Energy Storage Technologies

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Overview

- Why Energy Storage ?
- Types of Energy Storage
- How Energy is Stored ?
- Pros & Cons
- Applications
- Conclusion & Future of Energy Storage Systems

Why Energy Storage

- Energy storage allows cheaper sources of electricity generation to produce power during low-demand periods and store it for later use during peak demand times. This flexibility has the potential to revolutionize both electricity production and consumption patterns.

- Energy storage is crucial for advancing and incorporating renewable energy technologies. Many renewable sources generate electricity intermittently, only when the sun is shining or the wind is blowing. This inconsistency between supply and demand arises because consumers still need electricity even when renewable sources are not producing.

- Enhances existing energy storage methods and creating new ones aim to minimize energy loss, decrease storage expenses, and ensure a dependable power provision

Types of Energy Storage

1. Pumped Hydroelectric Storage (PHS)
2. Batteries
3. Compressed Air Energy Storage (CAES)
4. Super Capacitors
5. Super Conducting Magnetic Energy Storage (SCMES)
6. Flywheel

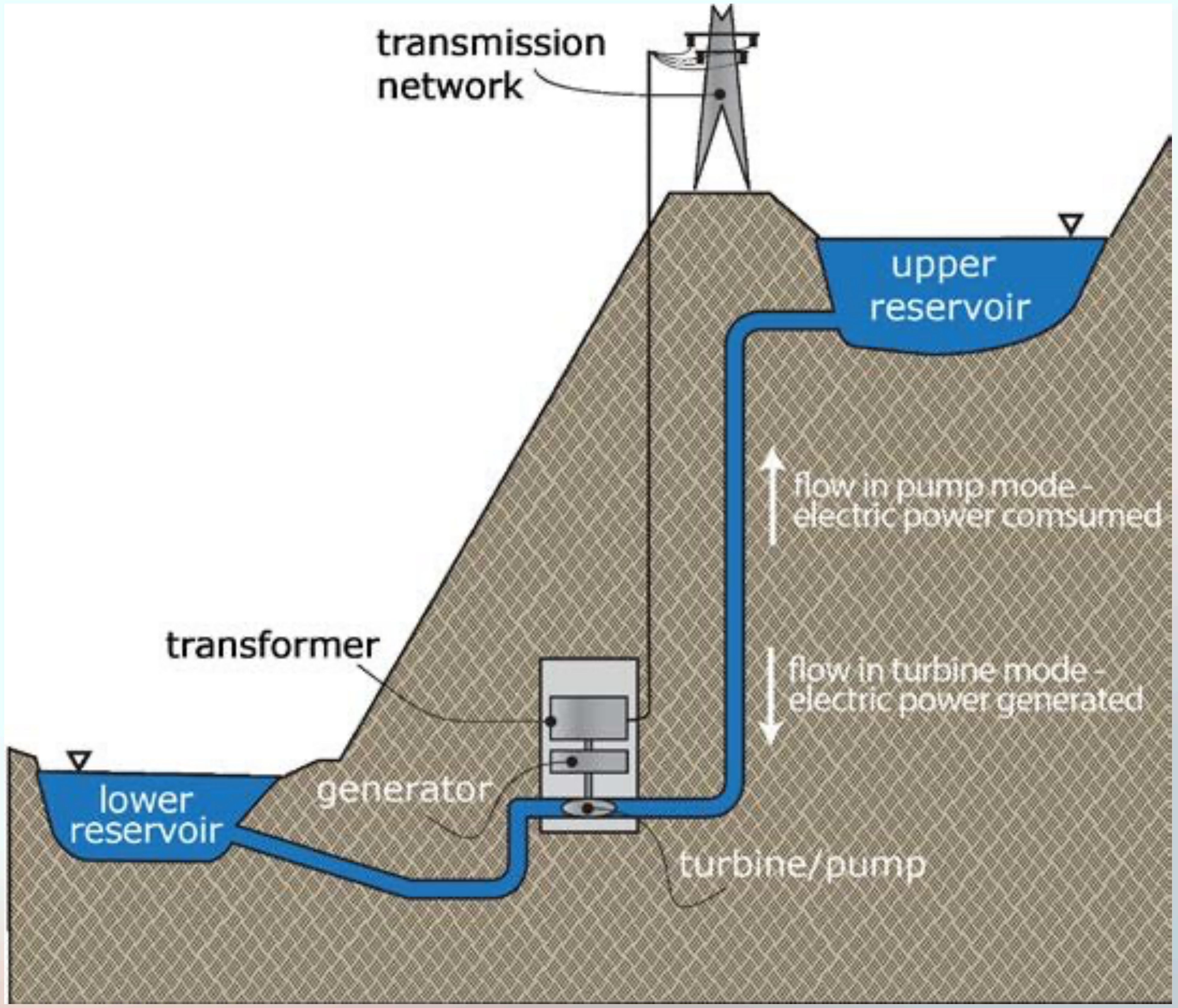
Pumped Hydroelectric Storage (PHS)

