RENEWABLE ENERGY SYSTEMS

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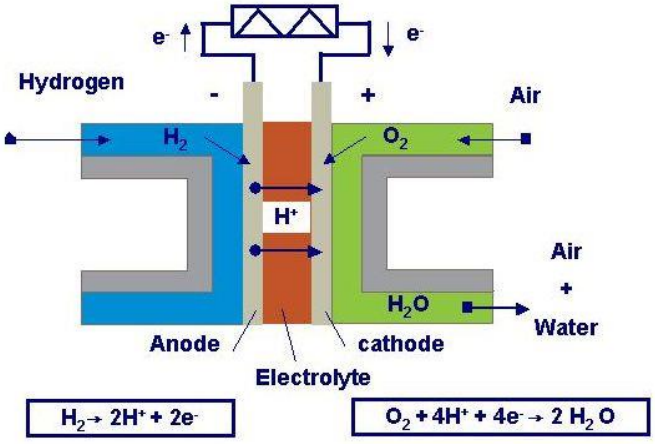
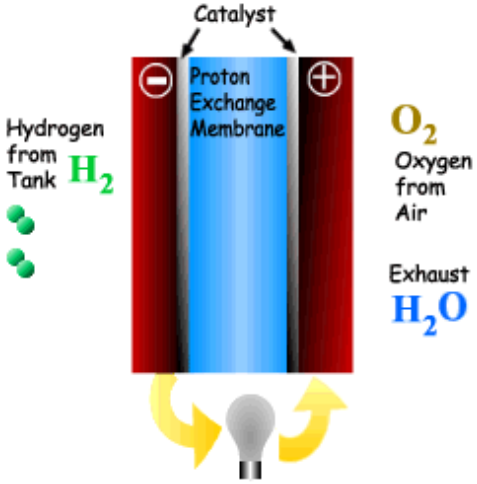
Lecture V: Other RES Types and Energy Storage Systems

HYDROGEN POWER PLANTS

Hydrogen Power Plants

- The hydrogen with the simplest atomic structure in the nature is the fundamental material of all stars and planet.
- Hydrogen has the highest energy content per unit mass within all types of fuels.
- Hydrogen that is gathered via the electrolysis of water, reformation of conventional fuels such as natural gas, etc. is used in power systems via the fuel cell technology.
- A fuel cell is an energy convertor that generates electric energy and heat by electrochemically merging a fuel in gaseous phase (hydrogen) and an oxidant (oxygen in air). The waste after this process is just water.





Hydrogen Power Plants

- The fundamental principles of fuel cell was provided by Swedish scientist Christian Friedrich Schönbein in 1938.
- In 1839, Sir William Grobe provided the first fuel cell structure by aplying the reverse of electrolysis process.
- In 1950, Francis Becon from Cambridge University developed the first 5 kW alkaline fuel cell system.
- In 1970, NASA developed a 12 kW alkaline fuel cell system to use in space stations.
- Since mid 1960s, different fuel cell types have been investigated to use in transportation systems, portable applications, etc…
- There are different types of fuel cell systems: Proton exchange membrane (PEM) fuel cell, alkaline fuel cell, molten carbonate fuel cell, solid oxide fuel cell and phosphoric acid fuel cell.
- 11.2 MW fuel cell power plant in South Korea is the biggest fuel cell power plant application.
- Among them PEM fuel cell is the one that is more widely used in many applications among other fuel cells.

Hydrogen Power Plants

Hydrogen Power Plants

Some advantages of fuel cells are as follows:

- They can provide high operational efficiency.
- They have a significantly modular structure.
- They do not produce wastes that can give harm to environment.
- As they do not have moving parts, they require lower requirements.
- They can provide power as much as there is fuel supply, thus they are controllable in terms of power generation.

Some disadvantages of fuel cells are also as follows:

