Unit 4: Energy Conservation through Co-generation and Tariff 16M

* Concept of Co-generation :

A Co-generation system is a single, integrated system in which many forms of useful energy are simultaneously generated mostly electrical or mechanical and thermal using single source of fuel.

A Co-generation system is also called as Combined Heat & Power (CHP) system.

* Significance of Co-generation for Energy Conservation :

1) Efficiency : Traditional power generation methods typically have an efficiency of around 30-40%. But in Co-generation system the efficiency can be as high as 80-90% because the generated heat, which would otherwise be wasted is utilized.

2) Economic Savings : By generating both heat & Power from a single energy source, operational & energy cost are significantly reduced.

3) Environmental Benefits : Increased efficiency leads to reduced fuel consumption & hence, lower emissions of pollutants. This reduces the carbon footprint & other environmental impacts.

4) Reduction in Transmission & Distribution Losses : Co-generation plants are typically situated closer to the point of consumption. This method reduces energy losses associated with long distance transmission

* Concept of Tariff :

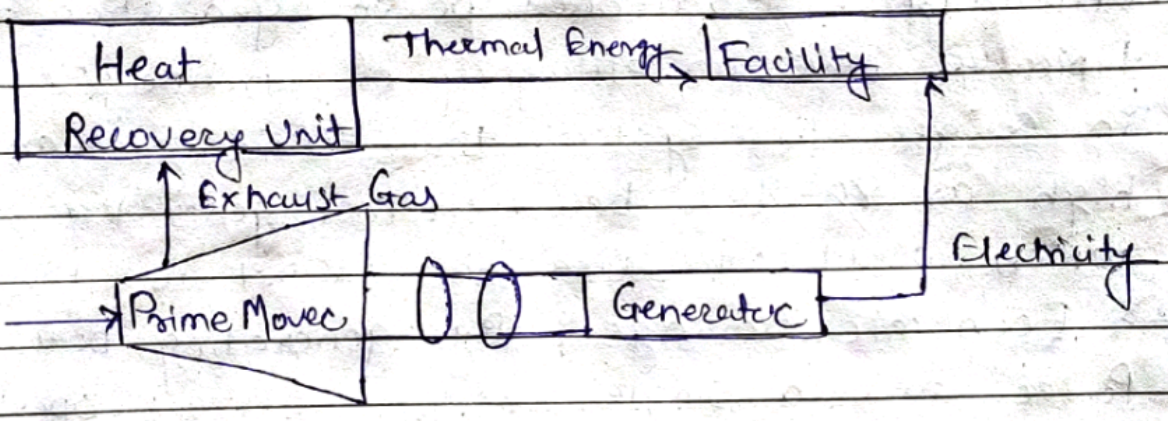
Tariff is the rate or pricing structure set by an energy provider for the supply of electricity to its consumer / customers, are called as tariff.

* Types of Co-generation System :

a) On basis of sequence of energy use :
   1) Topping cycle 2) Bottoming cycle

b) On basis of technology :
   1) Steam turbine Co-generation
   2) Gas turbine Co-generation
   3) Reciprocating engine Co-generation

a) 1) Topping cycle :



- In above fig. shows topping cycle co-generation system.
- In Topping cycle co-generation system the fuel is burnt for electricity generation.
- At the time of fuel burning process the excess thermal energy present in the system is recovered by heat recovery system & it is utilized.
- The topping cycle co-generation system is popular method & it is widely used.

2> Bottoming Cycle :

