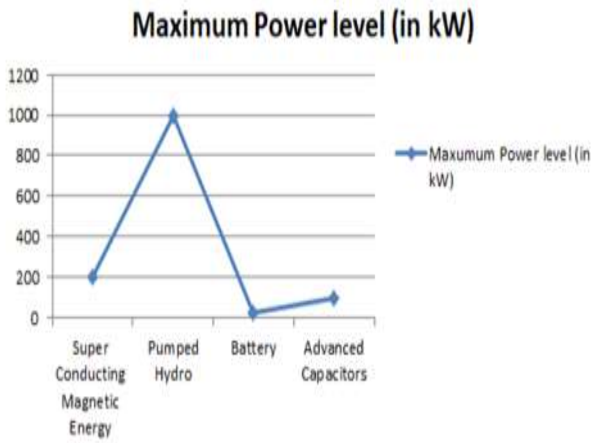

Fig. 1 (b)

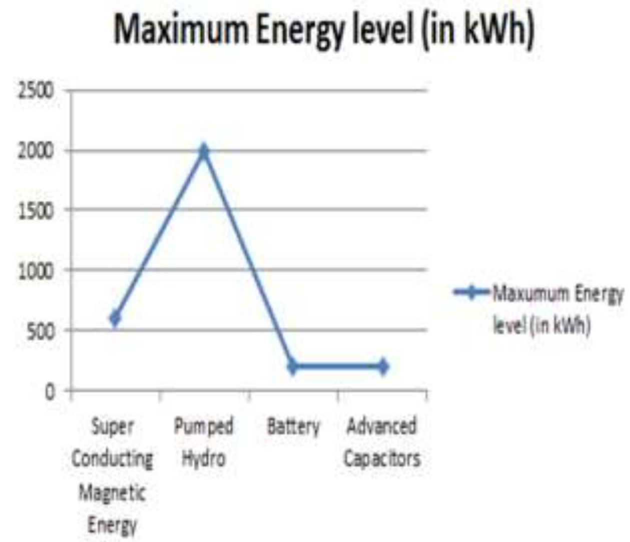

Fig. 1 (c)

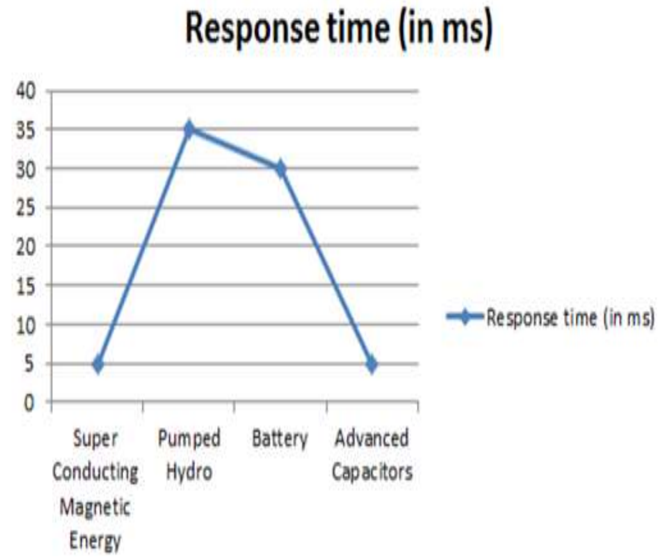

Fig. 1 (d)

In this paper, a review has been presented for Electrical energy storage system, chemical energy storage system and mechanical energy storage systems and section 2 describes energy storage methods (ESM) and its types, section 3 describes Electrical energy storage system, section 4 describes chemical energy storage system, section 5 describes mechanical energy storage systems, section 6 concludes the paper and section 7 comprises the list of references.

2. ESM AND ITS TYPES

ESM is classified in numerous ways. Here the classification is made based on the type of energy medium through which energy is stored [40,41].
Energy Storage (ES) is done by converting electric energy to other forms of energies like chemical energy and converting it back to electric energy.

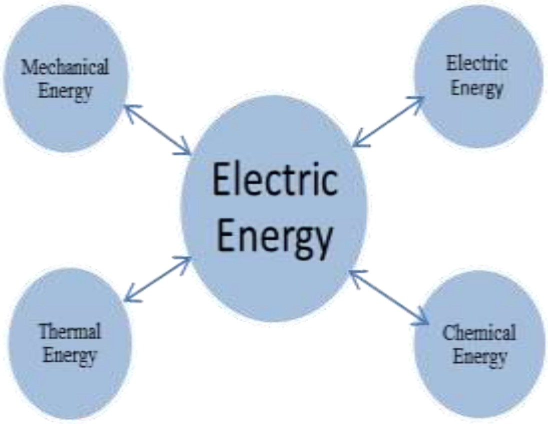

Fig. 2. Types of ESM

Though ES can possibly take place through several ways as shown in fig. 2, it is also important to analyse different factors such as energy storage capacity, efficiency, emission level, cost and lifetime. Since Electrical Energy Storage method (EESM), Chemical Energy Storage Method (CESM) and Mechanical Energy Storage Method (MESM) are the predominant methods in ES, all the three methods are discussed in the paper.