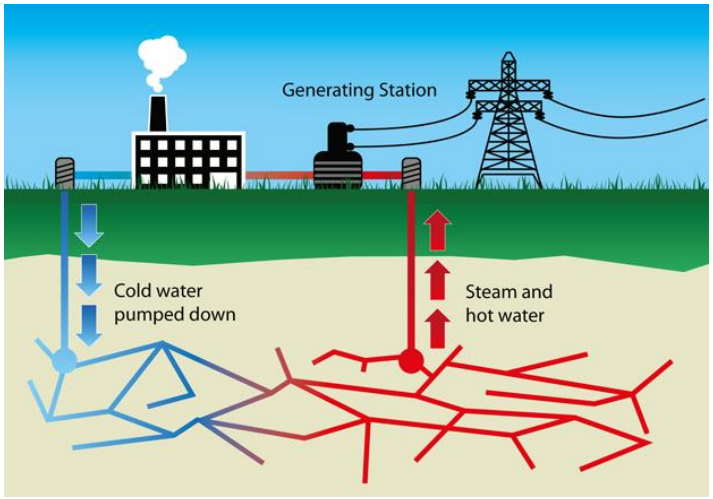
- All fuel cells are significantly costly compared to conventional systems due to special components in their structure.
- If there will be a fuel reformation to produce hydrogen, this technology is also costly and this reformation also requires some energy consumption.
- The negative first impression on using flammable hydrogen in daily life is a question to be wider acceptance of fuel cell utilization by end-users.

OTHER TYPES OF POWER PLANTS

Other Types of Power Plants

Geothermal Energy:

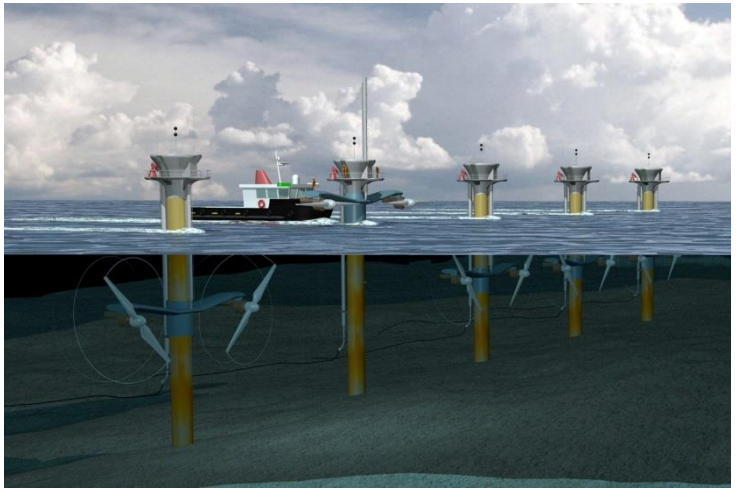
Geothermal energy is thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter. The geothermal energy of the Earth's crust originates from the original formation of the planet (20%) and from radioactive decay of materials (80%). The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. The adjective *geothermal* originates from the Greek roots *γη (ge)*, meaning earth, and *θερμος (thermos)*, meaning hot.

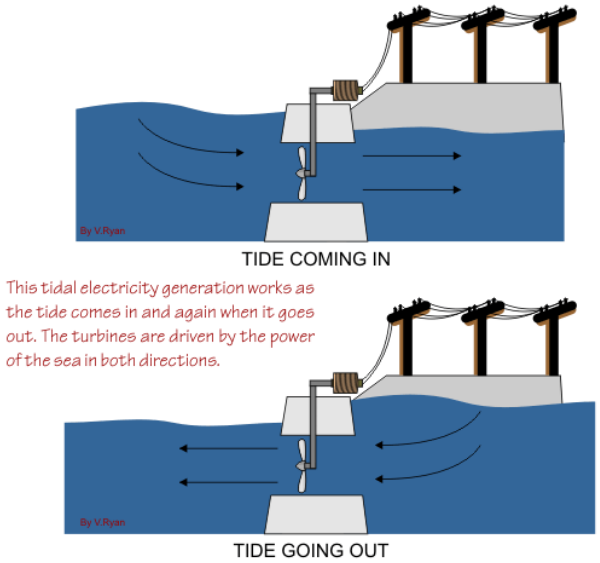


The Earth's geothermal resources are theoretically more than adequate to supply humanity's energy needs, but only a very small fraction may be profitably exploited. Drilling and exploration for deep resources is very expensive. Forecasts for the future of geothermal power depend on assumptions about technology, energy prices, subsidies, and interest rates.

