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Electrical Energy Storage

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Abstract: Energy storage is a natural course of action but is an imperative topic to be researched upon so as to meet the energy requirements of the future and at critical stages. High amount of energy can be synthesized over a short period of time but the real challenge is to satisfy energy demand whenever needed. Energy storage implies transformation of difficult to store form of energy to a readily storable one. Assorting commercially, energy storage systems can be grouped into chemical, mechanical, thermal, electrical and biological. This paper focuses on technologies of storage of electricity.

Keywords: EES, PHS.

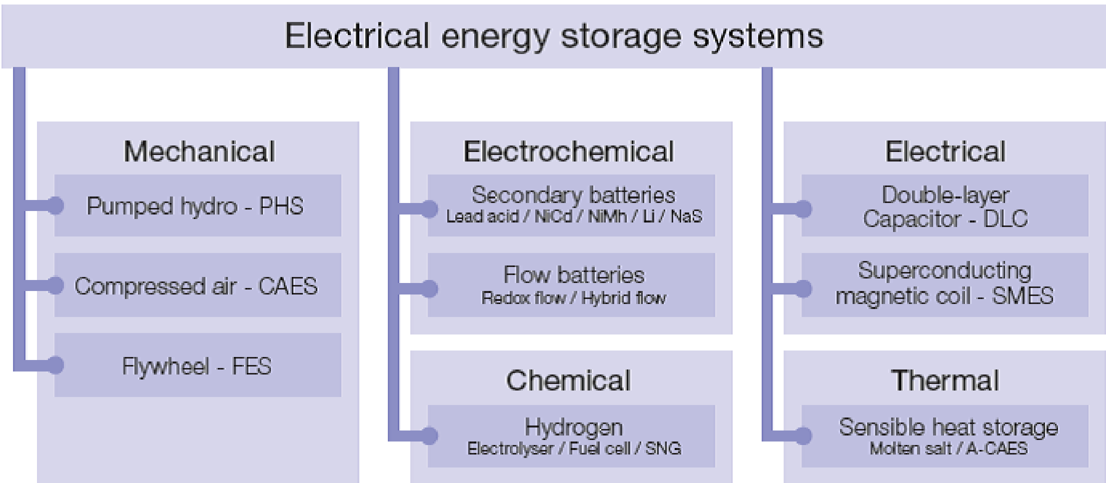

Fig 1.1 : classification of energy storage sysytems

INTRODUCTION

Electrical Energy Storage (EES) enables electric power to be produced at times when supply of electricity is less than its demand. The power is produced and stored for further use when the energy requirements are low or by utilizing intermittent energy sources.

EESs are in peak demand in context of conventional electricity generation industries. The insufficient and expensive setups are needed to be replaced and EES should be employed instead by large utility generation systems. Also proper system management should be explored so as to build proper storage systems, ensure generation of adequate supply and several other areas such as power distribution and so on.

TECHNOLOGIES OF ELECTRICAL ENERGY STORAGE:

1) *MECHANICAL ENERGY STORAGE SYSTEMS*:

a) PUMPED STORAGE HYDROELECTRICITY (PHS):

So far, pumped hydro plants are considered as the only way to store huge amount of energy with high efficiency and being economical. Thus, they share a total of 98% in global storage grid. It consists of two reservoirs interconnected with each other and at different elevations.

At the times of high production and low energy demand, the water is pumped to the higher reservoir from the lower reservoir, storing the electricity in the water in the form of potential energy.

And at the times of peak demand, the water is released down the pipes and allowing it to fall on the turbine generating electricity. The power output (P) = Q*p*g*h*n where,

Q= volume flow rates passing the turbine

p= density of water

g= acceleration due to gravity

h= elevation of the reservoirs

n= hydraulic efficiency of the turbine

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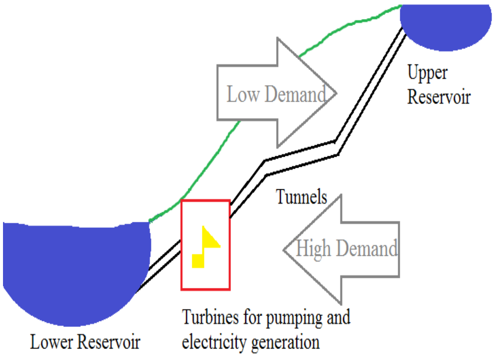

Fig 3.1: PHS system

The efficiency of the PHS plant lies in the range of 70%-85%. They are used to store energy from 8-10 hours, energy to power ratio. As a general rule, with a head of 200m, a reservoir having 1km diameter and 25m deep can produce power of 10,000MWh.