1. **Pumping Water Up**: During periods of low electricity demand, pumps are used to lift water from a lower reservoir to a higher reservoir.

2. **Storing Potential Energy**: By moving water uphill, it gains gravitational potential energy. The higher the water is lifted, the more potential energy it possesses.

3. **Releasing Water Down**: When electricity demand increases and more power is needed on the grid, the stored water in the upper reservoir is released. As it flows downhill, it passes through turbines that are connected to generators. The turbines convert the potential energy of the falling water into kinetic energy, which in turn drives the generators to produce electricity.

4. **Generating Electricity**: The electricity generated during this process is then fed into the grid to meet the increased demand.



Pros:

- Huge energy and power capacity

Cons:

- Requires special location
- Expensive to build
- Not suitable for Distributed energy resources

Batteries

- Batteries store energy in chemical form during charging and discharge electrical energy when connected to a load. In its simplest form a battery consists of two electrodes, a positive and a negative placed in an electrolyte.

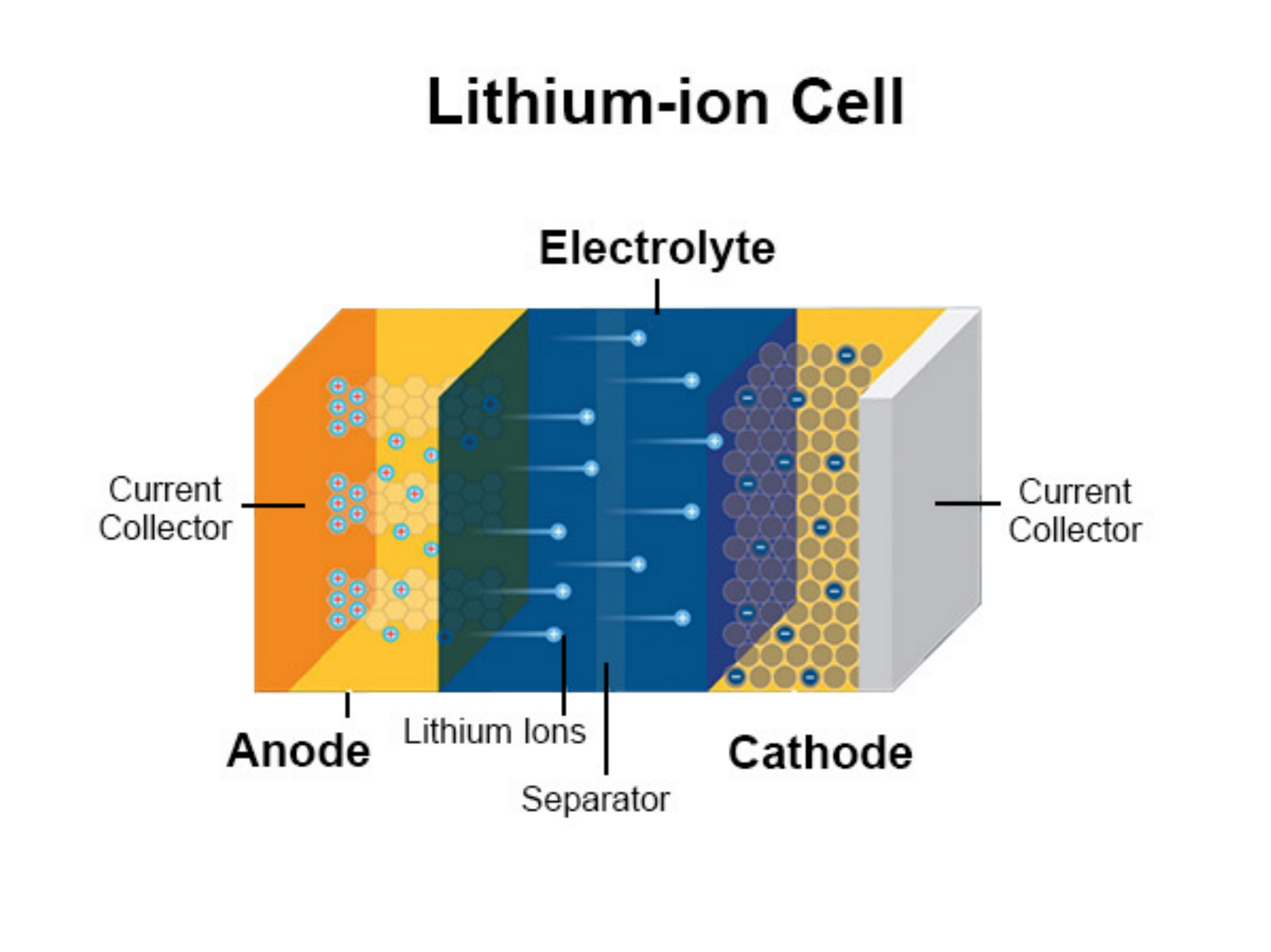
- A battery consists of three main components: electrodes, electrolyte, and casing.
- The electrodes are typically made of different materials, such as lithium, lead, or nickel.

