MODULE – 4

Energy storage and management: types of energy storage, thermal energy storage: sensible heat storage and latent heat storage (simple numerical on sensible and latent heat storage), **Energy management and principles of energy management.**

Steam and Gas Power plant: working principle of steam power plant and gas power plant.

Energy storage and management:

Energy is the capacity for doing work. It may exist in potential, kinetic, thermal, electrical, chemical, nuclear, heat and work or other various forms.

Energy storage is the capture of energy produced at one time for use at a later time to reduce imbalances between energy demand and energy production.

Energy storage is critically important to the success of any intermittent energy source in meeting demand. For example, the need for storage for solar energy applications is severe, especially when solar energy is least available in winter.

Classification of energy storage methods

For many energy technologies, storage is a crucial aspect. If we consider the storage of fuels as the storage of the energy embedded in them, then oil is an excellent example. The massive amounts of petroleum stored worldwide are necessary for the reliable, economic availability of gasoline and petrochemicals.

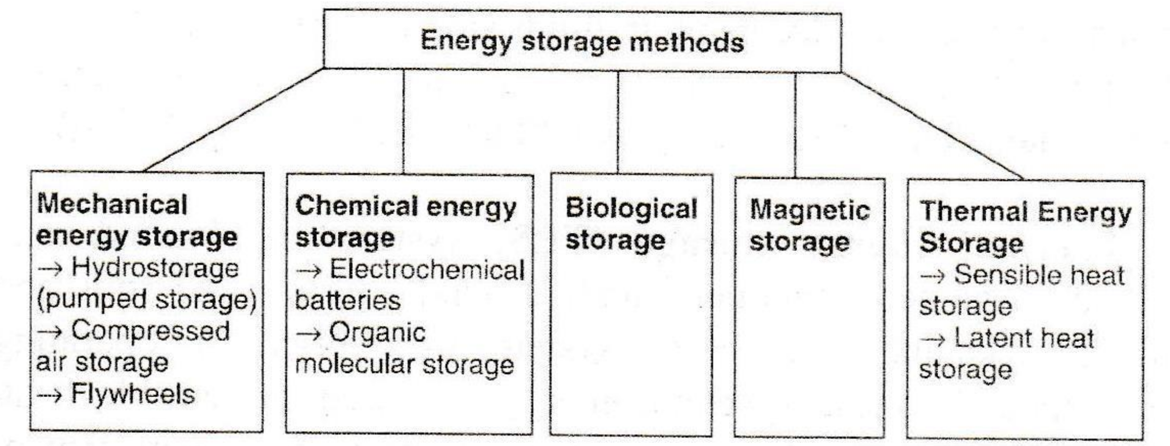


Fig: Classification of energy storage methods

THERMAL ENERGY STORAGE:

Thermal energy storage refers to the process of capturing and storing thermal energy for later use. It is a technology that allows excess thermal energy, often in the form of heat, to be collected and stored during periods of low demand or when the energy source is readily available. This stored energy can then be retrieved and utilized when there is a higher demand or when the primary energy source is less available.

Thermal energy storage is required for several reasons, and it plays a crucial role in improving the efficiency, reliability, and sustainability of energy systems.

NEEDS OF THERMAL ENERGY STORAGE

- Primary energy source -Hydro, Gas, Coal and Nuclear fuels transformed directly in to electricity as a power source for industrial and household appliances.
- In principle, electricity generation has to be balanced with the exact time of the consumption to satisfy the fluctuating demand at the lowest possible cost.
- Fluctuating seasonal and specific time demands outside their control.
- Utility companies generate electricity using different types of primary energy sources to offset peak.
- Almost every modern society has a mid-day or late evening peak electricity demand.
- This essential demand force utility companies to build new additional peak demand power stations considerable investment that operate only during peak demand periods and shutdown the rest of the time.
- They use expensive primary energy stores and are subject to the standard cost of maintenance; consequently, production cost per kWh is 3-4 times higher than the standard base load electricity Production cost.

BENEFITS OF THERMAL ENERGY STORAGE:

Thermal energy storage is beneficial in many ways and some of the significant are listed below:

1. Load Shifting and Peak Demand Management
2. Integration of Renewable Energy
3. Increased Energy Efficiency
4. Grid Stability and Reliability
5. Cogeneration and Combined Heat and Power (CHP) Systems
6. Reducing Energy Costs
7. Industrial Processes
8. Building Comfort and HVAC Systems.