Other Types of Power Plants

Tidal Energy:

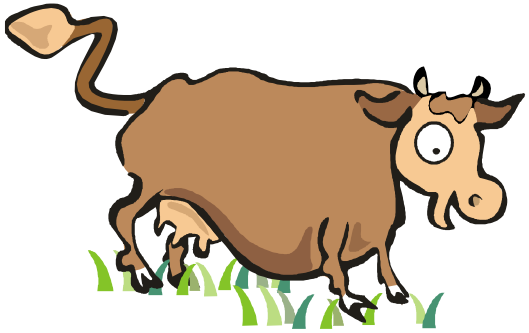




Tidal power is taken from the Earth's oceanic tides; tidal forces are periodic variations in gravitational attraction exerted by celestial bodies. These forces create corresponding motions or currents in the world's oceans. Due to the strong attraction to the oceans, a bulge in the water level is created, causing a temporary increase in sea level. When the sea level is raised, water from the middle of the ocean is forced to move toward the shorelines, creating a tide. A tidal generator converts the energy of tidal flows into electricity. Greater tidal variation and higher tidal current velocities can dramatically increase the potential of a site for tidal electricity generation.

Other Types of Power Plants

Bio-Energy:



Bioenergy is renewable energy made available from materials derived from biological sources. Biomass is any organic material which has stored sunlight in the form of chemical energy. As a fuel it may include wood, wood waste, straw, manure, sugarcane, and many other byproducts from a variety of agricultural processes. Also animal wastes, etc. Everything biological can be a bioenergy resource.

ENERGY STORAGE SYSTEMS

Energy Storage Systems

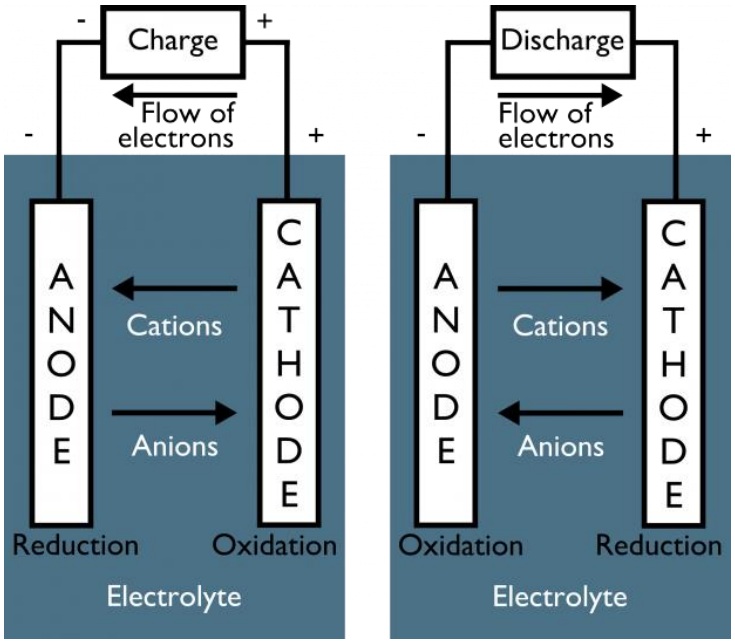
- The renewable energy systems such as wind, solar, etc. are totally dependent on meteorological conditions. Therefore, there can occur great changes in power production of these resources seasonally, daily and even instantly. This issue results in unbalance between the produced and consumed electrical energy.
- In order to supply the energy requirement in all conditions, energy storage units play an important role. The excess energy generated by the renewable resources is transferred to energy storage units and this stored energy is then used to supply the load demand when the main power sources are not existent or not sufficient.
- Especially for stand-alone systems (no power grid existence) the research and examination on energy storage units show significant importance.
- Energy storage technologies can be electrical or thermal. There is an electrical input-output for electrical energy storage systems while a thermal input-output exist for thermal systems.
- The mentioned electrical energy storage systems can be in form of electrochemical (battery, etc.), kinetic (flywheel, etc.) or potential (pumped hydro, compressed air, etc.). There are also different technologies used for thermal energy storage.

Energy Storage Systems

Electrical Energy Storage Systems:

Batteries:

Batteries are the most mature technology of storing electric energy in chemical form. Batteries are classified as non-rechargable (primary) and rechargable (secondary) batteries. Below is the diagram of charge-discharge of a secondary battery.