Pros:

- Convenient sizing, voltage characteristics, portable

Cons:

- Limited life span
- Voltage and current limitations, requiring complex series/parallel system



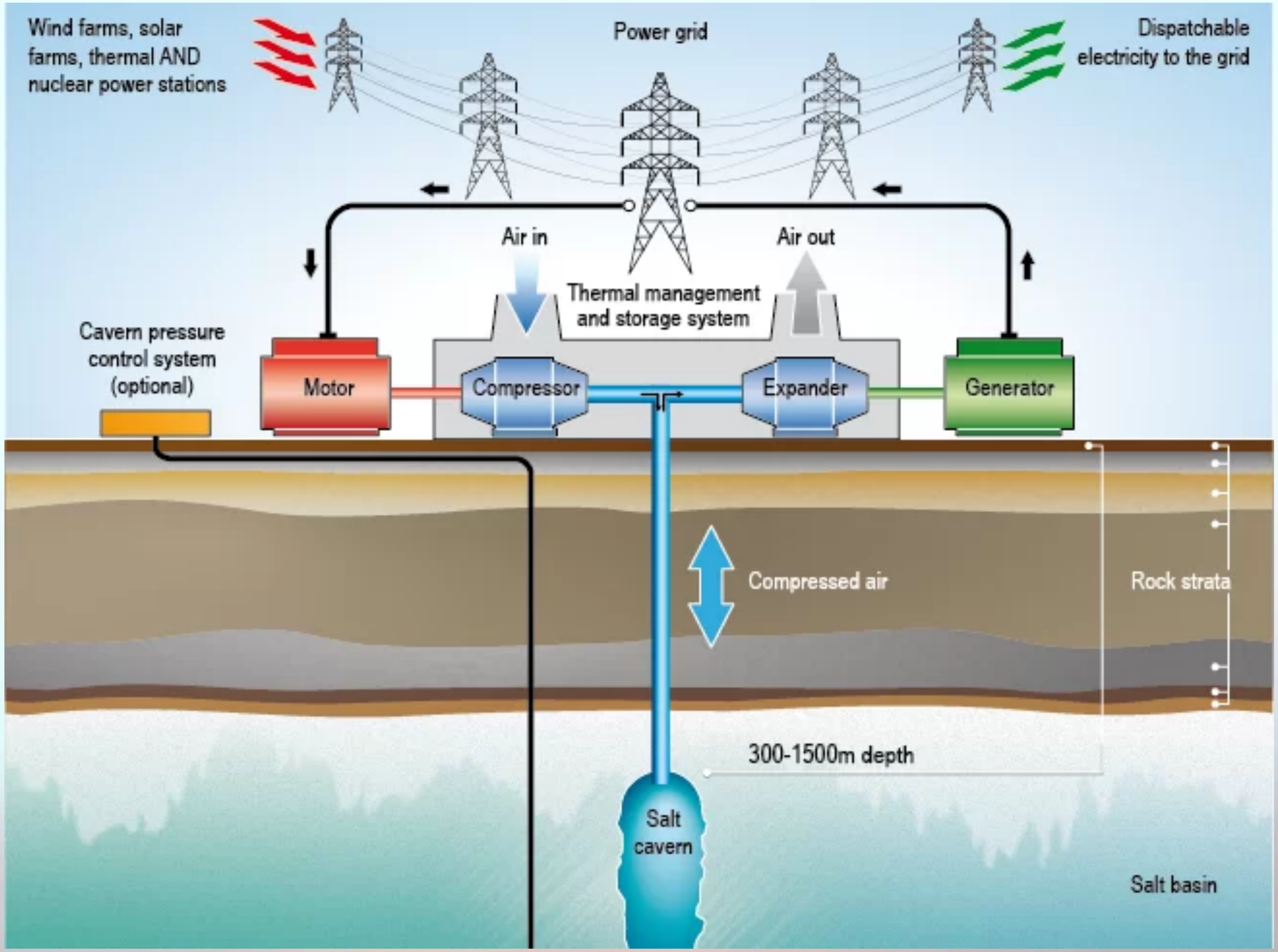
Compressed Air Energy Storage (CAES)

