Energy Storage Devices and Their Applications

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ABSTRACT:

Nowadays the penetration of renewable sources in the power system network has been increasing rapidly.With increasing penetration of renewable energy,the grid is becoming more weather dependent. The variable nature of the renewables i.e. sun shine or wind speeds on a typical day may results in intermittency of renewable generation.This may leads to fluctuation of power at the terminals of generating units too. One of the solutions being proposed to improve the reliability and performance of these systems is to integrate energy storage device into the power system network. Thus energy storage device plays a vital role in stabilization of RES integrated network. This paper discusses the state of art of energy storages devicesand their importance in power system.

Keywords- ESS, SMES,BES, FESS, Advanced capacitor.

INTRODUCTION

The renewable energy sources (RES) are clean source of energy. RES such assolar, wind,biomass, hydro and geothermal are available in bulk amount.Nowadays PV plants are used most widely for thegeneration of electricity because of its numerous advantagessuch as no pollution and maximum power availability at peak hours etc. Such PV system, consist of PV panels, power Converter, Inverter, load. But this solar energy is not equally available in cloudy days and nighttime.This requires some form of energy storage device.SoThat stored energy must be available to compensate for the loss of sunlight and forfeeding into large grids. Hence the energy storage become a dominant factor in economic development of grid system and for balancing the energy in the grid[1,3].

This paper presents comparison of different energy storagedevices considering the different vital parameters along with their advantages and disadvantages. objective of this paper is to learn importance of energy storage devices in the power system operation.

NEED OF ENERGY STORAGE:

These days renewable energy source becomes most important part of the power system.Its intermittentnature bring issues such as frequency changes,power-fluctuation, poor power quality.this can lead to instability of the system hence to maintain the reliability and stability of the system, it required the storage device so that system can operate in secure manner[6].

These days the cost of the electricity has extended to high level hence the customer have to pay more amount money for getting electricity from the grid system. Hence researchers are using different optimization techniques of thepower system, so that itreduces energy cost.One of the techniques which found more successful is the energy storage integration into the grid system[4].

ENERGY STORAGE SYSTEM (ESS):

Energy storage system is an indispensabletechnology for the gridoperation,renewable energy integration,micro grid,electrical vehicles development. It can effectively resolve problem of demand-sidemanagement, smoothing of the load .It can improve the efficiency of the system and can reduce the cost of power supply.Various energy storage systems havedifferent energy density,power density andlifetime. While power system also put forward different requirements for different applications of energy storage system at same time of interval. Thesestorage systems are divided into mechanical energy storage, chemical energy storage, electromagnetic energy storage etc.Different energy storage system and their applications are explained below[4,6].

1. Superconducting Magnetic Energy Storage (SMES):

In the SMES system, electric power is stored in the magnetic field ofa large superconducting magnet and can be used for short duration energy storage. Power conditioning systems are required to convert the DC power in the magnet to AC for grid when discharging the SMES, and vice versa when recharging. SMES has severalapplications due to its fast response and high efficiency. Various applications including load leveling, voltage stability, frequency regulation, transmission capability enhancement, and power quality improvement. When it compared with other energy storage technologies, SMES systems are still more expensive. The use of high temperature superconductors can also make cost effective system due to reductions in refrigeration needs [2]. The inductively stored energy (in joules) and the rated power (in watts) are commonly given specifications for SMES devices, and they can be expressed as follows:

$$E=\frac{1}{2}LI^2 \text{ , } P=\frac{dE}{dt}=LI\frac{dI}{dt}=VI \text{--------(1)}$$

where L is the inductance of the coil, I is the dc current flowing through the coil, and V is the voltage across the coil. Since energy is stored as circulating current. An SMES unit consists of a three-partsuperconducting coil,power conditioning system, cryogenically cooled refrigerator. A

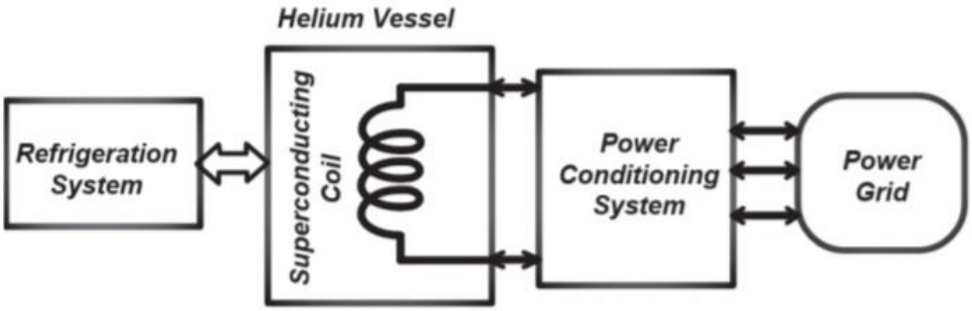

Fig 1: SMES[2]

powerconditioning system (PCS) uses inverter/rectifier to transform the alternate current power to direct current or to convert DC back to AC. Two types of power conversion systems are commonly usedOne is current source converter (CSC), second one is a voltage source converter (VSC). Rectifier/inverter account for 2-3% energy loss in each direction which is very least compared to other storage devices. Abovefig.1 shows SMES,The modes of charge/discharge/standby are obtained by controlling the voltage across the SMES coil. Several factors are taken into consideration for design of the coil including coil configuration, energy capability, structure, and operating temperature[5,2].

