

# **ATME COLLEGE OF ENGINEERING**

**13th KM Stone, Bannur Road, Mysore - 570 028**



## **DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING**

### **NOTES**

**COURSE TITLE: ELECTRICAL POWER GENERATION AND  
ECONOMICS**

**COURSE CODE: BEE405A**

**SEMESTER: IV**

**MODULE-2: a) Steam Power Plant  
b) Diesel Power Plant  
c) Gas Power Plant**

**Prepared by**

**Department of EEE,  
ATME College of Engineering**

# **INSTITUTIONAL VISION AND MISSION**

## **VISION:**

- Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

## **MISSION:**

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torchbearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence.

## **Department Vision and Mission**

### **Vision:**

To create Electrical & Electronics Engineers who excel to be technically competent and fulfill the cultural and social aspirations of the society.

### **Mission:**

- To provide knowledge to students that builds a strong foundation in the basic principles of electrical engineering, problem solving abilities, analytical skills, soft skills and communication skills for their overall development.
- To offer outcome based technical education.
- To encourage faculty in training & development and to offer consultancy through research & industry interaction.

### **Program Educational Objectives (PEOs)**

**PEO1:** To produce competent and ethical Electrical and Electronics Engineers who will exhibit the necessary technical and managerial skills to perform their duties in society.

**PEO2:** To make Graduates continuously acquire and enhance their technical and socio-economic skills.

**PEO3:** To aspire Graduates on R&D activities leading to offering solutions and excel in various career paths.

**PEO4:** To produce quality engineers who have the capability to work in teams and contribute to real time projects.

### **Program Outcomes (POs)**

**Engineering Graduates will be able to:**

**PO1: Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

**PO2: Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

**PO3: Design / Development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

**PO4: Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

**PO5: Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

**PO6: The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

**PO7: Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

**PO8: Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

**PO9: Individual and team work:** Function effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO10: Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

**PO11: Project management and finance:** Demonstrate knowledge and understanding of the engineering management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

**PO12: Life-long learning:** Recognize the need for and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

### **Program Specific Outcomes (PSOs)**

The students will develop an ability to produce the following engineering traits:

**PSO1:** Apply the concepts of Electrical & Electronics Engineering to evaluate the performance of power systems and also to control industrial drives using power electronics

**PSO2:** Demonstrate the concepts of process control for Industrial Automation, design models for environmental and social concerns and also exhibit continuous self- learning

### **Module – 2(a) STEAM POWER PLANT**

#### **Structure**

2.0 Introduction

2.1 Objective

2.2 Efficiency of Steam Power Plant

2.3 Merits and Demerits of the Plant

2.4 Selection of Site for a Steam Power Plant

2.5 Working of Steam Power Plant and Layout

2.5.1 Main Equipments of Steam Plant

2.5.2 Fuels and Fuels Handling

2.5.3 Combustion and Combustion Equipments

2.5.4 Ash Disposal and Dust Collection

2.5.5 Draught System

2.6 Feed Water

2.7 Steam Station Control

2.8 Outcome

2.9 Further Readings

#### **2.0 Introduction**

Thermal power plant converts heat energy of a coal into electrical energy. Coal is burnt in boilers which convert water into steam. The expansion of steam in turbine produces mechanical power which drives an alternator. Thus the main equipment of a plant is boiler, steam turbine and

## Module – 2(a) Steam Power Plant

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an alternator. There is other auxiliary equipment which help in efficient conversion of heat energy.

The station can be used as private industrial plants or as a central station. Where in industrial plant handles with low pressure for generation and central plant operate at high pressure to produce higher power. India started with the generation of 50MW and now we are generating with a unit capacity of 500MW.

