ENERGY STORAGE SYSTEMS
UNIT-I
INTRODUCTION

1.1 **Necessity of energy storage:**

Energy Storage is the capture of energy produced at one time for use at a later time. A device that stores energy is generally called an accumulator or battery .

Energy comes in multiple forms including radiation, chemical, gravitational potential, electrical potential electricity, elevated temperature, latent heat and kinetic. Energy storage involves converting energy from forms that are difficult to store to more conveniently or economically storable forms. Some techniques provide short term energy storage, while others can endure for much longer.

1.2.Types of energy storage

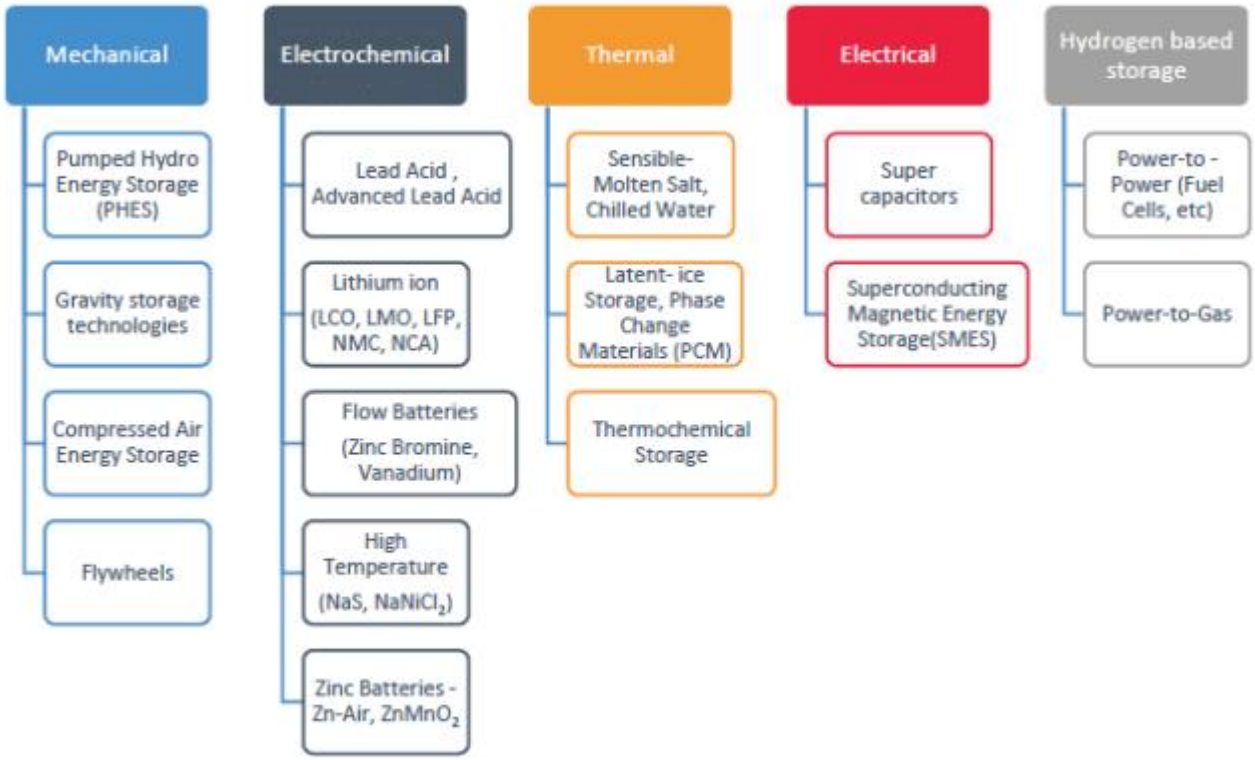


Figure 1: Classification of Energy Storage Technologies

1.Mechanical Energy Storage System

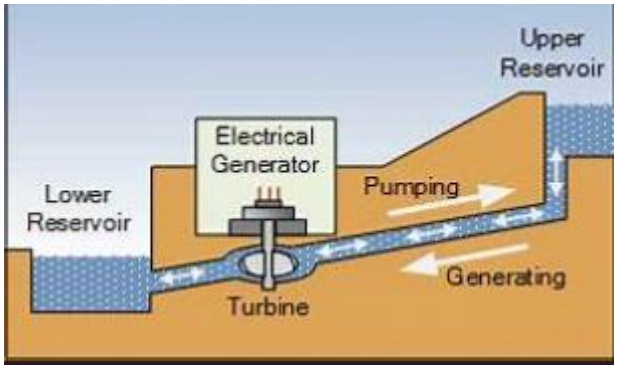
Mechanical Energy Storage Systems (MESSs) are commonly used to produce electricity throughout the world. MESSs are classified into Pumped Hydro Energy Storage (PHES),Gravity Storage Technologies (GST), Compressed Air Energy Storage (CAES), and Flywheel Energy Storage (FES). The most popular MESS is PHES, which are used in pumped hydroelectric power plants.