TYPES OF THERMAL STORAGE SYSTEMS:

1. Cold storage
2. Fabric and slab energy storage
3. Solar storage
4. Packed Rock Beds
5. Low temperature CO2 Storage System
6. Thermo - chemical Energy Storage
7. Sensible heat
8. Latent heat

1. Cold storage: Storage receiving and accumulating cooling capacity output from the refrigeration plant.

2. Fabric & Slab energy storage: Building materials absorbed heat/ cooling during a particular period and
release it at another period.

3. Solar storage: Solar collector along with its associated pump to convert solar radiation into heat. The store which receives the heated water from the collector delivers heated water to the space heating heat exchanger. It contributes to the building's hot water requirements of between 6% and 12%.

4. Packed Rock Beds

• A Packed rock bed utilizes the available thermal energy by means of circulating through a packed rock bed to add heat or remove heat from the system for charging and discharging respectively.

• The energy can be transferred from a fluid but the most common systems utilize air due to tire high heat transfer coefficient between air and rock.

5. Low Temperature CO2 Storage System

• Carbon dioxide offers the most compact latent heat storage system due to the commercially obtainable triple point which allows the utilization of a single substance as static latent heat of fusion storage.

• Carbon dioxide can be stored at it's triple point of -570C And 518 kPa with solid fraction of 70-80% by mass and the system can provide 140 kJ/kg thermal storage capacity.

6. Thermochemical Energy Storage

• Recent research shows that various alcohols and ketones are potential thermochemical storage media but due to the relative cost and complexity, no commercially viable systems have yet emerged.

• Typical examples are the mixture of Sulphuric Acid and water, and alliteratively Sodium Hydroxide and water.

• Systems in which the water is separated by the heat input to the mixture and as soon as the two substances are mixed the chemical reaction of the substances liberates heat.

7. Sensible heat storage:

A heat storage system that uses a heat storage medium, and where the additional or removal of heat results in a change in temperature.

Solar pond Technology

• The vertical configuration of salt-gradient solar pond consists of following three zones: Adjacent the surface there is a homogeneous convective zone that serves as a buffer zone between environmental fluctuations at the surface and conductive heat transport from the layer below. This is the upper convective zone (UCZ).

• At the bottom of the pond there is another convective zone, the lower convective zone or LCZ. Tiris is the layer with the highest salt concentration and where the high temperature are built up.

• For given salinities and temperature in the upper and lower convective zones, there exists a stable intermediate gradient zone. This zone keeps the two convective zones apart and gives the solar pond its unique thermal performance. This intermediate zone provides excellent insulations for the storage layer. While simultaneously transmitting the solar radiation. To maintain a solar pond in this non-equilibrium stationary state, it is necessary to replace the amount of salt that is transformed by molecular diffusion from the LCZ to the UCZ. This means that salt must be added to the LCZ, and fresh water to the UCZ whilst- brine is removed. The brine can be recycled, divided into water and salt (by solar distillation) and returned to the pond.

• The major heat loss occurs from the surface of the small pond. This heat loss can be prevented by spreading a plastic grid over the ponds surface to prevent disturbance by the wind. Disturbed water tends to lose heat transfer faster than when calm.

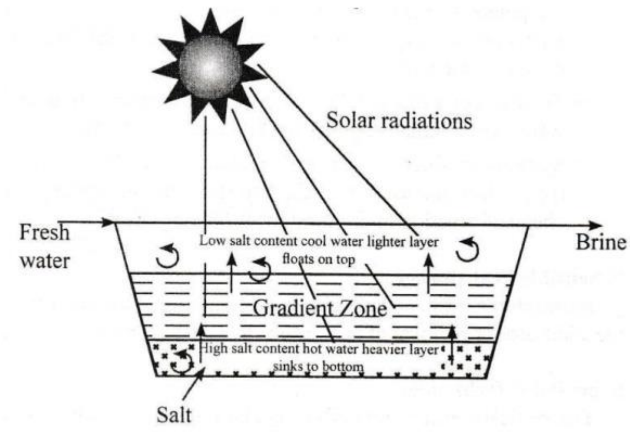


Fig: Principle of solar pond

8. Latent heat storage:

A heat storage system that uses the energy absorbed or released during a change in phase, without a change in temperature(isothermal).