1. **Compression**: During periods of low electricity demand or when excess electricity is available on the grid, electrically driven compressors are used to compress air.

2. **Storage**: The compressed air is stored in large underground reservoirs or above-ground tanks. The reservoirs are typically located in geological formations such as salt caverns or depleted natural gas fields, where the high-pressure air can be safely stored.

3. **Expansion:** When electricity demand increases, the stored compressed air is released from the reservoirs. The air is expanded through turbines driving them, which are in turn connected to generators, converting the stored energy into electrical energy.

4. **Generating Electricity**: The electricity generated during this process is then fed into the grid to meet the increased demand.


Wind farms, solar farms, thermal AND nuclear power stations
Power grid
Dispatchable electricity to the grid
Air in
Air out
Thermal management and storage system
Cavern pressure control system (optional)
Motor
Compressor
Expander
Generator
Compressed air
Rock strata
300-1500m depth
Salt cavern
Salt basin

Pros:

- Large-Scale Storage, efficiency of 70%, long duration of storage

Cons:

- **Geographical constrains:** Require suitable geological formations for underground air storage, which may limit their deployment in certain regions.

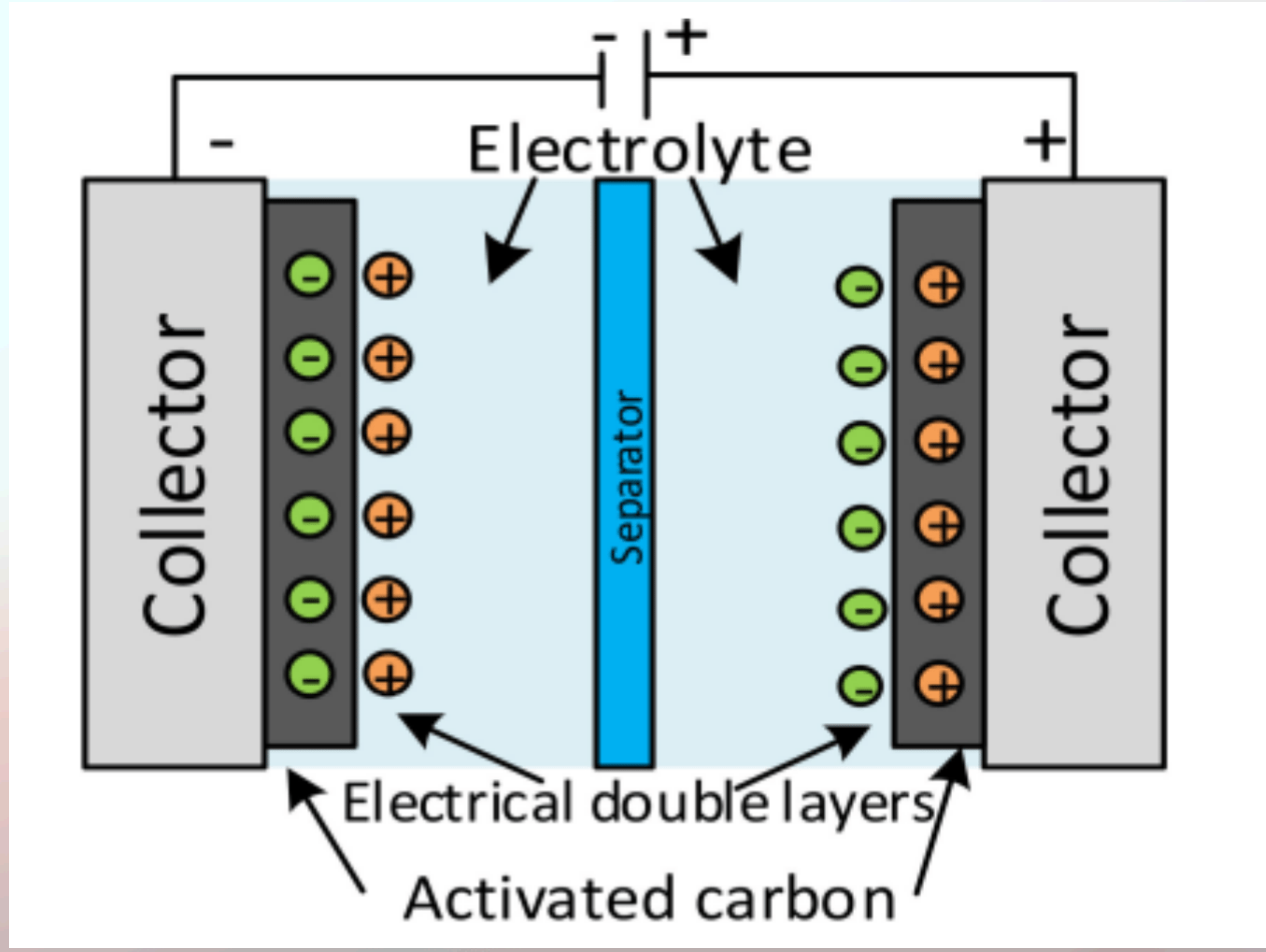
- **Energy Losses**: Due to air compression and expansion, which incur energy losses which in turn can reduce overall system efficiency.