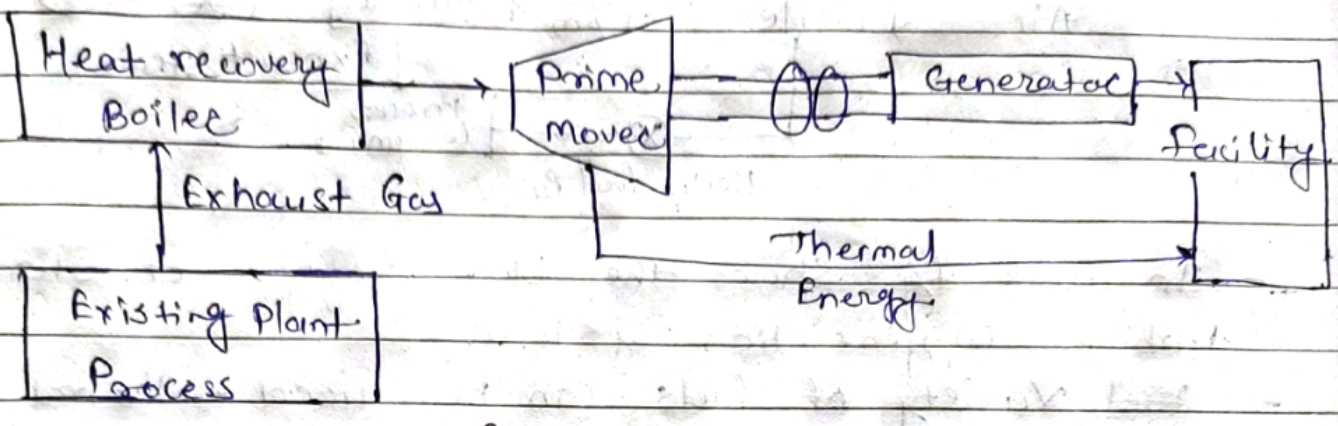
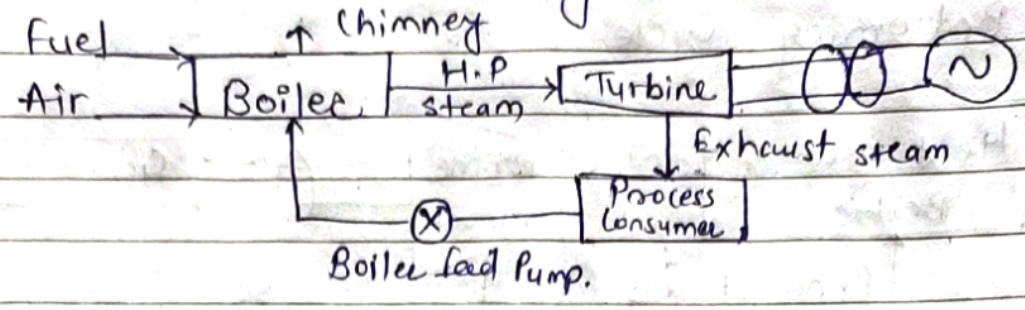


fig. Bottoming cycle.

- Bottoming cycle of co-generation system is that in which high temperature heat energy is produced using primary fuels.
- This heat produced is mainly used for other process except generation of electricity.
- Rejected heat from process is utilized to generated electricity.
- The rejected heat is taken from recovery boiler & then it is applied to the turbine connected to the generator to produce electricity.
- The main purpose of bottoming cycle co-generation system is to get the thermal energy after burning of fuel.
- Bottoming cycle are suitable for cement industries, steel industries etc.

b) 1) Steam Turbine Co-generation :



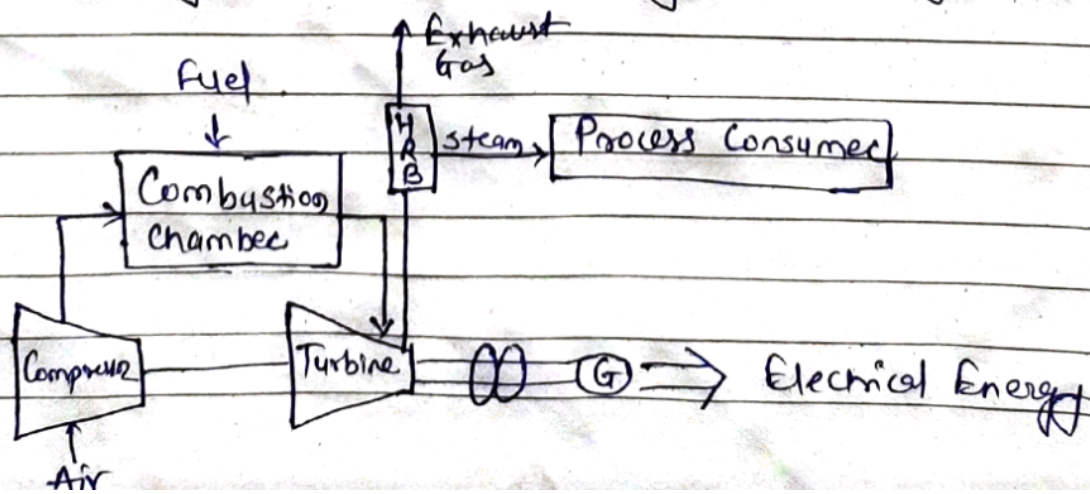
- In above fig. Shows the block diagram of steam turbine co-generation system.
- ~~Fuel~~ Variety of fuels can be used - Natural gas wood, coal, solid wastes & agricultural byproduct
- In this system a boiler produces steam, which drives a steam turbine connected to an electricity generator. After passing through the turbine then steam used for heating application.
- Steam turbine co-generators can have general service lifetime range bet^n 25 to 35 years.
- Installation of these system may take 12-18 months for smaller unit & 3years in case of large plants.

