MODULE 2 QB

-PP

1) List the various thermal storage methods. Explain sensible heat and latent heat storage methods.

Ans) The various thermal storage methods are:

1. Cold storage
2. Fabric and slab energy storage
3. Solar storage
4. Packed rock beds
5. Low temperature CO_2 storage system
6. Thermo chemical energy storage
7. Sensible heat
8. Latent heat

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.
- The vertical configuration of salt - gradient solar pond consists of following zones.

1) 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)**.

2) At the bottom of the pond there is another convective zone, the **lower convective zone (LCZ)**. This is the layer with the highest salt concentration and where the high temperature is built up.

3) For given salinities and temperature in the upper and lower convective zones, there exists a stable **intermediate gradient zone**.

- This zone keeps the 2 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 transported 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 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 pond's surface to prevent disturbance by the wind.
- The disturbed water tends to lose heat transfer faster than when calm.

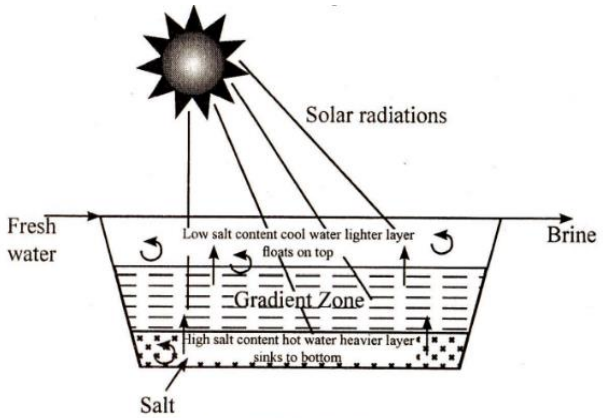

Fig. 2.6 Principle of solar pond

Latent heat storage:-

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

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.
- The containers occupy about two-thirds of the tank's volume.
- Remaining one-third of the tank is occupied by the water used as the heat-transfer medium.
- Since energy densities for latent TES exceed those for sensible TES, smaller and lighter storage devices and lower storage losses normally result.

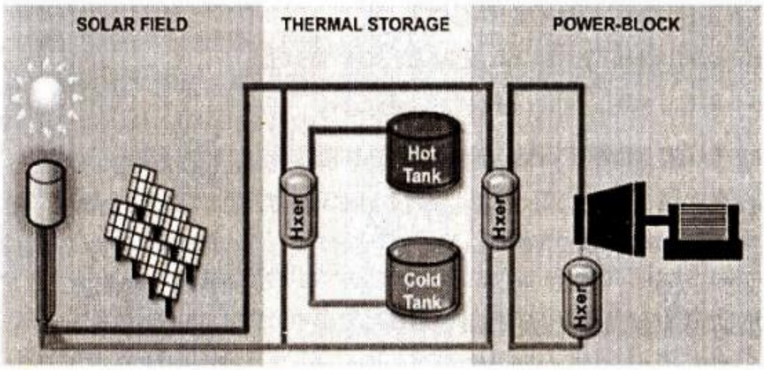

Fig. 2.7 Principle of use of PCM

2) List the principles of energy management system.

Ans)

- **S**ubstitute materials
- **U**se most appropriate technology
- **C**onstruction of new facilities
- **H**istorical Energy Use
- **H**ousekeeping & maintenance
- **R**euse and recycle energy by cascading
- **R**educe the available losses
- **A**nalysis of Energy use
- **A**ggregation of Energy sources
- **A**lternative Energy Sources
- **M**ore efficient equipments
- **M**ore efficient process
- **M**anage the energy at the highest energy efficiency.
- **E**conomic Evaluation
- **E**nergy Audits
- **E**nergy Containment - confine energy, reduce losses & recover heat

(1 - **S**, 1 - **U**, 1 - **C**, 2 - **H**'s, 2 – **R**'s, 3 - **A**'s, 3 - **M**'s, 3 - **E**'s)

3) Explain different phases involved in detailed energy audit methodology.

Ans)

SL. NO	Plan of action	Purpose /Results
Step 1	Phase 1-Pre audit Phase • Plan and organize • walk through Audit • informal interview with energy manager, production/ plant manager	• Resource planning, establish/organise a energy audit team • organize instruments & time frame • macro data collection • Familiarization of process/ plant activities • first hand observation and assessment of current level operation and practices.
Step 2	• **Conduct of brief meeting/ awareness programme with all divisional heads and persons concerned (2-3 hrs)**	• **Building up cooperation** • **issue questionnaire for each department** • **Orientation, awareness creation**
Step 3	Phase –II Audit Phase • Preliminary data gathering, process flow diagram and energy utility diagram	• Historic data analysis, baseline data collection • prepare process flow chart • all service utilities system diagram (single line diagram, water compressed air and steam distribution) • design, operating data and schedule of operation • annual energy bill and energy consumption pattern (refer manual, log sheet, name plate , interview)
Step 4	**Conduct survey and monitoring**	**Measurements** **Motor survey, insulation, and lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.**
Step 5	Conduct of detailed trials/experiments for selected energy users	Trials/experiments • 24 hours power monitoring like MD, PF, kWh etc • load variations trends in pumps. Fan, compressors etc. • boiler/ efficiency trials for 4 to 8 hours • furnace efficiency trials equipments, performance equipment's etc
Step 6	Analysis of energy use	Energy and material balance and energy loss/waste analysis
Step 7	Identification and development of energy conservative opportunities.	• Identification and consolidation energy conservation measures • concieve, develop and refine ideas
		• **Review the previous ideas suggested by unit personal** • review the previous ideas suggested by energy audit • Use brainstorming and value analysis techniques • contact vendors for new/efficient technology
Step 8	Cost benefit analysis	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • select the most promising projects • prioritize by low, medium long term measures
Step 9	Reporting and presentation to the top management	Documentation, report presentation to the top management