- **Limited Ramp Rates**: CAES systems have limited ramp rates, meaning that they may not respond as quickly to rapid changes in electricity demand compared to other energy storage technologies.

Super Capacitors/Ultracapacitors/Electrochemical capacitors:

1. **Working Principle**: Energy is stored in an electric field formed between two electrodes, typically made of activated carbon, with an electrolyte in between. Unlike batteries, which rely on chemical reactions for energy storage, super capacitors store energy electrostatically.

2. **Energy Storage Mechanism**: When a voltage is applied, ions from the electrolyte accumulate on the surface of the electrodes, forming an electric double layer. This process allows for rapid charge and discharge, providing high power density.



Pros:

- High Power Density
- Long Cycle Life
- Quick Recharge
- High Efficiency

Cons:

- Low Energy Density
- Voltage Limitation
- High Self Discharge compared to batteries

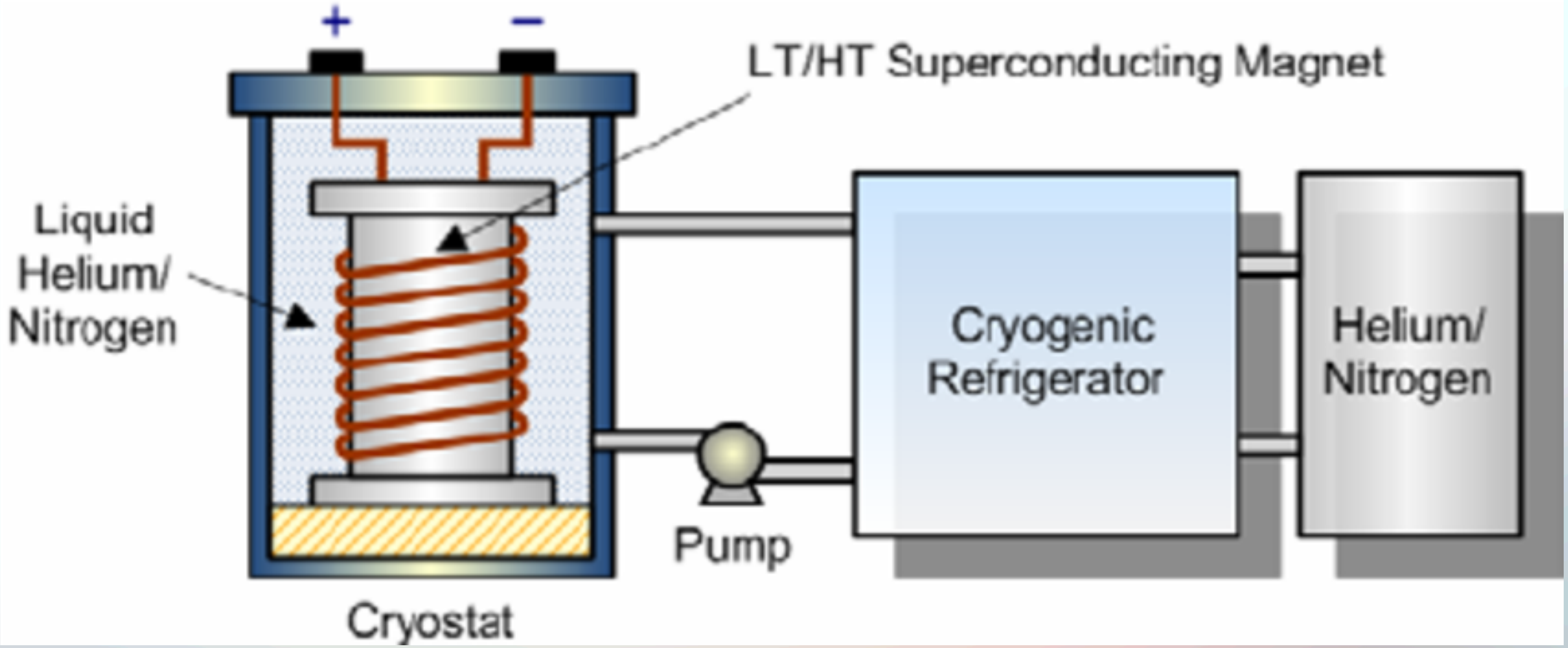
Superconducting Magnetic Energy storage(SMES)

1. Superconducting Magnetic Energy Storage (SMES) is a technology that stores electrical energy in the form of a magnetic field generated by a superconducting coil.

2. Energy Storage Mechanism: When electrical energy is supplied to the SMES system, it is converted into a magnetic field by passing a current through the superconducting coils. The magnetic field is stored within the coils as long as the superconducting state is maintained.

3. In a superconducting coil, resistive losses are negligible and so the energy stored in the energy magnetic field does not reduce with time.

4. However, in order to maintain the superconductivity of the SMES coil, a cryostat which can keep the temperature of the coil below the superconductor temperature limit is required.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−
LT/HT Superconducting Magnet
Liquid
Helium/
Nitrogen
Cryogenic
Refrigerator
Helium/
Nitrogen
Pump
Cryostat