- **Pumped Hydro Energy Storage (PHES)**

Working Principle

- PHES works by using the potential energy of water to store electricity.

- When water is pumped from the lower reservoir to the upper reservoir, it gains potential energy.
- This potential energy is then converted into electricity when the water is released from the upper reservoir through turbines.



Advantages

- High storage capacity.
- Long operational life and high efficiency (70–85%).
- Mature and reliable technology.

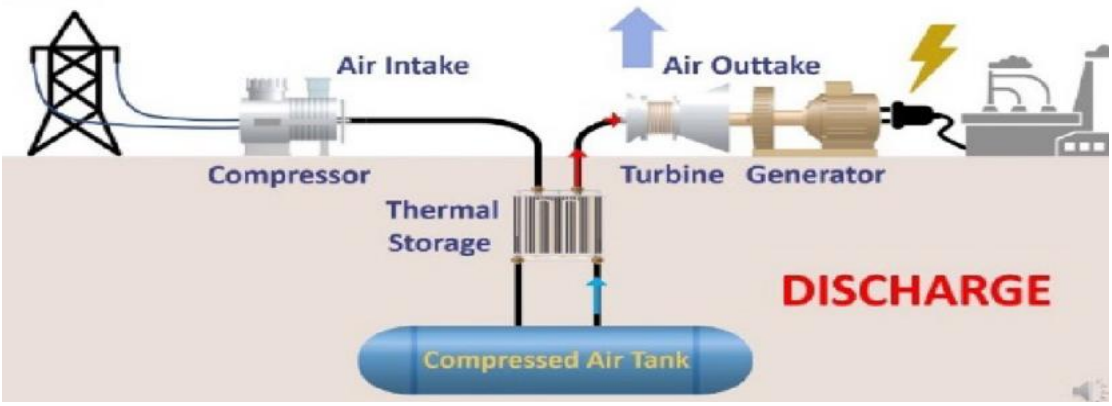
Limitations

- Requires suitable geography (elevation).
- Large environmental and land-use impact.
- Long construction time and high capital cost.

❖ **Compressed Air Energy Storage (CAES)**

Working Principle

- Air is compressed and stored in underground caverns or high pressure tanks .
- The compressed air is heated and expanded through turbines to generate electricity.



Advantages

- Large capacity (similar to PHES).
- Long storage duration.
- Lower cost per kWh for large installations.

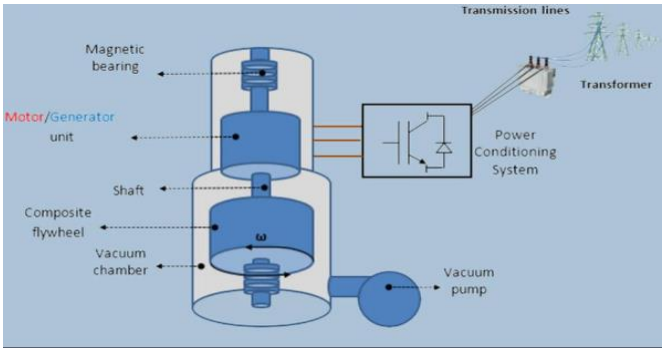
Limitations

- Lower efficiency (40–70%) due to heat loss.
- Requires suitable geological formations.
- Complex system with combustion in some designs.