	Phase III -post audit phase	
Step 10	Implementation and follow up	Assist and implement ENCON recommendation measures and monitor the performance • Action plan schedule for implementation • follow up and periodic review

4) Define energy audit. Explain the need for energy audit.

Ans) Energy audit is the key to a systematic approach for decision making in the area of energy management.

Need for Energy Audit:-

- In any industry, the 3 top operating expenses are often found to be energy (both electrical and thermal), labour and materials.
- If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker.
- Thus energy management function constitutes a strategic area for cost reduction.
- Energy audit will help to understand more about the ways in which the energy and fuel are used in any industry.
- It helps in identifying the areas where waste can occur and where scope for improvement exists.
- It would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities.
- Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.
- The primary objective of energy audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs.
- Energy audit provides a “bench mark” for managing energy in the organization and also provides the basis for planning a more effective use of energy.

5) Explain various methods of energy: mechanical energy storage, hydro storage, compressed air storage, flywheels, chemical energy storage, electrochemical batteries.

Ans)

Mechanical energy storage:-

- Mechanical energy may be stored as the kinetic energy of linear or rotational motion, as the potential energy in an elevated object, as the compression or strain energy of an elastic material, or as the compression energy in a gas.
- It is difficult to store large quantities of energy in linear motion.
- However, it is simple to store rotational kinetic energy.
- Potter’s wheel, the first form of ES used by man, was developed several thousand years ago and still it is used.

Hydro storage:

Upper Reservoir:-

- Like a conventional hydropower plant, a dam creates a reservoir.
- The water in this reservoir flows through the hydropower plant to create electricity.
- Using a reversible turbine, the plant can pump water back to the upper reservoir.
- This is done in off peak hours .
- Essentially, the second reservoir refills the upper reservoir.

Lower Reservoir:-

- Water exiting the hydropower plant flows into a lower reservoir rather than re-entering the river and flowing downstream.

Compressed Air Storage:

- In a compressed air ES system, air is compressed during off peak hours and stored in large underground reservoirs, which may be naturally occurring caverns, salt domes, abandoned mine shafts, depleted gas and oil fields or man-made caverns.
- During peak hours, the air is released to drive a gas turbine generator.
- The technique used by such a system to compress air to store energy is relatively straightforward.
- In a conventional gas turbine, high pressure hot gas is supplied, and about two thirds of the gross power output is used to drive the compressor.
- A compressed air ES system decouples the compressor and the turbine.
- The compressed air is stored in natural caverns, old oil or gas wells, or porous rock formations.

Flywheels:

- The flywheel is a wheel of relatively large mass that stores rotational kinetic energy.
- It has been used to smooth out the shaft power output from one or two cycles engine.
- Used for adjusting uneven loads.
- New uses of this device, and of the other 2 mechanical storage techniques discussed in this section, take advantage of the ability of the electric motor/ generator operation to reverse.
- Such a device can be designed to work both as a motor when driven by electric power and as a generator when driven by mechanical power.

Chemical Energy Storage:-

- Energy may be stored in systems composed of one or more chemical compounds that release or absorb energy when they react to form other compounds.
- The most familiar chemical ES device is the battery.
- Energy stored in batteries is frequently referred to as electrochemical energy because chemical reactions in the battery are caused by electrical energy and subsequently produce electrical energy.

Electrochemical batteries:

- Batteries chemically store energy and release it as electric energy on demand.
- Batteries are a stable form of storage and can provide high energy and power densities, such as those needed for transportation.
- The lead sulphuric acid battery has long been considered to be advantageous and has been widely applied.
- Recently, fuel cells have demonstrated the ability to act as large scale chemical storages like batteries.

6) Elaborate the benefits of thermal energy storage.

Ans)

1) Increase generation capacity:

- This process allows a smaller production unit to be installed (or to add capacity without purchasing additional units), and results in a higher load factor for the units.

2) Enable better operation of cogeneration plants:

- Combined heat and power, or cogeneration, plants are generally operated to meet the demands of the connected thermal load, which often results in excess electrical generation during periods of low electricity use.
- By incorporating TES the plant need not be operated to follow a load.
- Rather it can be dispatched in more advantageous ways (within some constraints).