Phase Change Materials (PCMs)

When a material melts or vaporizes, it absorbs heat; when it changes to a solid (crystallizes) or to a Liquid (condenses), it releases this heat. This phase change is used for storing heat in PCMs typical PCMs are ice, salt hydrates, and certain polymers. The eutectic salt does not expand or contract when it freezes and Melts; so, there is no fatigue on the plastic container. The eutectic Salt -filled containers are placed in a tank, typically in a below-grade concrete structure. The containers occupy about two-thirds of the tank's volume. So, that one-third of the tank is occupied by the water used as the heat-transfer medium. Since energy densities for latent Thermal energy storage (TES) exceed those for sensible TES, smaller and lighter storage devices and lower storage losses normally result.

Other early applications of PCMs included "eutectic plates" used for cold storage in trucking and railroad transportation applications. Another important application of PCMs is association with space technology, with NASA sponsoring a project on PCM applications for thermal control of electronic packages.

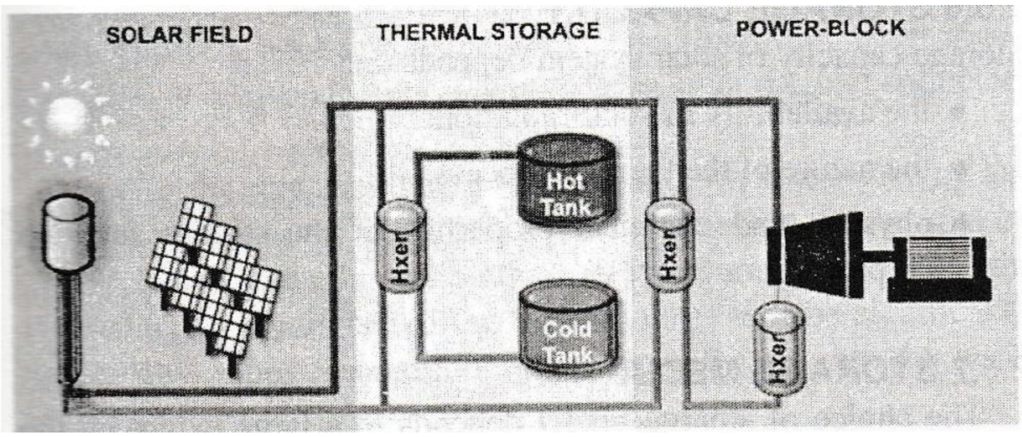


Fig: Principle of use of PCM

ENERGY MANAGEMENT:

Energy management has been an important tool to help organizations meet these critical objectives for their short-term survival and lone-term success.

The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect.

Definition:

"The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems"

Objectives of Energy Management:

The objective of Energy Management is to achieve and maintain optimum energy procurement and utilization, throughout the organization and:

- To minimize energy costs / waste without affecting production & quality
- To minimize environmental effects.

PRINCIPLES OF ENERGY MANAGEMENT

1.Review of historical data

2.Energy audits (review of current practice)

3. Operation and maintenance ("housekeeping")

4. Analysis of energy use (engineering analysis, building simulation, system modelling, availability studies)

5. Economic evaluation (cost/benefit, rate of return, life cycling costing)

6. More efficient equipment

7. More efficient processes

8. Energy containment (heat recovery, waste reduction)

9. Material economy (scrap recovery, salvage, recycle)

10. Substitute material

11. Material quality (purity and properties)

12. Aggregation of energy uses

13. Cascade of energy uses

14. Alternative energy sources (substitute fuel or energy form)

15. Energy conversion

16. Energy storage.

Simple numerical on sensible and latent heat storage.

Example:1

How much water at 50°C is needed to just melt 2.2 kg of ice at 0°C?

Solution:

Heat (Q)= mCΔT

Where Q=Heat in Joules

m= mass of the substance in kg.

C= Specific heat of the substance in J/kgK

ΔT=Change in temperature in °C

<u>Take:</u>

Specific heat of water (C_{water})= 4200 J/kgK

Specific heat of ice (C_{ice})= 2100 J/kgK

Latent heat of water (L_{water}) =22.5×10^5 J/kg

Latent heat of ice (L_{ice}) = 3.34×10^5 J/kg

Therefore,

Heat loss=Heat gain

Heat loss of water = Heat to melt ice

$m_{water}\times C_{water}\times \Delta T = m_{ice}\times L_{ice}$

$m_{water}\times 4200\times (50-0) = 2.2\times 3.34\times10^5$

m_{water}**= 3.50 Kg**

Example:2

How much heat energy is required to convert 2 kg of ice at 0°C in water at 20°C?