3. Electrical ESM (EESM)

An EESM is possible in power system of with several methods [3] such as capacitor storage (CS), super capacitor energy storage (SCES) and super conducting magnetic energy storage (SCMES). The comparison of different EEST is as follows.

Table 1. Comparison of EESM

Factor	CS	SCES	SCMES
Energy Storage Capacity	0.3 kWh	< 1 MW	0.1 MW – 10 MW
Maximum Efficiency	70%	>95%	90 % - 92 % (for large plants)
Cost	100 $/kWhr/Cycle	660 $/kW	For 1 MW plant for 10 years 1s discharging – 1,56,640 $ 30s discharging – 3,02,720 $ 60s discharging – 4,08,320 $
Emission Level	Vey less	Very Less	Less
Application	Reactive power compensation, System Stability	Connected in parallel with battery during peak load and Electrical cars	Demand side management, Power System stability, damping and Power quality.
Lifetime	>20 Years	>10 years	20 Years

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From Table 1, It is evident that, based on the energy storage capacity level, SCMES can store upto 10 MW which is the highest value among different EESM. The SCMES can be operated at higher efficiency when the size of the plant is large and cost is also comparatively lower than SCMES. Since the lifetime of SCMES is higher, in GEP studies, SCMES shall be the better choice among different types of EESM. Emission of greenhouse gases is the only drawback of the SCMES system.

4. Chemical ESM (CESM)

Batteries Energy Storage Devices (BESD) are the predominant CESM system, which stores the electric energy through electrochemical reactions [1, 13, 14, 15]. The classification of CESM is given in fig. 3.

In electrochemical reactions, electrical energy stored as chemical potential and release the stored potential as electrical energy with respect to the power demand. The classification of CESM is as follows:

4.1 Solid State Batteries: Electrochemical cells that are available inside have positive and negative terminals. Movement of ions is excited by electrolytes from one electrode to another, thereby causing current flow. Types of solid state batteries is given in Fig. 4.1