Battery technologies:

- Lead-Acid Batteries
- Nickel-Cadmium Batteries
- Sodium-Sulphur Batteries
- ZEBRA Batteries
- Lithium-Ion Batteries, etc…

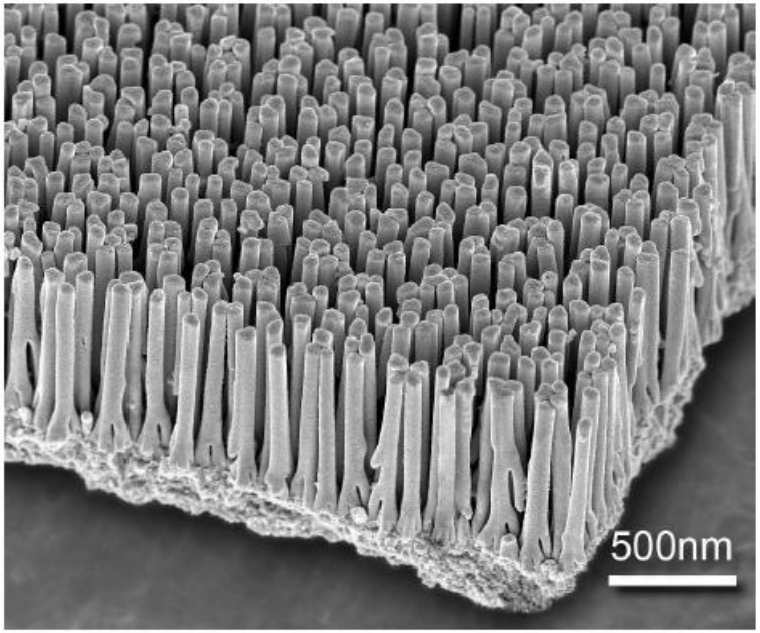
Batteries have higher energy densities than many storage types. However, many batteries are prone to operating temperatures, charge-discharge cycles, lower power densities, etc.

Energy Storage Systems

Electrical Energy Storage Systems:

Ultracapacitors:

- Nano-technology! This means so much greater Farads in significantly small areas compared to conventional capacitors.



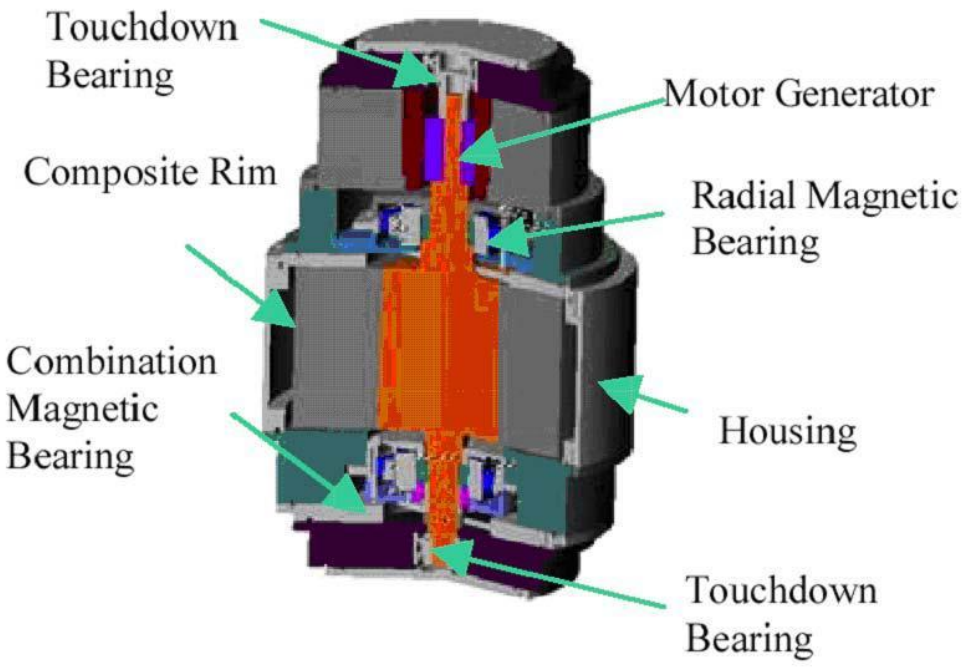
- They have significantly high power densities that is an important advantage for structures like electric vehicles.
- The cycle life of ultracapacitors is assumed infinite.
- Operating temperatures have very limited impact on performance compared to batteries.
- However, they have significantly low energy densities.

Energy Storage Systems

Electrical Energy Storage Systems:

Flywheels:

Flywheel is a rotating mass in one axis that stores electric energy mechanically in kinetic energy form.