Solution:

Total heat = Heat required to convert 2kg of ice to 2kg of water at 0℃ + Heat required to convert 2kg of water at 0℃ to 2kg of water at 20℃

Heat (Q)= $mC\Delta T$

Mass of ice (m_{ice}) = 2kg

<u>Take:</u>

Latent heat of ice (L_{ice}) = 3.34×10^5 J/kg

Specific heat of water (C_{water})= 4200 J/kgK

Change in temperature (ΔT) = (20℃ - 0℃) = 20℃

Therefore,

Heat required (Q)= $m_{ice}\times L_{ice} + m_{water}\times C_{water}\times \Delta T$

$Q = 2\times3.34\times10^5 + 2\times4200\times(20-0)$

= 835480 Joules or 835.48 Kilo Joules

Therefore, to melt 2kg of ice 835.48kJ of heat is required

Example : 3

A copper cup holds some cold water at 4°C. The copper cup weighs 140g while the water weighs 80g. If 100g of hot water, at 90°C is added, what will be the final temperature of the water?

Solution:

Take

Specific heat of copper (C_{copper}) = 390 J/kgK

Mass of cup (m_{cup}) 140 g = 0.14 kg

Mass of cold water ($m_{cold\ water}$) 80g = 0.08 kg

Mass of hot water ($m_{hot\ water}$) 100g = 0.1 kg

Initial temperature of cold water in the cup ($T_{Initial}$) = 4°C

Final temperature of water in the cup (T_{Final})=?

Heat loss=Heat gain

Heat gain of cup + heat gain of cold water = heat loss of hot water

$$m_{cup}\times C_{cup}\times \Delta T + m_{cold\ water}\times C_{water}\times \Delta T = m_{hot\ water}\times C_{water}\times \Delta T$$

Where:

$m_{cold\ water}$ = mass of cold water

C_{water} = specific heat of water

$m_{hot\ water}$ = mass of hot water

$$0.14\times 390\times (T_{Final}-4) + 0.08\times 4200\times (T_{Final}-4) = 0.1\times 4200\times (90-T_{Final})$$

$$390.6T_{Final} - 1562.4 = 37800 - 420T_{Final}$$

$$810.6T_{Final} = 39362.4$$

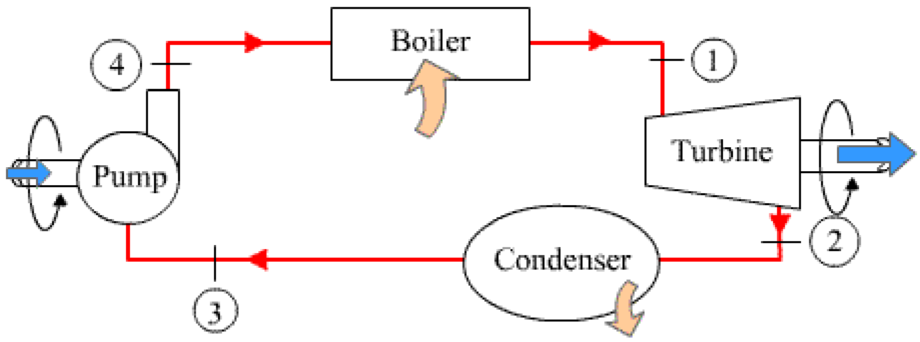
$$T_{Final} = 48.6\ ℃$$

Steam and Gas Power plant:

Steam:

The vapour into which water is converted when heated, forming a white mist of minute water droplets in the air. When water is heated at atmospheric pressure, its temperature rises until it reaches 100°C,the highest temperature at which water can exist at this pressure. Additional heat does not raise the temperature, but converts the water to steam.

working principle of steam power plant.



A steam power plant is used to convert the energy stored in fossil fuels, nuclear fuel, or renewable sources into electricity through the use of steam. The basic components of a steam power plant include a boiler, turbine, generator, condenser, and various pumps and valves.