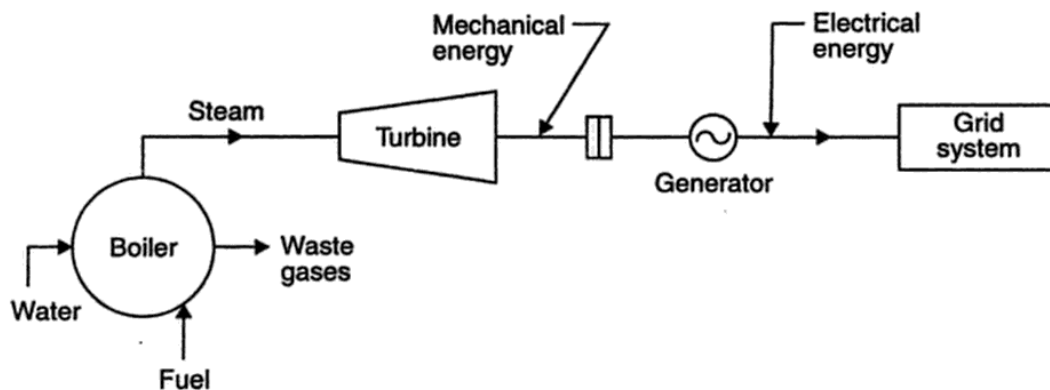


Fig.2.1 Production of electrical energy from a steam power plant.

### 2.1 Objective

Students will be able to

- Understand the working principle of steam power plant
- Working of the main Equipments used in plant
- Disposal of waste
- Steam station control

### 2.2 Efficiency of Steam Power Plant

- The overall efficiency of a steam power plant is low being 30% - 40%.
- The drop is due to the heat loss in different equipment such as boiler(9.45%), turbine, generator.
- Heat balance to be studied by knowing the input, losses and utilization of heat of equipments so that the efficiency of a plant can be increased.

## Module – 2(a) Steam Power Plant

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- The main reason for low efficiency of thermal plant is poor efficiency of thermodynamic cycle i.e. heat cannot be converted to mechanical energy without a drop in temperature and steam in the condenser will be at low pressure.
- The turbine efficiency is 85% and generator efficiency is 98% at full load.
- The factors which cause decrease in efficiency are.
  - Turbine deterioration
  - Vacuum deviation
  - Turbine valve temperature
  - Water temperature
  - Excess combustible in refuse
  - Excess loss in dry flue gas
  - Excess quantity of makeup
  - Excess steam combustion
- STEP (station thermal efficiency performance) factor it is the ratio of actual efficiency to targeted efficiency.  
Also defined as, ratio of target heat rate to the actual heat rate of the station.
- Steam flow at any load = no load flow + [ load \*  $\frac{FL\ Flow - NL\ Flow}{FL\ Flow}$  ]
- Overall efficiency of steam station = generator efficiency \* thermal efficiency of steam turbine \* boiler efficiency

### 2.3 Merits and Demerits of the Plant

#### Advantages:

- They can respond to rapidly changing loads without difficulty.
- A process of the steam generated can be used as a process steam in different industries.
- Can be located near the load center.
- Can be set up near the industries so the transmission cost will reduce.
- Fuel is cheaper.
- Steam turbine and engines can be over loaded upto 25%.
- Less space is required for Thermal plant.
- Production cost and initial cost is less as compared to the diesel power plant.

## Module – 2(a) Steam Power Plant

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Disadvantages:

- Maintenance and operating cost are high.
- The cost of a plant increases with increase in pressure and temperature.
- Long time is required setup and put the plant in action.
- Large quantity of water is required.
- Great difficulty in handling coal.
- Efficiency decreases below 75% of the load.
- Presence of problem due to smoke and heat in the plant.

