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Mini review on Energy Storage System

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Abstract:

Electric energy and other energy sources will be combined using energy storage systems as the primary equipment. The use of renewable energy sources has increased demand for high-efficiency energy storage technology globally (EST). As a result, a variety of energy storage technologies will be essential to the integration of renewable energy sources (RES) in the current electrical power system. This paper provides a brief overview of several EST that enhance the network's efficiency, reliability, and energy storage density.

Keywords: Energy storage technology, Distributed Generation, Renewable energy sources.

Introduction:

Despite the presence of many energy storage technologies, electricity has always been seen as a commodity that cannot be stored (EST). Due to factors like high construction costs and a shortage of storage space suitable for usage in power systems, this storage technology has not previously been taken into consideration [1]. However, thanks to significant efforts made by scientists and researchers from both industry and academia around the world, attention is now being paid to the field of EST.This is demonstrated by advances in component and system level design, developments in modelling and control for power electronic interfaces, and the successful integration and execution of EST[2]– [5].

Since the need for power has grown dramatically in recent years, distributed generation has become more and more popular (DG)world-wide innovations and renewable energy sources [6-7]. According to estimates, RES can supply 14% of the world's total energy needs. Since RES technologies make it possible to generate energy at or around where it is utilised, this type of energy generation is now referred to as distributed generation (DG) [9].

The availability of inexpensive energy and the little environmental impact of RES made it a top priority for people all over the world to use this energy by developing an effective energy management using on-grid power systems. Since RES is a weather-dependent energy source with nonlinear power production, an appropriate efficient energy storage technology must be employed to increase the grid's efficiency, stability, and dependability [10].

Energy storage has developed into a crucial enabling technology for use in large-scale centralised energy generating and distributed generation, as well as having several crucial roles: (1) The coordination of energy storage systems can lead to the active and reactive power balances necessary for a dynamic system power balance. To maintain a balance between voltage and frequency, take the initiative to do this. (2) Working with other devices can enhance power quality through swift adjustment. With a super-capacitor energy storage device, for example, the power of a system can be quickly switched (3). Energy storage technologies effectively reduce the fluctuation of the generation of renewable energy sources, enabling a substantially higher penetration of renewable energy sources in the power system[1,11,12].

The purpose of these papers is to demonstrate several energy storage technologies and their applications based on a variety of parameters, including total cost, environmental conditions, consistency, energy density, and most importantly, overall efficiency [13–20].

Various EST:

ESS transforms energy, whether it is electrical or from another source, into what is needed. Application power and energy ratings, reaction time, weight, volume, and operating temperature are just a few examples of the variables that are considered while choosing an energy storage technology[21].Figure 1 displays some graphical information on energy storage technologies for various applications.

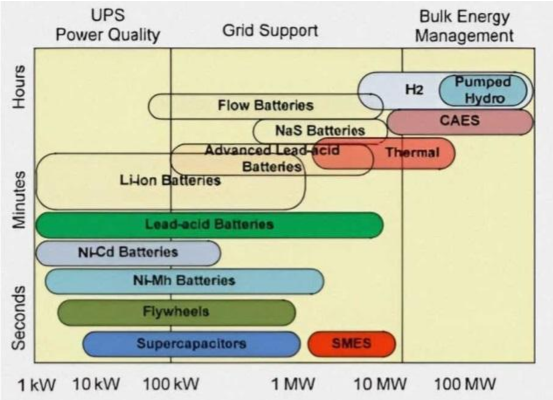

Fig.1 Performance characteristic of ESS for different application

EST examples include the following:

A. Pumped Hydroelectric Energy Storage (PHES):

Hydraulic potential energy is the way in which PHES stores electrical energy. [22] PHES was first utilized in 1929, and US army corps engineers divided it into two categories:

i) Pure/ Off stream/ close loop PHES.
ii) Pumped back PHES.

The modern PHES is situated where two coordinating reservoirs with an upper and lower reservoir are constructed. according to figure 2.

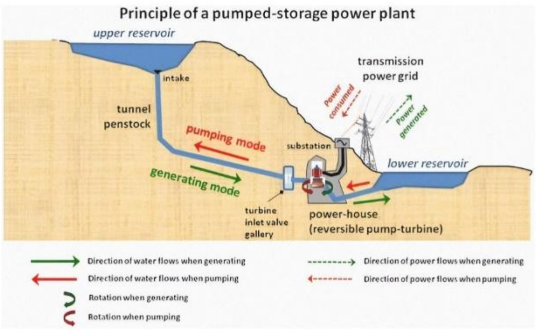

Fig.2 Observe the principle of pumped storage power plant

According to the load requirements, the pumped back PHES system helps to increase the system's efficiency. The amount of water in the upper reservoir, the height of the water fall, and the separation between the upper and lower reservoirs are all strongly correlated with the ability to store energy[23].