2) Gas Turbine Co-generation System :

There are two types of Gas Turbine co-generating system :

1) Open cycle Gas Turbine Co-generation System
2) closed cycle Gas Turbine co-generation System

1) Open cycle Gas Turbine Co-genecation system :



- Most of the available gas turbine systems in any field are open cycle gas turbine systems.
- Combustion chamber receives atmospheric air through compressor at increased temperature & pressure.
- Mixing this air with injected fuel & the mixture is burnt in combustion chamber.
- Combustion gases are supplied to the gas turbine at high temperature & pressure.
- This produces mechanical energy which is used to drive electric ~~generator~~ Turbine.
- Turbine rejects exhaust gases at temperature in the range of 450°c to 600°c to the heat recovery boiler & useful heat is used for process.
- The exhaust gases are liberated (not circulated) thus mixture classified as open cycle.
- Installation may take 9-14 months for smaller unit up to 7MW & 2 year for large plants.
- Useful service life is 15-20 years.

2) Close Cycle Gas Turbine Co-generation System:

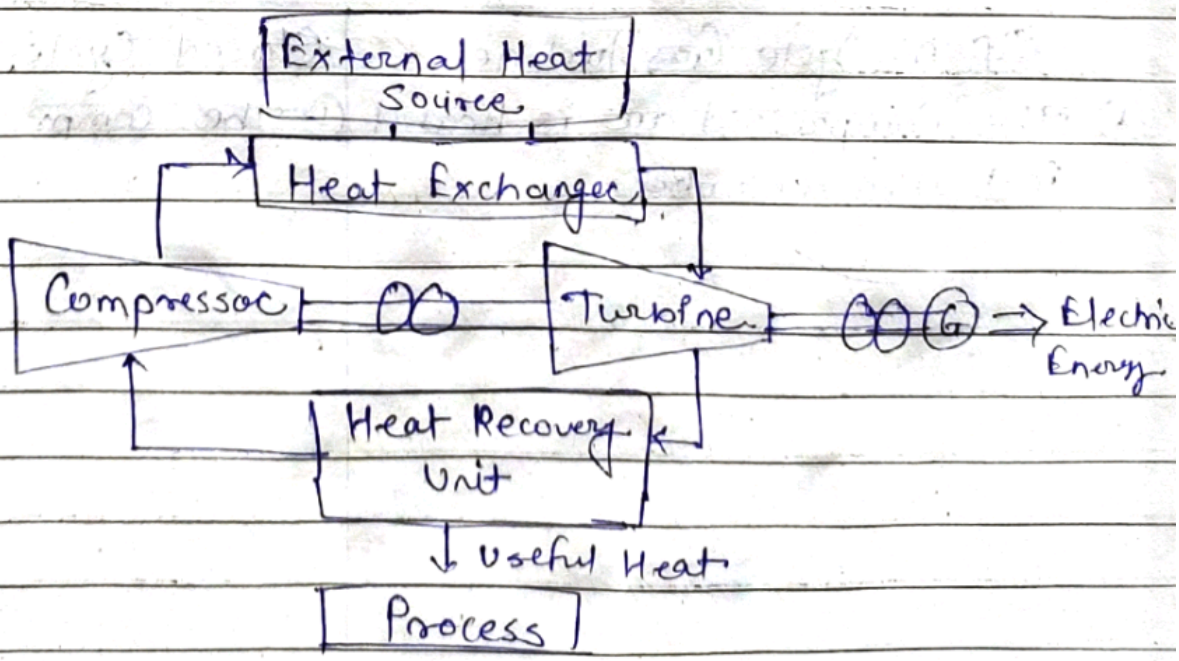


fig. close cycle Gas turbine Co-generation system

- In case of close cycle gas turbine Co-generation System, instead of combustion chamber an external heat source is used to add heat at constant pressure.
- Heat Exchanger provided high temperature of pressure to produced mechanical energy to drive the turbine. This mechanical energy
- Turbine produces provided by the turbine is paves to the generator & generator produces mechanic energy into electrical energy and the result as electricity.
- After that the rejected gases passes to the heat recovery unit for the process & expansion gases passes again into the compressor
- Estimated installation time for a capacity of 25 MW is near about 4-5 years.
- Useful service life of 20 years is expected.