❖ **Fly wheels Energy Storage**

Working Principle

- Energy is stored in the form of mechanical energy.
- A heavy rotating rotar is accelerated by an electric motor, which acts as a generator on reversal, slowing down the disc and producing electricity.



Advantages

- Very fast charge/discharge.
- High cycle life and very low maintenance.
- High power density.

Limitations

- Short duration storage (seconds to minutes).
- High cost for large energy capacities.
- Safety concerns if rotor fails at high speeds.

❖ **Gravity-based energy storage systems:**

Gravity-based energy storage systems store energy by lifting a mass to height. When the mass is released, it falls and its potential energy is converted into kinetic energy, which can then be used to generate electricity.

Advantages

- They have a long lifespan and require little maintenance.
- They are relatively inexpensive to build.
- They can store large amounts of energy for long periods of time.

Limitations

- They are not as efficient as other types of energy storage systems.
- They can only be used in certain locations with the right terrain.
- They can have a visual and environmental impact.

2. Electrochemical Energy Storage System or Battery Energy Storage System

This involves storing energy through chemical reactions through rechargeable battery systems.

✧ **Lithium ion Battery:** Lithium ions moves between electrodes during charging and discharging.

Applications: Electric Vehicles,grid storage,Smartphones,Laptops

✧ **Lead Acid Battery:** Chemical reaction between lead oxide and lead in sulphuric acid electrolyte.

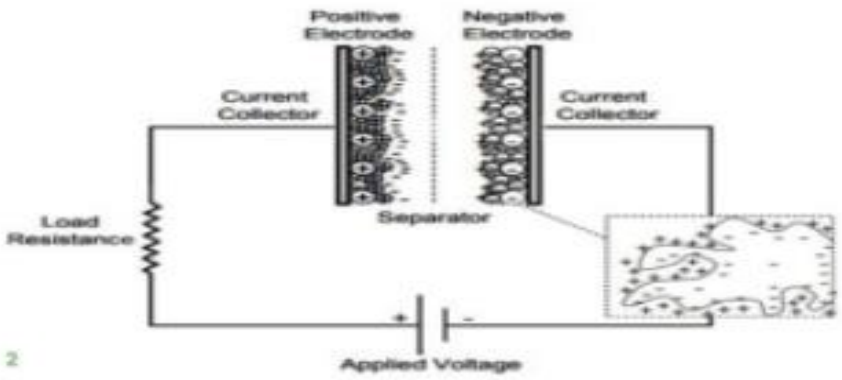
Applications: Backup power, vehicles(starting batteries), off-grid systems

✧ **Flow Batteries:** It is a rechargeable battery that stores energy in liquid electrolytes stored in external tanks flow through a central cell stack tom produce electricity..

Applications: Stationary energy storage for renewable integration.

- ✧ **Sodium Sulphur (NaS) Batteries:** Molten sodium and sulphur react at high temperatures(~300^0C).

Applications: Grid storage in countries like Japan



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3. Thermal Energy Storage System

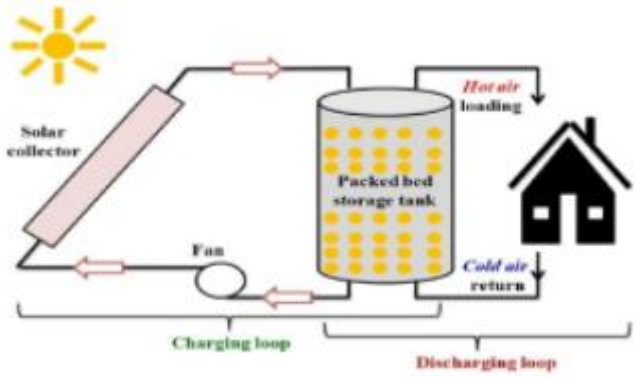
Thermal Energy Storage (TES) Systems can store heat or cold for later use, which can help to balance energy demand and supply. It reduces energy costs, and improve energy efficiency. TES systems are used in a variety of applications, including heating and cooling of buildings, industrial processes, and power generation.

