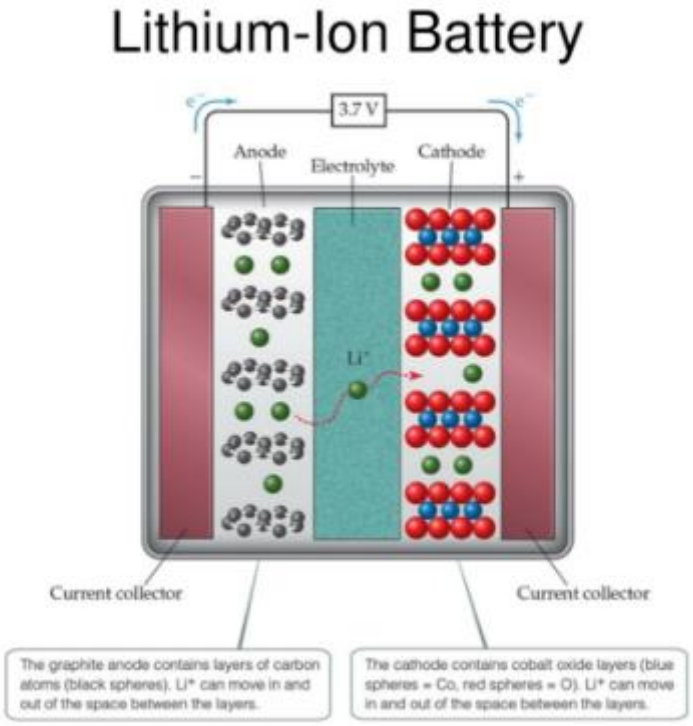
ENERGY STORAGE SYSTEMS
UNIT-I
INTRODUCTION

Comparison of Energy Storage Technologies

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



Advantages

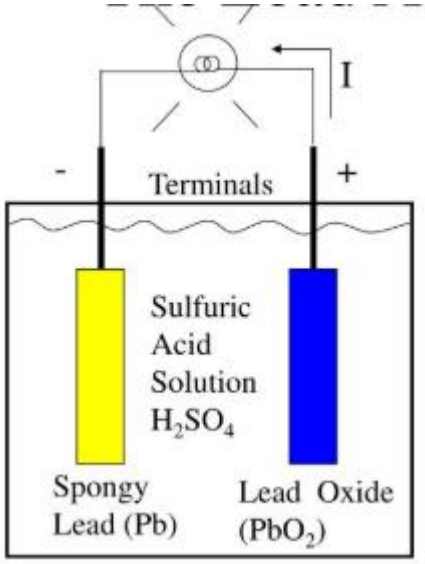
- high energy density
- Long life cycle
- Fast charging
- Low self discharge

Limitations

- Expensive
- Thermal runaway risk
- Limited raw material

Applications: Electric Vehicles,grid storage,Smartphones,Laptops

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



Advantages

- Low cost
- Mature technology

Limitations

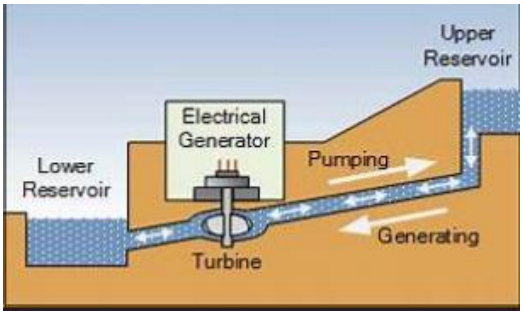
- Low energy density
- Short life cycle
- heavy

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

3. 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

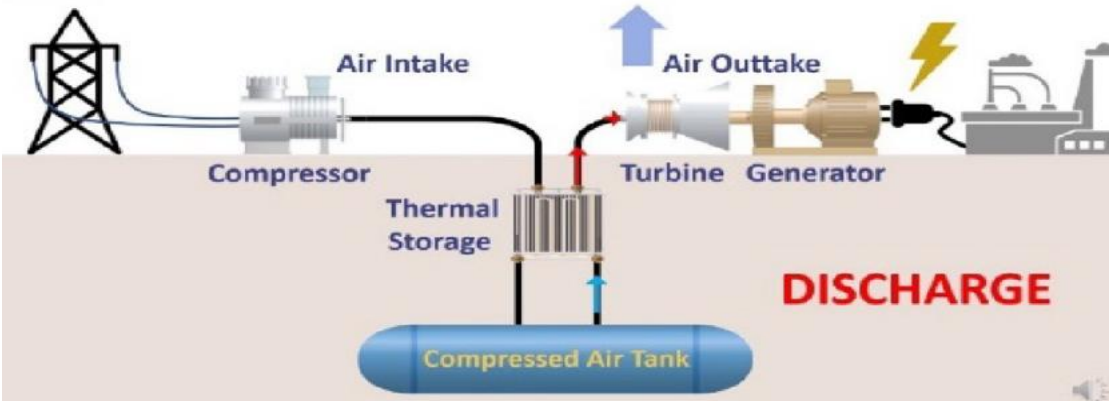
- Requires suitable geography (elevation).
- Large environmental and land-use impact.
- Long construction time and high capital cost.

Application: Grid-scale energy balancing, peak shaving

4. Compressed Air Energy Storage

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

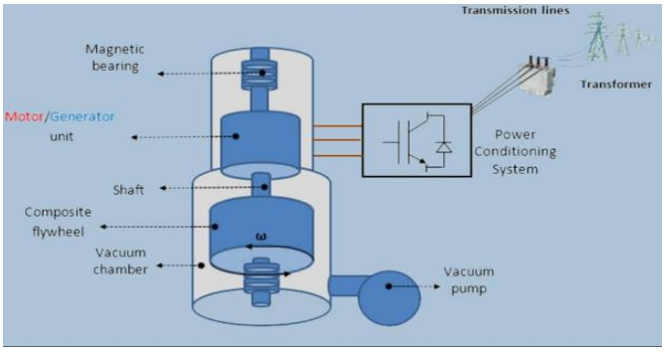
- Lower efficiency (40–70%) due to heat loss.
- Requires suitable geological formations.
- Complex system with combustion in some designs.

Application: Grid energy storing, load leveling

5. 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.

Application: Frequency regulation,UPS systems,transit systems

6.Thermal Energy Storage

Thermal Energy Storage (TES) Systems can store heat or cold for later use, often using molten salt or chilled water.

Types of TES systems:

- **Sensible heat storage:** Stores heat energy by raising the temperature of a material.
- **Latent heat storage:** Stores heat energy by using phase change materials.
- **Thermochemical storage:** Stores heat energy by using chemical reactions

Advantages

- Cost effective
- Suitable for solar thermal plants
- Long duration

Limitations

- Limited to heating /cooling applications
- Heat losses over time

Application:district heating,concentrated solar power,building HVAC

Comparison of Energy Storage System

Energy Storage System	**Efficiency**	**Life cycle**
Pumped Hydro Energy Storage	70- 85%	40-60 years
Compressed Air Energy Storage	40-70%	20-40 years
Flywheel Energy Storage	85-95%	>20 years
Lithium ion battery	90-95%	2000-6000 cycles
Lead-acid battery	70-85%	500-1500 cycles
Thermal Energy Storage	50-90%	long