2. Battery Energy Storage (BES):

Electrochemical Chemical Batteries are one of the cost-effective energy storage technologies available nowadays.Lead acid batteries are the world's most widely used battery type.Batteries start charging when they undergo an internal chemical reaction when potential is applied at the terminals. They start discharging when theyundergoreverse the chemical reaction. Key factors of batteries for storage applications include: high energy density, high energy capability, life span, and initial cost [6]. Lead-acid batteries found to be the mature technology and these batteries can be designed for bulk energy storage or for rapid charge/discharge.Their typical applications are emergency power supply systems, stand-alone systems with PV, battery systems for mitigation of output fluctuations from wind power and as starter batteries in vehicles. Lead-acid batteries still represent a low-cost option for most applications requiring large storage capabilities, with the low energy density and it has disadvantage of short life span.Other types of lead acid batteries also developed these days for Mobile applicationsfavoring sealed lead-acid battery, for better performance and low cost at stationary level application Valve regulated lead-acid (VRLA) batteries are most effective.One more disadvantage of lead acid battery is usable capacity decrease when high power is discharged along with these Other disadvantages are lower energy density and the use of lead, a hazardous material prohibited or restricted in various jurisdictions[2].

3.Advanced capacitors:

Advanced capacitors are also known as supercapacitors,which is high-capacity capacitor with much high capacitance value when compared to other capacitors. they can store 10 to 100 times more energy per unit volume or mass then the traditional electrolyte capacitor. it can deliver and accept the charge much faster than conventional batteries and can tolerate many cycles of charging and discharging. It has mainly two type one is double layer capacitor and another is pseudocapacitors. unlike ordinary capacitor it does not use the solid dielectric but rather it uses combination of electrostaticdouble layer capacitance and electrochemical pseudocapacitance. There are many other advantages of advanced capacitor which include durability, high reliability, no maintenance, long lifetime and can operate over high temperature range and in diverse environments (hot, cold and moist).It has disadvantage of low energy density and They are environmentally friendly and can be easilyrecycled or neutralized. The efficiency is typically around 95% [2,6].

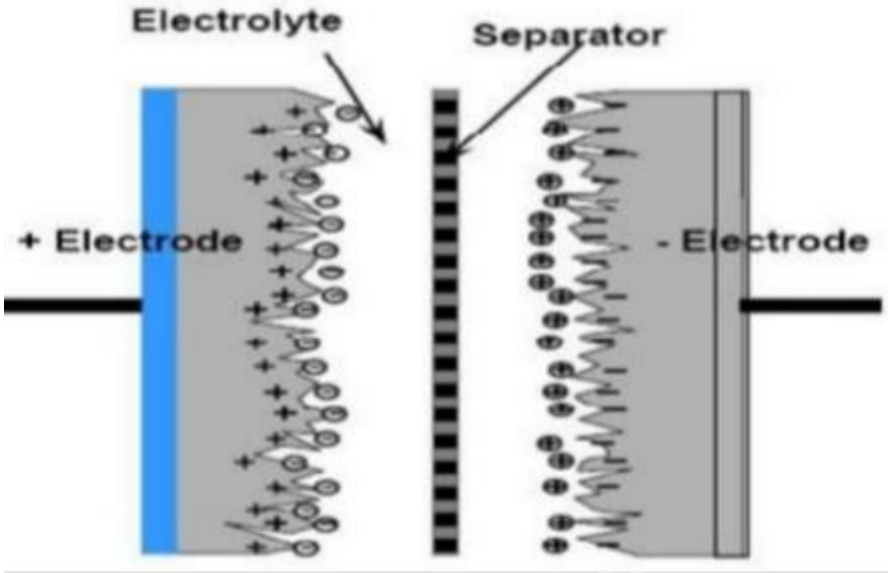

Fig 2: Advanced capacitor [6]

Above fig.2 shows the advanced capacitor and relationship between the stored charge **q** and the voltage between the plates **V**, as shown below.

$$q = CV,\ E = \frac{1}{2} CV^2 \text{-------(2)}$$

Which shows that, the amount of energy stored on the capacitor depends on the capacitance and on the square of the voltage[5].