Flywheel

- The principle behind flywheel energy storage is to store energy in the form of rotational kinetic energy.

- It is a motor generator set.

In Vacuum

- To charge the flywheel, useful energy is used to increase the rotational speed of the flywheel- thus increasing its energy content.
- To discharge, kinetic energy is extracted from the flywheel (the flywheel is slowed) and converted into electricity via a generator (driven by the flywhe

Pros:

- High Power Density
- Long Life and Good Efficiency (95%) over short time scales
- Quick Recharge
- Power & Energy Sizing

Cons:

- Low Energy Density
- Large Standby Losses
- Potentially dangerous failure mode

Applications of ES Technologies

- Li-ion batteries are now being widely used for applications such as powering laptop computers, mobile phones, camera, EVs etc.
- Super capacitors: Regenerative Braking in Electric Vehicle, UPS(Uninterruptible Power Supplies) Systems etc.
- Flywheel: Aircraft launching system,Amusement Rides etc.
- CAES: Manufacturing, Automotive Industries.
- All ES technologies have a wide range of applications such as:

1.Grid Stabilization and Balancing

2. Renewable Energy Integration

3. Peak Load Management

4. Backup Power and UPS

5. Residential, Commercial and Industrial use etc…..

Conclusion & Future of ES Technologies

- In conclusion, energy storage technologies represent a critical component of modern energy systems, offering solutions to address challenges such as grid stability, renewable energy integration, peak load management, and transportation electrification. From batteries and pumped hydro storage to flywheels and super capacitors, a diverse range of energy storage options exists, each with its unique characteristics and applications.

- Key trends shaping the future of ES include: Advancements in Performance and Efficiency, Hybrid and Integrated Systems, Smart Grid and Energy Management Solutions.

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