Stepwise working principle is explained below:

1. The process begins in the boiler, where fuel is burned to produce high-temperature and high-pressure steam. Pump is used to transfer water from the condenser to the boiler.
2. The high-pressure steam generated in the boiler is directed to a steam turbine. The steam expands as it passes through the turbine blades, causing the turbine to rotate. This rotation converts the thermal energy of the steam into mechanical energy.
3. The rotating shaft of the steam turbine is connected to a generator. As the turbine spins, it drives the generator, converting the mechanical energy into electrical energy.
4. After passing through the turbine, the low-pressure steam is sent to a condenser, where the steam is condensed back into water by transferring its heat to a cooling medium .This creates a vacuum, which improves the efficiency of the turbine.
5. The cooling medium used in the condenser is circulated through a cooling system to dissipate the absorbed heat. In some power plants, cooling towers are used to release excess heat to the atmosphere.

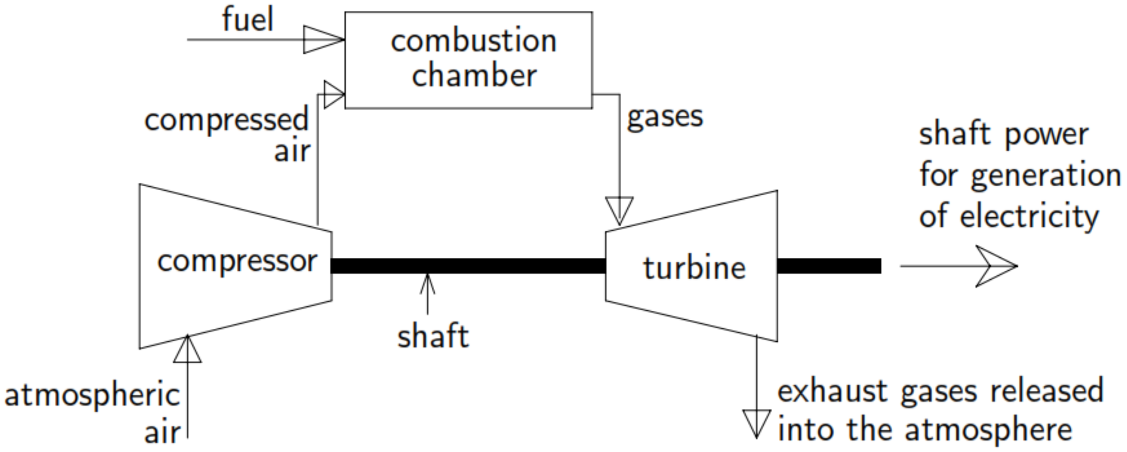
Steam power has many benefits , one such advantage is that water is cheaper than fossil fuel alternatives. Steam power is used to spin turbine blades, thereby generating electricity.

Steam power plants finds applications in chemical industry, oil and gas, waste plants , sugar Mills etc.

GAS POWER PLANT

Gas power plant is a thermal power station that burns natural gas to generate electricity.

The working principle is explained with schematic diagram below



1. The process begins with drawing air from the atmosphere and is compressed to a high pressure in a compressor.
2. The high-pressure air enters a combustion chamber, in which fuel is sprayed onto the compressed air, and the fuel-air mixture is burned at constant pressure.
3. The gases leaving the combustion chamber at high pressure and high temperature are directed towards the turbine blades so as to rotate the turbine shaft.
4. In general, nearly half of the work output of the rotating turbine shaft is used to rotate the compressor shaft, and the rest is used to produce electricity. Thus, part of the heat generated in burning the fuel in the combustion chamber is converted into useful electrical energy.
5. The gases leaving the turbine are released into the atmosphere. These gases contain carbon dioxide, nitrous oxides, sulfur oxides and particulate matter.
6. The temperature of the exhaust gases can also be very high. Before releasing these gases into the atmosphere, therefore, it is essential to make sure that the polluting potential of these exhaust gases is reduced to the level set by the environmental authority of the country concerned.

Gas turbines are used to power aircraft, trains, ships, electrical generators, pumps, gas compressors, and tanks

Text Books

1. Elements of Mechanical Engineering, K R Gopala Krishna, Subhash Publications, 2008
2. Elements of Workshop Technology (Vol. 1 and 2), Hazra Choudhry and Nirzar Roy, Media Promoters and Publishers Pvt. Ltd., 2010.

Reference Books

1. An Introduction to Mechanical Engineering, Jonathan Wickert and Kemper Lewis, Third Edition, 2012
2. Manufacturing Technology- Foundry, Forming and Welding, P.N.Rao Tata McGraw Hill 3rdEd., 2003.
3. Robotics, Appu Kuttan KK K. International Pvt Ltd, volume 1