4.Flywheel

Flywheel energy storage device that store the energy mechanically in the form of kinetic energy. It has different components like flywheel, motor/generator, magnetic bearings.FESS have advantage of high power density but it has low energy densityas the most of energy is lost due to friction so, its efficiency can enhance by creation of enclosed vacuum [6]. it has the different application such as in transportation and power quality applications for short period because of short discharge time[5].depending upon the speed it is classified mainly as low speed flywheel and high-speed flywheel. it does not require the periodic maintenance. When compared to other storage device it is much costlier[6].

$$E=\frac{1}{2} I\omega^2 \text{--------(3)}$$

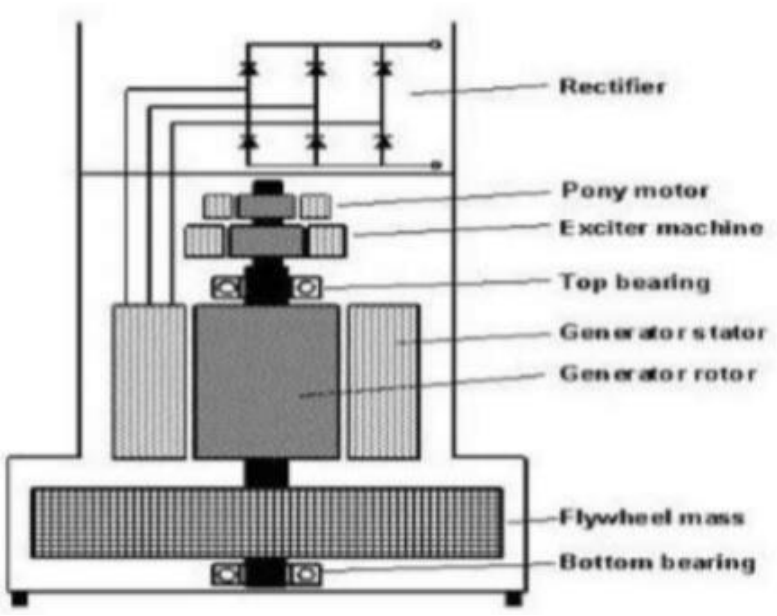

Fig.3 flywheel [6]

Above relationship, shows that amount of Stored energy in flywheel depends on the moment of inertia of the rotor **I**and the square of the rotational velocity of the flywheelω**,** fig.3 shows flywheel.

COMPARISON OF DIFFERENT ENERGY STORAGE SYSTEMS:

The superconducting energy storage or advanced capacitors comes under the catogary of electromagnetic energy storage.the flywheel energy storage comes under the category of mechanical energy storage while batteries comes under the categories of electrochemical energy storages[2].

According to characteristics of energy storage,electrochemical batteries are suitable for large emergency power supplies application but superconducting,flywheel and supercapacitors energy storage are suitable for large power for short duration applications.lead-acid batteries is still battery of largest production and the consumption[2].

Superconducting energy storage andelectrochemical battery energy storage can have extra feature to perform the frequency regulation and inhancement of transmission capability. other storage device such as flywheel and advanced capacitor don't have the abilityas like SMES and chemical battery to perform frequency regulation and inhancement of transmission capability[5].

When Comparing the lifetime of storage,the flywheel and superconducting energy storage have more lifetime comparing to supercapacitor and electrochemical batteries[2,5].

CONCLUSION

This paper concluded that Energy Storage System is found to be new key technologies in the grid system, which gives cost effective and reliable production of electricity.More and more application of energy storage system will bring the many important reform to national grid system. energy storage also needs to be studied so that issue related to existing storage system get solved out earlier, which will help to improve its performance for future use.

REFERENCE

[1] T Kour, "Solar PV Integration in Smart Grid - Issues and Challenges," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 4, Issue 7, July 2015.

[2] Mustafa farhadi,osamamohmmed"Energy storage system for high for application" IEEE Trans.2015-ESC-0464.

[3] TamilmaranVijayapriya, DwarkadasPralhadasKothari,"Smart Grid: An Overview"Smart Grid and Renewable Energy, 2011, 2, 305-311.

[4] G. M. Tina, "Grid-Connected Photovoltaic System with Battery Storage System into Market Perspective",IEEE trans. October 2009.

[5] PAULOF. RIBEIRO, BRIAN K. JOHNSON,MARIESA L. CROW, AYSEN ARSOY,YILU LIU "Energy storage for advanced power application" IEEE Trans. January 2002.

[6] Youjie Na,Peilin Yang, XuesongXhou, Zhiquiang Gao "research review on energy storage techonology",International Conference on Mechatronics and Automation August 7 - 10, Harbin, China.