ADVATAGES:

* deals with huge amount of energy
* high efficiency
* response time is less
* economical way to store energy
* very long life time

DISADVANTAGES:

* requires large amount of water source
* less potential sites
* huge environmental impacts
* high investment cost

b) COMPRESSED AIR ENERGY STORAGE (CAES) SYSTEMS:

The CAES system uses the electricity of the off-peak hours to compress air and store it in reservoir either in pipes, vessels or in underground caverns. During the peak hours, the air is compressed, heated, expanded and directed towards the turbine to produce electricity. The compressor compresses the air up to 60 bars and stores it in underground spaces to power a turbine to generate electricity when needed. The efficiency of the CAES plant is from 50%-70%.

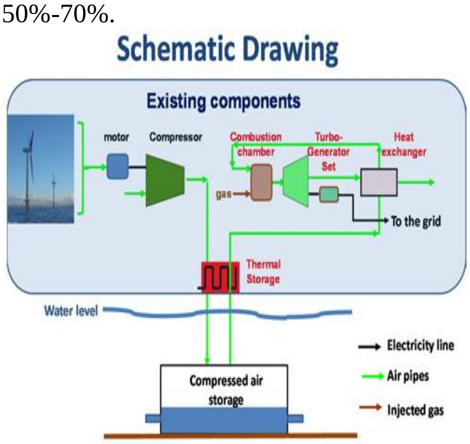

Fig 3.2: CAES

ADVANTAGES:

* capable of storing high amount of energy
* high efficiency
* fast response time
* low cost for energy storage due to caverns
* long life of the plant
* low self discharge of compressed air

DISADVANTAGES:

* required sealed storage caverns
* high self discharge of thermal storage
* economical up to a day of storage
* high cost of investment
* long return of investment

c) *FLYWHEELS*:

Flywheels store the energy in the form of a angular momentum of a spinning mass, called rotor. A flywheel is a mass rotating about an axis which stores the energy in the form of kinetic energy, during the charging process. The energy is maintained by keeping the rotating body at a constant speed in the flywheel. Higher speed results in higher energy storage. During the discharging process, the kinetic energy is extracted by deceleration of the rotating mass, by a generator driven by the inertia of the flywheel.

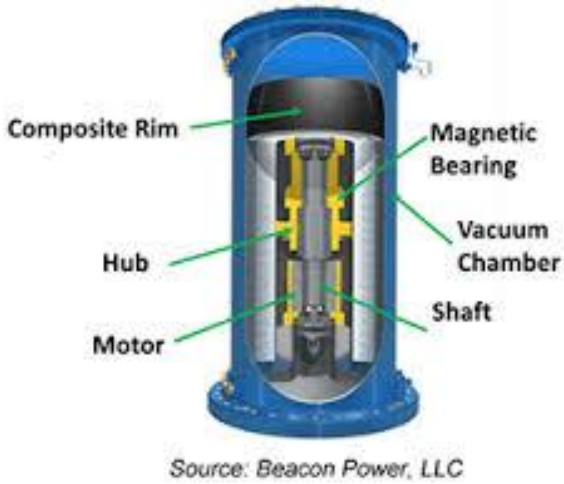

Fig 3.3: Flywheel

ADVANTAGES:

* fast charge capability
* low maintenance requirements
* higher rotational speed can be achieved byusing composite materials which increases the energy density
* long life time up to 20 yrs
* environment friendly
* advantageous for large scale grid applications
* high efficiency up to 90%

DISADVANTAGES:

* low energy density
* crack can occur due to dynamic loads and external shocks, thus safety is must
* vacuum chamber is needed
* cooling system for superconducting bearing
* low storage capacity from 0.5KWh to 10KWh

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* high acquisition cost
* high self discharge
* flywheel has a shorter energy duration system up to 1 hr

2) *ELECTRICAL ENERGY STORAGE SYSTEM*:

The need for storing electricity is because of its two main characteristics. The first being that it has to be consumed at the time of its production and the second is the use of power grids for its supply as to connect generator and consumers and so it forms power system which can lead to congestion and problems in the transmission line and so signal can be interrupted.

a) SUPER CAPACITOR:

It is an emerging technology that has higher power density than batteries and higher energy density than conventional capacitors. It stores energy in a similar way as the conventional capacitor but the charge in this case is accumulated between the electrodes and the ions in the electrolyte. So the electrical energy is stored in the static electric field. They are also used in hybrid storage systems with the batteries so as to increase batteries lifetime as their lifetime is long. Due to its high cost it can only be used in some specific fields.

ADVANTAGES:
*It has high efficiency.
*It has high power capability.
*It has long lifetime cycle.

DISADVANTAGES:
*It has high installation cost.
*For high power demands it is used with high power lithium ion batteries.

b) SUPERCONDUCTING MAGNETIC STORAGE:

It is a storage system in which there is near zero loss of energy takes place. The electricity from the grid is stored within the magnetic field of a superconducting coil. It works with the charging and discharging of the superconductive coil. Charging takes place when direct current is supplied from the inverter to the coil which induces a constant magnetic field, where energy can be stored. The coil is placed in the liquid helium (below -260°C) so as to enable its superconducting properties. The discharging starts when an external load is connected to the coil. It is a short-term storage system. It plays a crucial role in maintaining grid reliability to replace sudden power loss or dip in line power as it can release high power within a fraction of cycle.