So,
$E_{PHES} = \rho gHV$
Where,
E_{PHES} = the store electrical energy in joule.
P = water density.
g = acceleration
H = height of water.
V = amount of water store in upper reservoir.

This method for long-term energy storage is used on a huge scale. Additionally, the lifespan of this energy storage is 30 to 50 years. PHES operates with a 65-75% efficiency [24].The primary disadvantage of the PHES system, according to Ekman and Jensen, is that it required appropriate sites for deployment because of its environmental effect and high construction costs [25].

B. Compressed-Air Energy Storage:

It is possible to store compressed air for use at a later time by using it as an energy storage medium (CAES). By replacing the turbine's air compression stage with the CAES, the natural gas fuel previously required for air compression is eliminated, allowing energy to be extracted using a standard gas turbine.Compression and expansion of air are endothermic and exothermic reactions, respectively, which complicates system design. Compressed-air energy storage (CAES) compresses air into an above-ground system or an underground structure (such as a cavern, an aquifer, or an abandoned mine) using cheap off-peak electrical energy (tanks or pipes).

During peak hours, a modified gas turbine expands compressed air and natural gas to create electrical energy from the stored energy. The most notable load levelling applications for the electric grid [26] have been considered among the many applications of CAES. When there is a low demand for electricity, energy is captured, and when there is a high demand, it is converted back to electricity. Between 35 and 300 MW are available on installed commercial systems.

C. Battery Energy Storage:

Batteries are described in ESS as rechargeable electro-chemical systems. It has a 2% self-discharge rate and a high energy efficiency range between 85 and 90%. Lithium-ion, lead-acid, nickel-cadmium, and nickel-metal hydride batteries are the four most common types of batteries used in energy storage systems [27]. Table 1 displays the contrast between various batteries [46].

Table-1: Comparison Table of Different Types of Batteries

Parameters	Lithium Ion Battery	Lead Acid Battery	Nickel Cadmium Battery	Nickel Metal Hydride Battery
Charging temp (°C)	45 to 0	50 to -20	45 to 0	45 to 0
Discharging temp (°C)	60 to -20	50 to -20	65 to -20	65 to -20
Life (cycle)	3000-600	300-200	1000	600-300
Voltage (volts)	3.7-3.2	2	1.2	1.2
Energy Density (Wh/L)	250-400	90-80	80-50	120-60
Specific Power (W/Kg)	260	285	200	200
Specific Energy (Wh/Kg)	200-150	40-35	70-50	70-50
Energy Efficiency (%)	90	85	140-100	85
Nominal Voltage (V)	350	6	1.2/Cell	343
Rated Capacity (Ah)	158	215	2.5 to 20	77
Rated Capacity (Kwh)	55	1.29	0.024	26.4
Cost	More than lead	Cheap	Expensive	Expensive
Depth of Discharge (Approx)	20% for 300 cycles	20% for 500 cycles	20% for 2500 cycles	20% for 2500 cycles
Energy Density (W.h.Kg-1)	270-100	50-30	80-50	120-60
Power Density (W.Kg-1)	680-250	180	150	1000-250
Self-Discharge Rate (%.Month-1)	10 to 3	5	20	30
Charging Efficiency (%)	90-80	95-50	90-70	65

D. Flywheel Energy Storage:

Gyro buses developed in the 1950s that utilised the flywheel design idea marked the beginning of flywheel technology experimentation [28].Electricity is converted into kinetic energy by flywheels, which is then stored by quickening the rotation of the flywheel. In order to transform the stored kinetic energy back into electrical energy when electrical energy is needed, the motor/generator slows the flywheel's revolution [29]. The primary factor determining the building method used for each component is the maximum rotational speed of the flywheel. Figure 3 illustrates the flywheel's parts.