### 2.4 Selection of Site for a Steam Power Plant

- **Availability of raw materials:** it uses coal or a oil as a fuel a large quantity of it is required say about 5000-6000 tons per day. Storage of raw materials to be done so which increases the investment cost. And to be located near the coalfields or at the railways so it is easy to get raw materials required.
- **Nature of land:** the dead land to be selected which can bare the dead load. The capacity being  $1\text{MN/m}^2$
- **Cost of a land:** it should be very economical so it can be located at the heart of the city.
- **Availability of water:** water is used as a working fluid here large quantity is required for evaporation and condensation so that there should not be any loss in water, it is better located where the water source is easily available.
- **Transportation:** it is economical when located near the railway lines so that bringing equipments and fuels will be easier.
- **Ash disposal facilities:** as the ash comes out in a hot condition it is corrosive and pollutes air. In concern with human health it should be disposed in a larger and safer area.
- **Size of a plant:** The larger plant is more economical compared to the low capacity plant.
- **Load center:** to be located as far as possible to the load center in order to reduce the transmission line cost and losses in it.
- **Public problems:** in concern with the human health from smoke, fly ash and heat discharge it to be located away from the towns.



- **Future expansion:** the choice of site should allow the economical expansion of the plant as load increases in future.

### 2.5 Working of Steam Power Plant and Layout

A central steam station basically works on a Rankine cycle. A steam is produced in boiler expanded in prime mover and condensed in condenser and fed back to boiler. The layout of modern steam power plant consist of 4 circuits,

1. Fuel and ash circuit.
  2. Air and gas circuit.
  3. Feed water and stem circuit.
  4. Cooling water circuit.
- **Fuel and ash circuit:** fuel from the storage is fed to the boiler through a fuel handling devices known as coal handling plant (CHP). Ash produced due to combustion is collected at the back of the boiler and is removed to ash storage using ash handling equipment.
  - **Air and gas circuit:** Air is taken in from atmosphere through a process called forced or induced draught fan. And passes on the furnace through the air preheater, where it has been heated by the heat of flue gases which pass to the chimney via the preheater. The flue gases passes around boiler tube and superheater tubes-dust catching-economizer-air preheater before being exhausted to the atmosphere.
  - **Feed water and steam circuit:** the water and steam circuit condensate leaving the condenser, is first heated in the closed feed water heater through extracted steam from the lowest pressure extraction point of the turbine. And then passes through the deaerator and other heater before it enters the boiler through economizer. In the boiler drum and