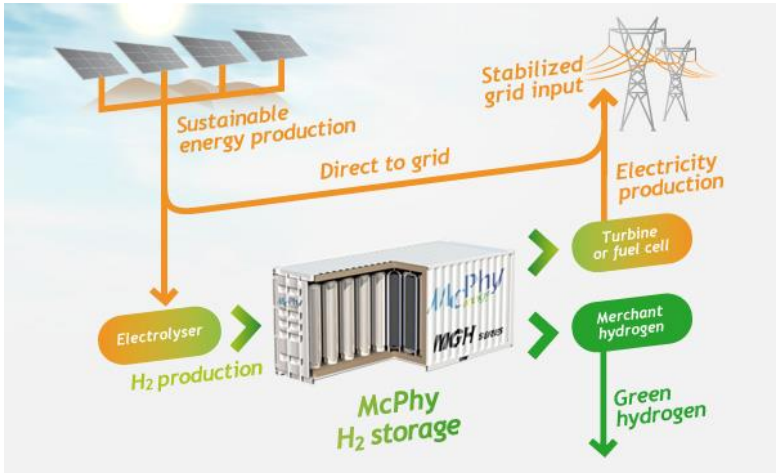
- Charging for flywheels means producing mechanical rotating energy via excess electrical energy in motor mode.
- Discharging for flywheels means slowing down the rotating mass to generate electricity in generator mode.
- The biggest problem is the self-discharge in idle mode!
- Thus they are more suitable for short term storage rather then long term.

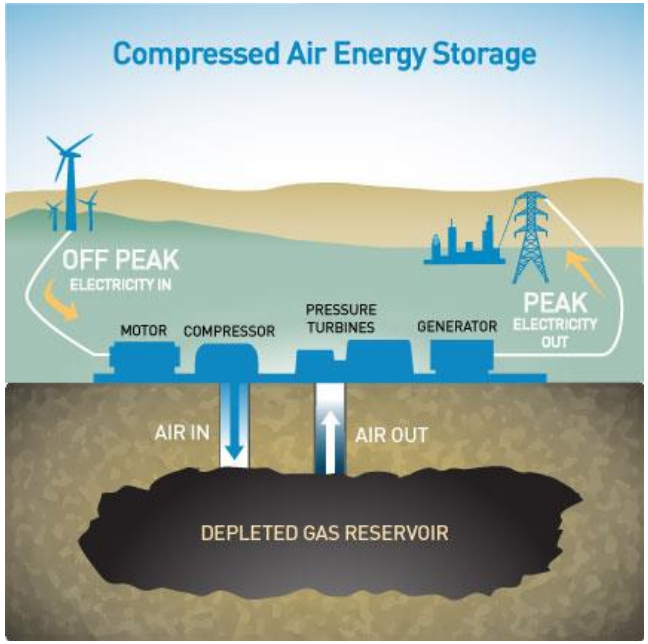
Energy Storage Systems

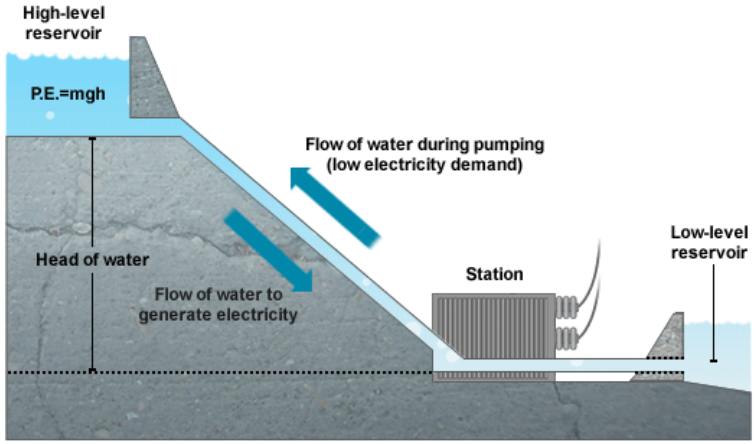
Electrical Energy Storage Systems:

Other methods:

- Hydrogen energy storage
- Pumped-hydro energy storage
- Compressed-air energy storage







Energy Storage Systems

Energy Storage Unit	Main Advantage	Main Disadvantage	Potential Area of Use
Battery	The most mature energy storage technology	Short cycle life	Electric vehicles, portable appliances, low power renewable energy systems
Ultracapacitor	Long cycle life	Low energy density	Electric vehicles
Flywheel	High power density	High self-discharge (losses in idle mode)	Grid integration of renewable energy systems, some space applications
Pumped-hydro and compressed air	Possibility of storing extremely high amounts of energy	Required terrain conditions	Significantly high power renewable energy systems

THANK YOU…