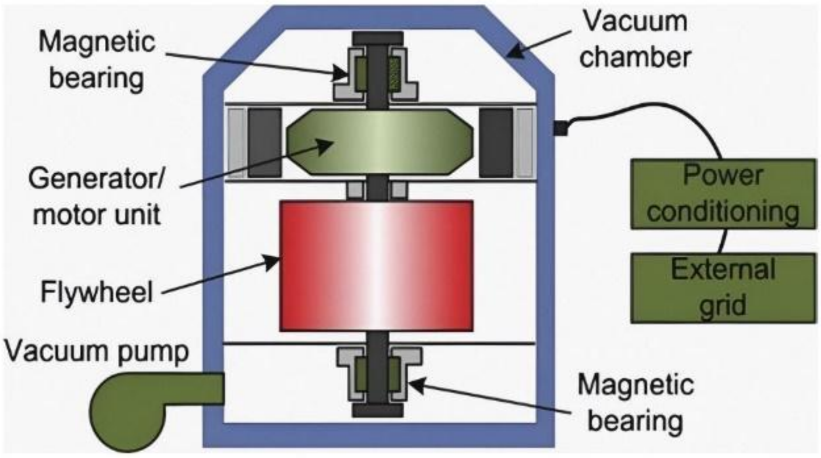

Fig.3 Structure and component of a FESS [10]

The FESS can be divided into two categories based on this speed [30]:

I. Low speed FESS.
II. High speed FESS.

The speed of a low-speed flywheel (LSFW), which is typically employed in industrial applications, is less than 10,000 rpm. The alternative variety, known as HSFW, operates at a speed greater than 10,000 rpm [31]. The advantages of flywheel storage devices are minimal maintenance needs, a long lifespan, and minimal environmental effect. Large-scale flywheel technology is currently being used for frequency regulation [32].

E. Super-conductive Magnetic Energy Storage:

In 1971, Boom and Peterson at the University of Wisconsin conducted an earlier examination [33] into SMES. A SMES unit with 1 GWh was constructed in 1980. In order to evaluate SMES technology, The Electric Power Research Institute started a research in 1981.The United States' Bonneville Power Administration developed and tested SMES in 1982 [34]. Direct current electricity is used to store energy. The method of storing electrical energy within the magnetic field produced by a direct current passing through a superconducting coil is known as superconductive magnetic energy storage (SMES). Cryogenically cooling the coil brings its temperature below the crucial point for superconductivity.

SMES are divided into two groups based on operating temperature:

I. low temperature superconductor (LTS)
II. high temperature superconductor (HTS)

Comparatively speaking,the HTS SMES systems are more practical and cheaper than the LTS SMES systems [35]. Figure 4 shows the fundamental architecture of SMES, which consists of the superconductor coil, refrigeration system, and power conditioning system.

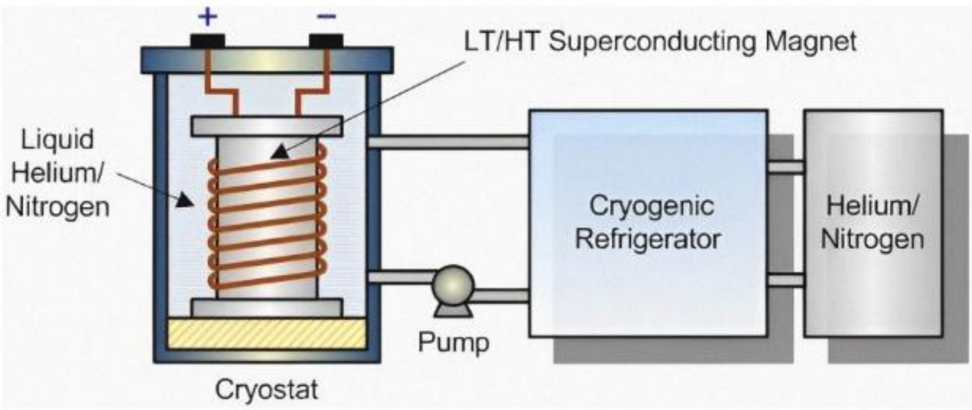

Fig.4 Super Magnetic Energy Storage [SMES] Design

The overall energy stored in superconductor coil of SMES is given below,

$E = 1/2\ Li^2$

where,

L =Coil inductance

i=Amount of current

The SMES has a high efficiency of 95% to 98% and a lifespan of around 30 years [36]. Very few superconducting magnetic energy storage devices have been built due to their exorbitant cost [37].