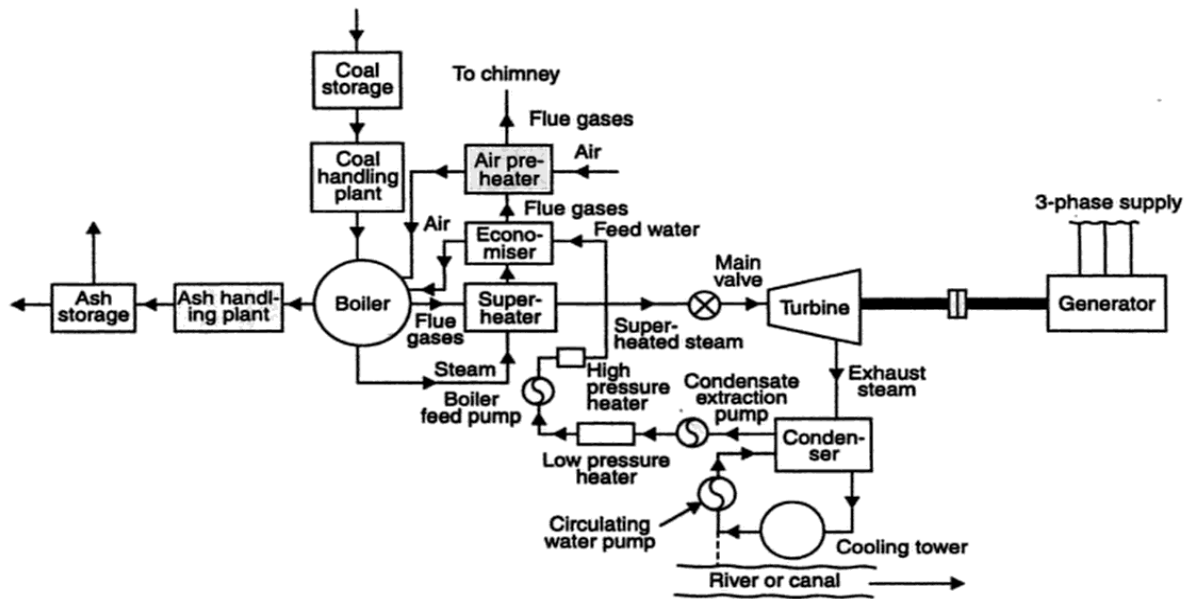


Fig.2.2 layout of steam power plant

tubes, water circulate due to difference in density of higher and lower temperature of water. Wet steam is heated in super heater and then passed to the prime mover. After expanding steam in prime mover it is taken to a reheat boiler and brought to its original dryness form. From there it is passed to condenser through a hot well. And condensate is heated in the feed heaters using a trapped steam from the different points of the turbine. During this process certain amount of water will be lost to repeat the cycle and the water must be purified and added before sending it to the boiler.

- **Cooling water circuit:** the cooling water supply to the condenser helps in maintaining the low pressure in it. The water may be taken from a neutral source from it such as rivers or ponds and pumped back. In the later case the cooling arrangement is made through spray pond or cooling tower.

### 2.5.1 Main Equipments of Steam Plant

- **Boiler:** The heat of combustion of coal in the boiler is utilized to convert water into steam at high temperature and pressure. The flue gases from the boiler make their journey through super-heater, economizer, air pre-heater and are finally exhausted to atmosphere through the chimney. Major types of boilers are: (i) fire tube boiler and (ii) water tube boiler

#### Fire Tube Boiler

## Module – 2(a) Steam Power Plant

- The boiler is named so because the production of combustion passes through the tubes which are surrounded by water.
- Depending on whether the tube is vertical or horizontal the fire tube boiler is divided into two types Vertical tube boiler and Horizontal tube boiler.
- A fire tube boiler is simple, compact and rugged in construction. Its initial cost is low.

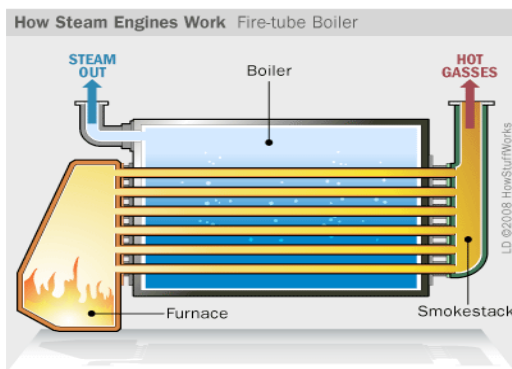
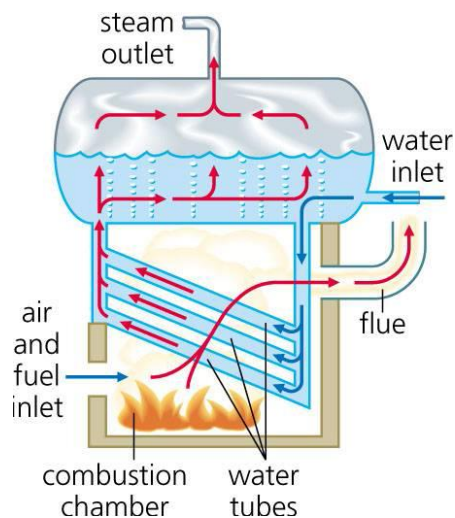


Fig:2.3 fire tube boiler

### Water Tube boilers

- In this boiler, the water flows inside the tubes and hot gases flow outside the tube.
- Water tube boiler are classified as vertical, horizontal inclined boiler
- The circulation of water in the boiler is may be natural or forced.