3) <u>Shift energy purchases to low-cost periods:</u>

- This measure constitutes the demand-side application of the first purpose listed.
- It allows energy consumers subject to time-of-day pricing to shift energy purchases from high to low cost periods.

4) <u>Increase system reliability:</u>

- Any form of energy storage from the uninterruptable power supply of a small personal computer to a large pumped storage project, normally increases system reliability.

5) <u>Integration with other functions:</u>

- In applications where on-site water storage is needed for fire protection, it may be feasible to incorporate thermal storage into a common storage tank.
- Likewise, equipment designed to solve prover-quality problems may be adaptable to energy storage purposes.

7) What are the general characteristics of capital investment?

Ans)

- Expenses are generally those cash expenditures that are routine, on going and necessary for the ordinary operation of the business.
- Capital investments, on the other hand, are generally more strategic and have long term effects.
- Decisions made regarding capital investments are usually made at higher levels within the organizational hierarchy.
- Three characteristics of capital investments are of concern when performing life cycle cost analysis.
- First, capital investments usually require a relatively large initial cost.
- The initial cost may occur as a single expenditure or occur over a period of several years.
- The second is that the benefits resulting from the initial cost occur in the future, normally over a period of years.
- The period between initial cost and the last future cash flow is the life cycle or life of the investment.
- The last important characteristic of capital investment is that they are relatively irreversible.
- Frequently, after the initial investment has been made, terminating or significantly altering the nature of a capital investment has substantial (usually negative) cost consequences.
- This is the one of the reasons that capital investment decisions are usually evaluated at higher levels of the organizational hierarchy.

<u>Problems:</u>

1) A power plant of 210mw installed capacity has the following details: capital cost =Rs 18000/kw installed, interest and depreciation=12%, annual load factor=60%, annual capacity factor=54%, annual running charges =Rs 200x10, energy consumed by power plant auxiliaries=6% solve and calculate the cost of power generation per unit.

Ans)

(Load factor/capacity factor) = (average load/maximum demand) x (capacity of plant/average load)

(0.6/0.54) = (210MW/maximum demand)

maximum demand = (210x0.54)/0.6 = 189MW

Reserve capacity=210-189=21MW

Average load = Lf x maximum demand = 0.6 x189 = 113.4MW

Energy produced/year = 113.4 x 1000 x 8760 = 993.384 x 10^6 units

Net energy delivered = 0.94 x 993.384 x 10^6 = 933.781 x 10^6 units

Annual interest and depreciation (fixed cost) = 0.12 x 18000 x 210 x 1000 = Rs 453.6 x 10^6

Total Annual cost = fixed cost + running cost

$= \text{Rs } 453.6 \times 10^6 + \text{Rs } 200 \times 10^6$

$= \text{Rs } 653.6 \times 10^6$

Cost of power generation = $(653.6 \times 10^6)/(933.781 \times 10^6)$

= Rs 0.70

2) Solve and calculate the cost of generation per unit for a power station having the following data. Installed capacity of the plant=200mw, capital cost=Rs 400crores, rate of interest and depreciation =12%, annual cost of fuel, salaries and taxation =Rs 5 crores, load factor=50%, also estimate the savings in cost per unit if the annual load factor is raised to 60%.

Ans)

Assuming the maximum demand equal to the capacity of the power plant

LF = (average load) / (maximum demand)

0.5 = (average load) / 200

Average load= 200x0.5=100MW

Energy generated per year = 100x1000x8760 = 876×10^6 units

Interest and depreciation (fixed cost) = 0.12 x 400 crores = Rs 48crores

Total annual cost = 48 crores+5 crores = Rs 53 crores

Cost per unit = (Rs 53 crores)/87.6 crores units= Rs 0.61

When the load factor is raised to 60%

Average load = 0.6x200 = 120MW

Energy produced per year = 120 x 1000 x 8760= 105.12×10^7 units

Total annual cost will remain same.

Cost per unit = $(\text{Rs } 53 \times 10^7) / (105.12 \times 10^7)$ = Rs 0.5

Savings in cost per unit= 61-50 = 11 paise

3) A thermal power plant of 210mw capacity has the maximum load of 160mw. Its annual load factor is 0.6. The coal consumption is 1kg/unit of energy generated and the cost of coal is Rs 450/tonne. Calculate a) the annual revenue earned if energy is sold at Rs 1/unit b) capacity factor of the plant.

Ans)

Annual Load factor = (average load/peak load)

Average load = 0.6x160 = 96MW

Energy generated/year = 96 x 8760MWh = 840960 $\times 10^3$ kWh

Coal required per year = 840960 x 10^3 kg = 840960 tonnes

Cost of coal per year =840960 x 450 = Rs 37.8432 crores

Cost of energy sold = 840960 x 10^3 x1 = Rs 840960000

Revenue earned by power plant per year = 84.096 crores - 37.8432 crores = 46.25 crores