F. Hydrogen Energy Storage:

Coal and other non-renewable energy sources are the most well-known alternative for producing hydrogen. Chemical energy storage that uses hydrogen as its primary component can be built up anywhere and can store energy for a very long time. It has been demonstrated that hydrogen can be used to store, transport, and carry energy [38]. In Figure 5, the fundamental components of a hydrogen energy storage system (HESS) are shown below,

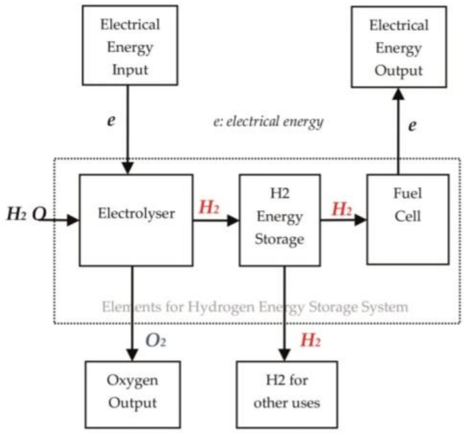

Fig.5 Basic elements of a HESS

An energy source (usually renewable) provides electrical energy, which is then converted into hydrogen for storage via an electrolyzer (hydrogen generator). The hydrogen storage system has multiple forms in which hydrogen can be stored. Following that, a hydrogen energy conversion system transforms the chemical energy held in the hydrogen back into electrical energy while emitting just heat and water as waste products without any carbon emissions.

With HES, you may create a process that doesn't emit any pollutants, has a high energy density, costs very little to operate and maintain, and can be stored for a very long period. With a capacity of more than 100 GWh and the ability to be employed simultaneously for both short- and long-term power delivery, HES is a special energy storage technology. It is regarded as a brand-new, highly promising large-scale energy storage technology [39–42].

G. Super Capacitor Energy Storage:

The usage of super capacitors for the electrostatic energy storage of these capacitors is regarded as one of the latest technologies, along with innovations in the field of electrical insulation [43]. Additionally, they are referred to as electric double layer capacitors or ultra-capacitor energy storage (UCES) (EDLC). The energy is stored as an electrostatic field when a steady dc voltage is supplied between two electrodes that are separated from one another by a thin layer of insulator or dielectric material [44].Supercapacitor Storage Systems (SSSs) are electrochemical cells with two electrode conductors, an electrolyte, and a permeable membrane that allows particles to pass between the two electrodes. Figure 6 depicts the fundamental design of a super capacitor energy storage system.

In a supercapacitor, capacity and the square of the terminal voltage are directly correlated to the quantity of energy stored.

E (Joules) =$1/2\ CV^2$

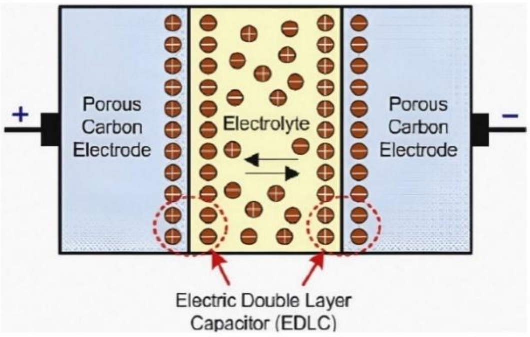

Fig.6 Graphical representation of symmetrical SCES

Compared to conventional capacitors, super capacitors have a specific energy density of roughly 5 Wh/kg, which is much greater, but only makes up 10% of the energy density of electrochemical batteries. However, compared to electrochemical batteries, super capacitors have a specific power density that is 10 to 100 times higher. The supercapacitor's charge-discharge efficiency is also between 75 and 80 percent. Supercapacitor technologies are beneficial for short-term applications as a result [23].

Conclusion:

This article reviews several ESS technologies andexplains how to use them to increase the stability and consistency of the electrical grid's operation. With regard to how dependable the energy supply is, we can install ESS technology. The goal of this study is to improve ESS technology for RES and for feeding the on-grid system without disrupting the power system network.

Electricity can now be stored for use when and where it is most needed thanks to energy storage technology. As a result, the electric grid becomes more efficient and capable, and its ability to lower greenhouse gas emissions is one of those capabilities. Energy storage can assist in integrating more solar, wind, and distributed energy resources by increasing the grid's flexibility. In addition, it can reduce the need for new peak power plants that emit pollution by raising the capacity factor of currently available resources. Energy storage makes it easier and more dependable for our energy supply mix to evolve as it becomes cleaner with low- and no-carbon resources.

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