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## Module – 2(a) Steam Power Plant

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Fig:2.4 water tube boiler

- **Super heater:** The steam produced in the boiler is wet and is passed through a super heater where it is dried and superheated (i.e., steam temperature increased above that of boiling point of water) by the flue gases on their way to chimney. Superheating provides two principal benefits. Firstly, the overall efficiency is increased. Secondly, too much condensation in the last stages of turbine (which would cause blade corrosion) is avoided. The superheated steam from the super heater is fed to steam turbine through the main valve.
- **Economizer:** An economizer is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economizer before supplying to the boiler. The economizer extracts a part of heat of flue gases to increase the feed water temperature.
- **Air preheater:** An air preheater increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced draught fan and is passed through air preheater before supplying to the boiler furnace. The air preheater extracts heat from flue gases and increases the temperature of air used for coal combustion. The principal benefits of preheating the air are increased thermal efficiency and increased steam capacity per square meter of boiler surface.
- **Steam turbine:** The dry and superheated steam from the super heater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy. After giving heat energy to the turbine, the steam is exhausted to the condenser which condenses the exhausted steam by means of cold water circulation.

There are two types of steam turbine:

Impulse	Reaction
Expansion happens in a nozzle	Expansion happens in turbine blades
High speed	Low speed
Sufficient number of impulse stages is provided.	

Compounding of steam turbines:

## Module – 2(a) Steam Power Plant

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Single stage turbines are of low efficiency. In compounding, a number of rotors are connected or keyed to the same shaft. Two types of compounding are used: velocity compounding and pressure compounding

- **Alternator:** The steam turbine is coupled to an alternator. The alternator converts mechanical energy of turbine into electrical energy. The electrical output from the alternator is delivered to the bus bars through transformer, circuit breakers and isolators.
- **Feed water:** The condensate from the condenser is used as feed water to the boiler. Some water may be lost in the cycle which is suitably made up from external source. The feed water on its way to the boiler is heated by water heaters and economizer. This helps in raising the overall efficiency of the plant.
- **Cooling arrangement:** In order to improve the efficiency of the plant, the steam exhausted from the turbine is condensed by means of a condenser. Water is drawn from a natural source of supply such as a river, canal or lake and is circulated through the condenser. The circulating water takes up the heat of the exhausted steam and itself becomes hot. This hot water coming out from the condenser is discharged at a suitable location down the river. In case the availability of water from the source of supply is not assured throughout the year.
- **Cooling towers:** are used. During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled. The cold water from the cooling tower is reused in the condenser.

### 2.5.2 Fuels and Fuels Handling

#### Fuels:

- Fuels can be classified as solid, liquid and gaseous fuel they are coal, oil and gas.
- Analysis of coal: to know the commercial value of coal two tests are carried out proximate analysis (heating and burning activities of coal) and ultimate analysis (composition of coal such as C, S, H, O, N and ash).
- Classification of coal: coal is classified as a increasing order of heat as follows: peat, lignite, bituminous, semi-bituminous, semi anthracite and anthracite.