ADVANTAGES:
*It has high power capability.
*It has cycle life.

DISADVANTAGES:
*It needs high cooling.
*It needs expensive raw materials for superconductors.

*Design of circuit is complicated.

3) THERMAL ENERGY STORAGE SYSTEM:

a) THERMOELECTRIC STORAGE:

High temperature thermo electric energy storage systems (TEES) are used to store the electrical energy. Thermal energy storage systems store the available heat by different means in an insulated repository, for its future use. The thermal energy storage technologies can be further sub-divided as: Storage of latent heat, storage of sensible heat and the thermo chemical adsorption and absorption storage. By an electrical heater during the charging process the high temperature heat is produced.

And in the discharging process, the heat is extracted from the thermal storage and steam is produced which drives a turbine. The heat is stored in a thermal storage like magnesium oxide bricks or molten salt brine. The turbine then finally feeds power into the electricity grid.

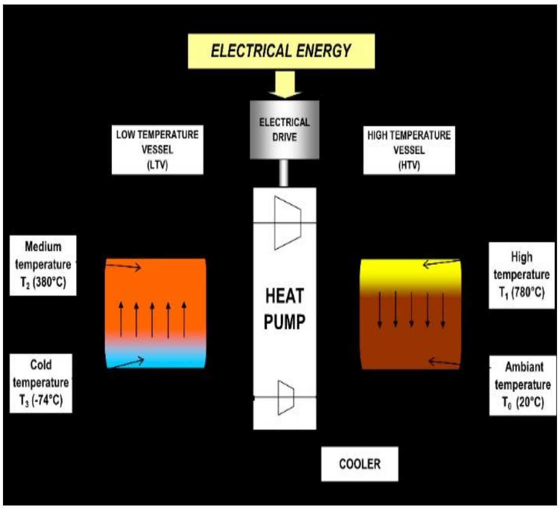

fig 3.4 : themral energy storage system

ADVANTAGES:
*no special site requirement
*large scale storage is possible
*energy density in the range of thermo chemical batteries

DISADVANTAGES:
*considerable thermal losses
*relatively low efficiency

4) CHEMICAL ENERGY SOTARGE TECHNOLOGIES:

The chemical energy storage can be majorly classified as:
* internal storages
* external storages

In external energy storage, the energy content and the power capability can be designed separately and in internal energy storage systems the energy content and power

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supply depend on each other. Higher energy content also means higher power capability.

a) CHEMICAL INTERNAL STORAGE SYSTEM

The internal energy storage can be further classified as:
* low temperature battery
* high temperature battery

(i)LEAD-ACID BATTERIES:
It is system in which two lead electrodes are placed in an acid which act as an electrolyte and it dissolute into cations and anions. It is the oldest and most widely used energy storage system. They can be utilised in various applications such as automotive starter batteries and UPS systems for telecommunications. Lead which is toxic in nature is used so its recycling is very important.

(ii) LITHIUM ION BATTERIES:
These are the most widely used rechargeable batteries. The positive electrode of the battery is made up of lithiated metal oxide, and the negative electrode composed of layered graphitic carbon. During the charging process, the lithium ions move from the positive to the negative electrode and are intercalated into the graphite layers. The electrolyte is made up of lithium salts and is dissolved into organic carbonates. Also, during the discharging process, the lithium ions move to the positive electrode where they are intercalated into the crystal structure.

(iii)HIGH TEMPERATURE BATTERIES:
These batteries are medium-term storage batteries .Sodium-Nickel-Chloride (also known as Zebra-battery) and Sodium-Sulphur batteries are the two examples of these. The electrolytes used in these are in solid form but for charging and discharging they should
be present in fluid form, so an operation temperature of 270C-350C is needed.These batteries are used for daily cycling but are not useful in those
purposes where uninterrupted power supply in needed.

b) CHEMICAL EXTERNAL STORAGE SYSTEM:

(i)FLOW BATTERIES:
In these batteries active materials are dissolved in the electrolyte and are stored in the tank. The electrolyte is pumped from the tank during charging and discharging .This technology can bridge the tank between medium-term storage and long-term storage.

(ii)HYDROGEN STORAGE SYSTEM:
During charging process hydrogen is produced which is used for driving combustion turbine and fuel cells.

CONCLUSION

EESs are of vital importance to the power production sector. Despite the fact that EES are enjoying some technical advancements currently, no such systems have been crafted which satisfies all the requirements such as being economical, highly efficient, environment friendly and so on. Even more developed technologies are being worked upon by researchers such as those which are benign to environment and have high energy density.

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