* Difference betn closed cycle Gas Turbine & Open cycle Gas Turbine :

closed cycle Gas Turbine	Open cycle Gas Turbine
- The compressed air is heated in heating chambers.	- The compressed air is heated in combustion chambers.
- As the gas is heated by an external source, hence the amount of gas remains same thought the cycle.	- The product of combustion are get mixed up in the heated air hence same gas doesn't remain in cycle.
- The gas after turbine is passed into the cooling chambers.	- The gas after turbine is exhausted into the atmosphere.
- The working fluid is circulated continuously.	- The working fluid is replaced continuously.
- The mass of installation per KW is more	- The mass of installation per KW is less.
- High maintenance cost	- Maintenance cost is low

* Reciprocating Engine Co-generation System :

- Reciprocating engine used in co-generation plant operates on the same principle on that of petrol or diesel engine.
- Mainly reciprocating engine drives the generator to produce electricity when it is fired.
- There are two types of reciprocating engines are used in cogeneration plants namely:
  (1) Spark ignition gas engine
  (2) Compression ignition engine.

1) Spark Ignition Gas Engine :

- These engines have shaft efficiency near about 35% but low capital cost/kW comparing to compression ignition engine.
- Temperature range of 70-80°C can be obtained at engine cooling system which is possible to increase up to 110°C.
- The sizes of the engine may range up to 4MW
- Spark ignition engines are suitable for small Co-generation plant.

2) Compression Ignition Engine :

- These are suitable for large Co-generation plants & shaft efficiency is in the range of 35-40%.
- These are direct injection engine which may employ turbochargee, intercooler on fittings.
- This system offers flexibility to make use of an alternative fuel that is oil.
- Compression ignition engines require complex cooling system as compare to spark ignition gas engine.

* Factors Governing the Selection of Co-generation system :

1) Load Requirements : The size & types of loads (electrical & thermal) dictate the cogeneration system capacity.
2) Quality of Energy Required : Some processes might require high-temperature steam, while others may be satisfied with low-temperature hot water.
3) Fuel Availability & Price : The availability & cost of fuels like natural gas, coal, biomass, or oil can influence the choice of co-generation technology.
4) Installation & Available space : In installation of co-generation plant available physical space regulate the types of equipments to be used. Gas Turbine & reciprocating engine are easy to install but Steam turbine co-generation plants are needs more preparation on the site.
5) Environmental Regulations : Poor maintenance & improper combustion process can cause increase in pollutants.
6) Grid Connected / independent System : If Co-generation system is grid connected it can purchase electricity from grid in need or sell in case of excess generation. If Co-generation system is stand alone it has to be satisfies all the energy needs.
7) Capital & operating Costs : The investment required for setting up & the costs associated with running the system.
) Thermal to Electrical energy Ratio : This is also called as Heat to Power Ratio & It is one of the most influential technical parameters which can govern the selection of Co-generation system. In which Co-generation produces electricity & heat in the same process.

* Tariff :

Tariff is the rate or pricing structure set by an energy provider for the supply of electricity to its consumer / costomer are called as tariff.

- It is very important factor in electrical system because an electric supply company invests large amount in generation, transmission & distribution of electrical energy. So, The power company's source of revenue is tariff, which obviously target return on investments as well as recovery of operating costs.

* Terms involved in Tariff :

1. Unit Consumed
2. Connected Load
3. Fixed charges
4. Electricity Tax
5. Tariff structure
6. Fuel structure

* Objectives of Tariff :

1. Equal Distribution of cost
2. Recovery of Capital Inv.
3. Recovery of Running cost
4. Recovery of Miscellaneous cost.

* Types of Tariff :

1. LT & HT Tariff
2. Flat Demand Tariff.
3. Simple Tariff
4. Flat Rate Tariff
5. Special Tariff
6. Time of Day Tariff.
7. off peak day Tariff.
8. Maximum Demand Tariff
9. Power factor Tariff.
10. Load factor Tariff.
11. Availability Based Tariff (ABT)

1) L.T & H.T Tariff :

a) L.T Tariff : (Low Tension Tariff)

- for consumers with a comparatively lower voltage requirement, usually up to 440V. e.g. Domestic & small commercial consumers.

b) H.T Tariff : (High Tension Tariff)

- for consumers with a higher voltage requirement, ~~up~~ above 11 kV. e.g. large Industries & factories.