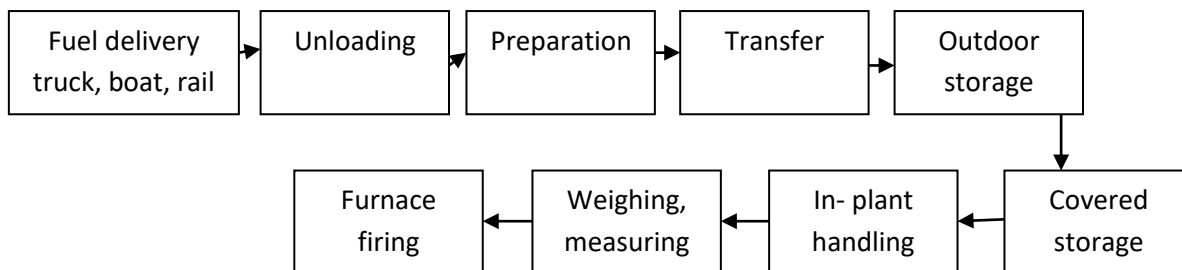
## Module – 2(a) Steam Power Plant

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- Solid fuels: Indian coal- coal have high ash content to reduce this ash content coal is been washed, the washing process creates a large proportion of middlings which can be used as a fuel for a thermal plant. If there is a high ash content it reduces the thermal capacity of the boiler and also adds to the ash disposal problem. A coal with high ash content will increase a size of plant, transportation charges and reduces in efficiency and not cost effective. Resent thermal plant uses a pulverized coal for greater efficiency.
- Liquid fuel: oil can be used a boiler furnace to generate steam. It as many advantages and disadvantages. Heat production will be costlier, fuel oil as more hydrogen in it hence it carries more moisture and this result in lower combustion efficiency.
- Gaseous fuels: natural or manufactured gas can be used. Natural gas such as petroleum wells which contain methane and hydrocarbons can be used which will be supplied from the gas well to the fuel point through pipes but it is costlier. It as all advantages with the disadvantage of storage. In this case plant must be located at the gas plant or cost of transportation will be high.

### Fuel handling:

The majority fuel used in steam power plant is coal, handling a coal is very important because it contributes to the half of the cost of a steam power plant. Following blocks shows the various steps involved in coal handling of a plant. In some plant some steps may vary or may be eliminated.



**Delivery of a coal:** coal may be delivered by sea, rail or road. Selection of proper method to supply coal depends on capacity in tones per hour, location of plant from the point, location of available storage and overhead bankers.

**Unloading:** Using equipments the coal received will be unloaded.

## Module – 2(a) Steam Power Plant

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**Preparation:** Before feeding the coal to the combustion chamber it is brought to the site and prepared for uniform size and suitable for combustion. The preparation of coal includes crushers, seizers, dryers and magnetic separators.

**Transfer:** The coal from a unloading point is carried to a site where it is discharged to the firing equipment. This is done by using equipments such as belt conveyors, screw conveyors, bucket elevators, grab bucket conveyors, skip hoists and flight conveyors.

**Outdoor storage:** The storage of coal is very important it can be done for the 2 reasons based on requirement due to transportation problem the storage is necessary and when coal cost goes low can be purchased and stored. There are many factors which affects the coal storage also such as deterioration of coal, coal handling, increase in capital cost. But the coal can be stored based on the size of the storage space, transportation facilities, weather the coal mines are close or away from the plant. Usually it has a backup for 15-30days.

**Indoor storage:** The amount of coal required by a plant for a day.

**Inplant handling:** The coal handling from a final point to firing point is inplant handling. The amount of coal required for the firing point is fed based on the requirement of the load. It increases as the load increases. Chutes may be used for this purpose. same equipments of coal transfer is used for this purpose.

**Coal weighing:** The coal is weighed at the unloading point and is fed to boiler. One should know whether the proper quantity of coal is fed to the burner is burnt or not. This can be done by weigh bridge, belt scale automatic recording system.

### 2.5.3 Combustion and Combustion Equipments

Fuel is burnt in a furnace. Fuel should be burnt efficiently for economical consumption of power plant. Unpulverized Coal can be burnt by using 2 methods, namely hand firing and stocker firing. In case of pulverized coal 2 systems namely unit system and central system are used.

#### **Hand firing:**

- This method of firing is simple, less capital cost.
- It is a mechanical method used for small installation.