Types of TES systems:

There are three main types of TES systems.

- ➢ Sensible heat storage
- ➢ Latent heat storage
- ➢ Thermochemical storage

- ➢ **Sensible heat storage:** Stores heat energy by raising the temperature of a material.
  Example: water, molten salt
  Applications: Concentrated solar power,district heating
- ➢ **Latent heat storage:** Stores heat energy by using phase change materials.
  Example: ice melting
  Applications: HVAC systems, solar heating
- ➢ **Thermochemical storage:** Stores heat energy by using chemical reactions
  Applications: Long duration storage, solar energy systems



4.Electrical or Electromagnetic Energy Storage:

Stores energy in magnetic or electric fields, typically for quality applications.It classified into two types. They are supercapacitors and superconducting magnetic energy storage

Advantages

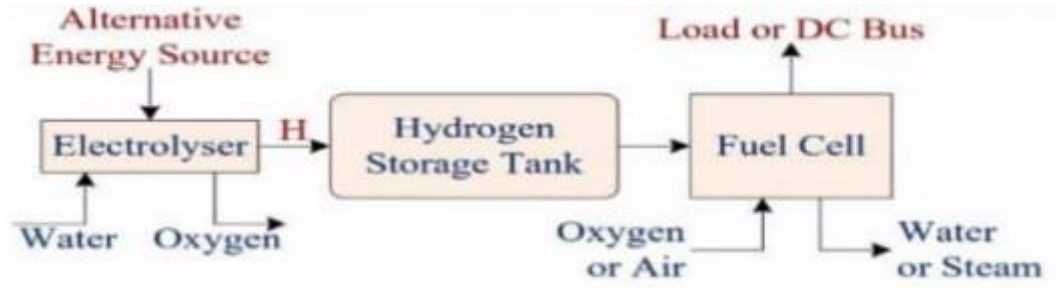
- Extremely fast response
- High efficienc
- Long cycle life
- No chemical degradation

Limitations

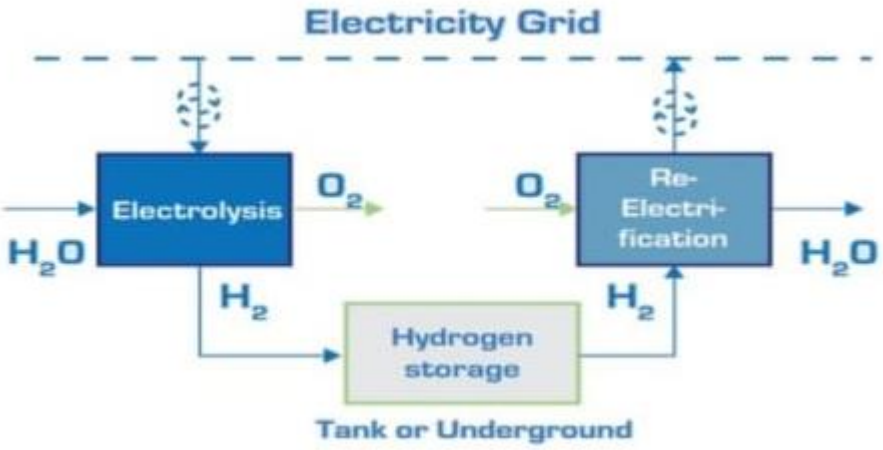
- Low energy density
- High initial cost (especially SMES)

5.Chemical Energy Storage: Electrical energy stored by producing chemical fuels.

- **Hydrogen Energy Storage**
  Electricity is used to split water into hydrogen and oxygen (electrolysis). Hydrogen is stored and later used in fuel cells or burned to produce electricity.
  Applications: Energy storage, transportation fuel, industrial use.



- **Synthetic Fuels(e-fuels)or Power -to-Gas**
  Electricity is used to create hydrocarbons from CO_2 and hydrogen.
  Applications: Aviation, shipping, heavy transport


Electricity Grid
Electrolysis
O2
H2O
H2
Hydrogen storage
Tank or Underground
O2
Re-Electri-fication
H2O
H2