2) Flat Demand Tariff :

- This is one of the oldest tariff scheme of charging the consumers for his electricity consumption.
- In olden days, electricity application was very limited such as lighting i.e Lamp Loads.
- In this tariff scheme, the points considered while charging the consumer are,
  - Total no. of lamps Installed
  - Total ~~Consum~~ Connected load in kW
  - Total time of use in hours.

3) Simple Tariff :

- This is the simplest tariff structure for charging the consumers for their consumption.
- Consumer has to pay on the basis of unit Consumed.

4) Flat Rate Tariff :

- This is probably the most popular tariff struct
- In this type of tariff various types of consumers are charged at different according rate.
- Flat rate for light loads like light, fan are charged & for heavy consumption charged high.

5) Special Tariff :
- Introduced for specific consumer categories or for particular durations.

6) Time of Day Tariff :
- Consumption varies depending on the time of the day.
- Electricity consumed during peak hours might be priced higher than that consumed during off-peak hours.
- This encourage consumers to shift some of their operations to off-peak hours, thus ~~flattie~~ flattening the demand curve.
- Peak power is very costlier than off-Peak P/w

7) Off Peak Day Tariff :
- Residential & Commercial consumers use less electricity at night until morning & the afternoon slot is also of less consumption known as off peak hours.
- During this off peak time, Generation & Distri. equipments may have to remain idle.

8) Maximum Demand Tariff :
- Energy charge depends on energy consumed by user in kWh.
- Based on the maximum ~~dep~~ demand of the consumer. A consumer pays for his maximum demand (KW or KVA) & the energy consumed. This encourages consumers to keep their peak demand as low as possible.

9) Power Factor Tariff :
- Under the poor Power Factor it causes line losses as well as more current is drawn from the equipment.
- So that consumers encourages to maintain their power factor near unity.
- If the power factor falls below the certain level then penalty might be imposed.

10) Load Factor Tariff :
- A tariff based on the load factor of the consumer.
- Load factor is the ratio of average load to the maximum demand over a period.
- Load factor of a domestic consumer is observed to be near about 0.5 & commercial as well as Industrial ranges from 0.5 to 0.8.
- This type of tariff is encourage consumer to improve his load factor.

11) Availability Based Tariff (ABT) :
- Availability Based Tariff is a frequency based pricing structure linked with grid frequency & power price.
- When frequency goes above a certain level, surplus power is indicated & Rate decreases.
- When frequency drop or below the certain level it indicates power shortage & rate increases.
- This type of tariff is Implemented for bulk power purchasers.

1) A consumer has a maximum demand of 100kW at 30% load factor. If tariff is Rs. 90/kW of maximum demand plus 10 paise/kWh. Find the overall cost/kWh.

Soln:

Given Data,

Maximum Demand = 100kW

Load factor = 30% or 0.3

Tariff = Rs. 90/kW

Find over all cost/kWh.

$$\text{Overall cost/kWh} = \frac{\text{Anual Charges}}{\text{Unit Consumed/year}}$$

Anual Charges = Annual M.D charges + Annual energy charges.

Unit consumed/year = M.D x L.F x Hrs (in year)

= 100 x 0.30 x 8760

= 2,62,800 kWh

Annual charges = Annual M.D charges + Annual energy charges

= (90 x 100) + (0.1 x 262800)

= 9000 + 26280

= Rs 35280

$$\text{Overall cost/kWh} = \frac{\text{Annual Charges}}{\text{Unit Consumed/year}}$$

$$= \frac{\text{Rs. } 35280}{262800}$$

= Rs. 0.1342

Overall cost/kWh = 13.42 paise

2) If minimum demand of a consumeer is 200 kW power factor 0.85 lag & load factor 70%. The tariff applied is Rs. 80/kVA of maximum demand plus is 15 paise/kWh consumed. Calculate annual bill of consumer.

Soln :-

Unit consumed/year = M.D × L.F × Hrs (in year)
= 200 × 0.7 × 8760
= 1226400 kWh

Maximum Demand in kVA = $\frac{M.D}{P.F.} = \frac{200}{0.85}$

= 235.29

Annual Bill = M.D charges + Energy charges
= (80 × 235.29) + (0.15 × 1226400)
= 18,823.2 + 183960
Rs. 202783.2