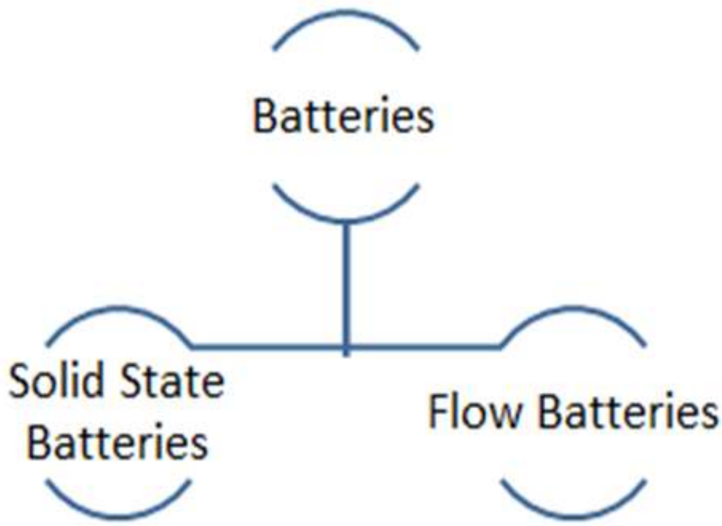

Fig. 3. Types of Battery Energy Storage System

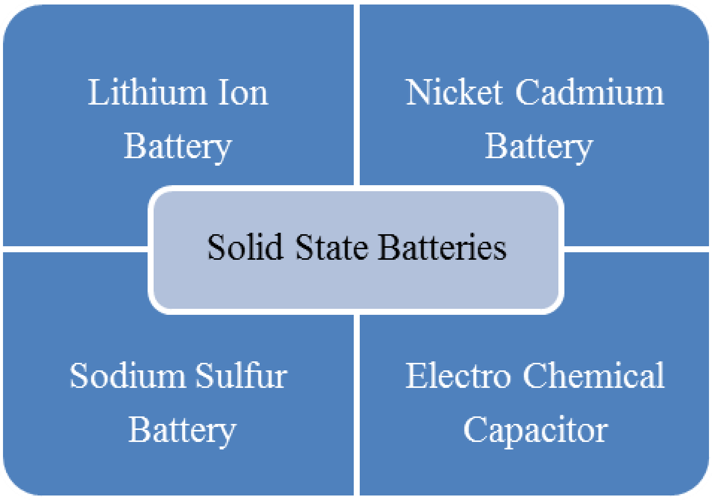

Fig. 4. 1. Types of Solid State batteries

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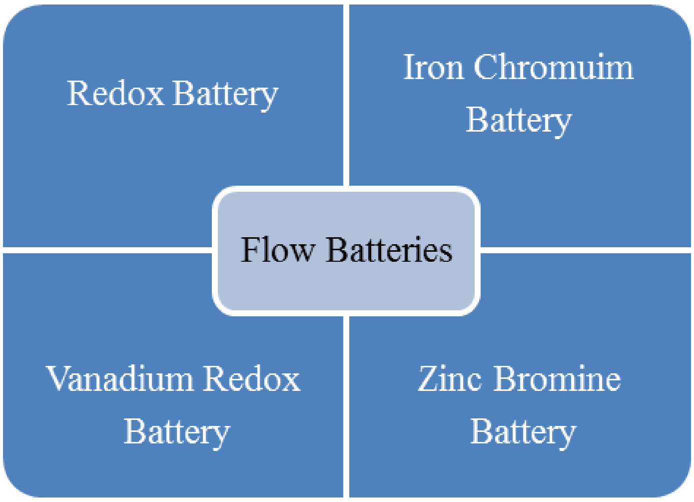

Fig. 4. 2. Types of Flow batteries

4.2 Flow batteries: It is a rechargeable battery and recharging is done by dissolving the chemical components in liquids. It can quickly charge the electrolyte liquid. Types of flow batteries are given in Fig. 4. 2

Table 2. Specification of BESD

Factor	**BESD**
Energy Storage Capacity	<200 MWh
Maximum Efficiency	70% - 80%
Cost	60 $/kWhr/Cycle/s
Emission Level	Less
Application	Reactive power compensation and Elelctric Cars
Lifetime	2-10 Years

From Table 2, it is clear that BESD cannot be used for heavy load for longer duration. The BESD will be charged during off-peak hours and gives back energy during peak hours. Since, the emission of harmful gases from the BESD is not so high, it can be located at any part of the power system. One of the major advantage, with the battery is portability, thus it can be located even in electric cars and other vehicles. Usage of electric vehicle (EV) is nowadays considerably increases year by year; due to recent advancement is BESDs. Hence the environmental constraints will be maintained within the limits. EV can largely eliminate the pollutant from environment.

Thus it can also be considered as one of the expansion candidates in GEP studies. In GEP, bulk ES is also analyzed for investment planning by means incorporating BESDs to a system. It is also reported that, BESDs are used for transmission line expansion planning studies. In distributed expansion planning, major challenges such as size and optimal allocation are carried out with BESDs.

5. MECHANICAL ESM (MESM)

MESM comprises several high energy capable systems which primarily involves pumped hydro energy systems (PHES), compressed air energy storage systems (CAESS) and flywheel energy storage systems (FWESS).[40]

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Fig. 5. a. comparison of MESM

From Fig. 5. PHES and CAESS have higher discharging/running time but as far as maximum cycling capacity is concerned, PHES has cycling capacity approximately 50,000 times. It is also clear that FWESS cannot be used for large scale storage system since, it has low power rating and maximum running/discharging time. In addition to that, initial cost for output energy in a cycle, is ranging from 0.1-1 $/kWh for PHES, 2-5 $/kWh for CAESS and 5-20 $/kWh for FWESS.

Fig. 5. b. Comparison of MESM

Fig. 5. c. Comparison of MESM

So based on the above all specifications, it is proposed that in MESM, only PHES is the techno economical solution for considering GEP since it has maximum power output and higher cycling capacity.

6. Conclusion & Future Scope

This paper has analyzed the characteristics of different ES with several parameters such as energy storage capacity, maximum output power, cost and efficiency. The similar analysis can be done with GHG emission and many others. Here, the importance of several energy storage systems with their specification are described. Despite Pumped Hydro storage plant has the potential to supply more amount of power to the grid, it is not possible to construct it at everywhere. Grid Scale battery is the recent advancement in many countries, through that from shorter duration to longer duration the peak demand is met. It is also reported that ESM leads to improvement in operational flexibility, reduction in GHG emission level, better reliability and loss reduction at transmission and distribution. Plugged in Hybrid Electric vehicle (PHEV) is the State-of-art technology in the automobile industry. Proper distribution of charging location for the vehicle could reduce the peak demand at few places. Electric Vehicle (EV) is the future of the world, hence in GEP studies, EV must also be addressed. Many research works are carried out to find optimal placement of DG in the existing power system. But only few research works are carried out for optimal allocation of ESS in DG. Generally, GEP implementation is done based on the cost, emission level to the environment and reliability of the supply. Many studies reported the optimal design and location of the ESM. It is concluded that, GEP studies while incorporating ESMs in DGs are yet to be analyzed on Gross Domestic Product (GDP) of the state or country. This is the novel analysis in GEP studies of a country for aiding towards GDP improvement. Interconnecting small scale units with the combination of wind and ESS, Solar and ESS, PHEV etc., for GEP studies can also be considered as future scope.

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