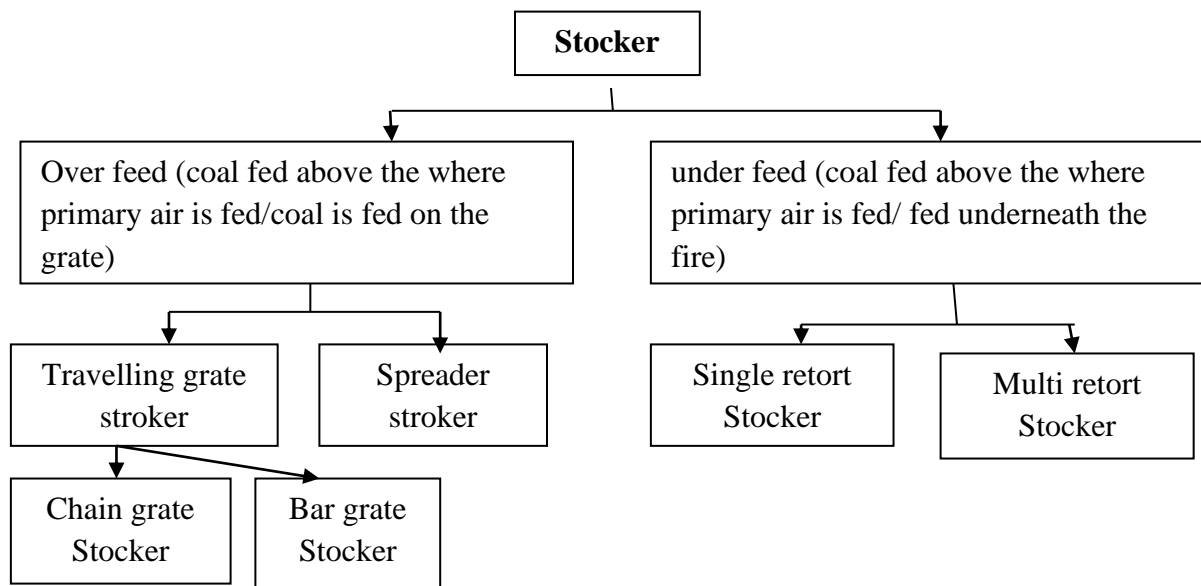
## Module – 2(a) Steam Power Plant

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- Uniform combustion is not possible.
- Supply of air should be given every time when coal is fed to the furnace.

### **Stoker firing:**

- In this method firing coal is carried into the furnace for combustion and ash formed after combustion is discharged at a given point.
- Help in meeting specific requirement of fuel.
- Possible to burn all types of fuels (bituminous and semi bituminous with ash fusing temperature above 3000 degree celces).
- It works with natural and mechanical draught.





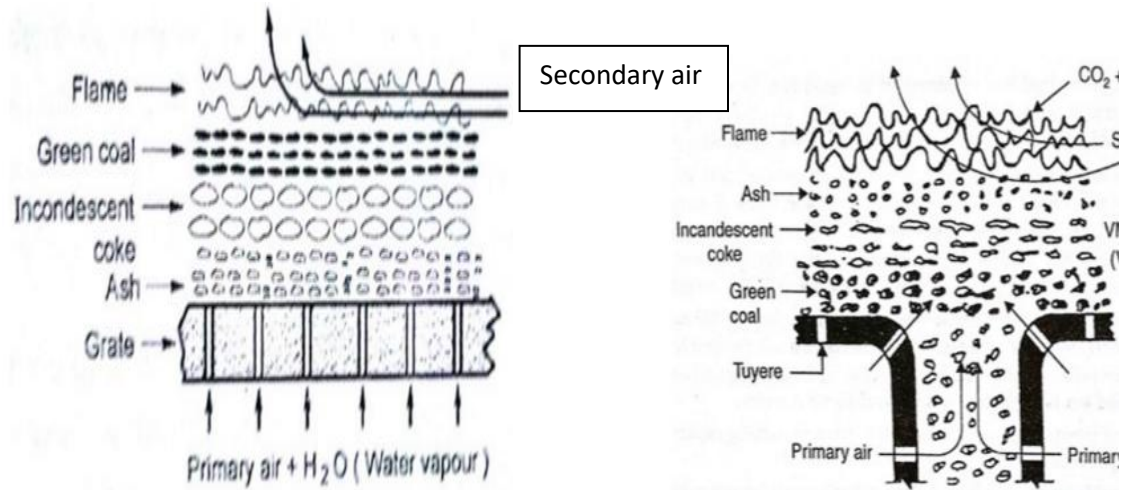


Fig.2.5 An Overfeed and Underfeed Stocker

### Pulverized fuel system:

**unit system:** Each boiler is fired by one pulverized unit.

**Central system:** Fuel is pulverized at center and is distributed to all furnace/boiler with the help of high pressure and high current.

In each system fuel processing equipment consist of crushers, magnetic separators, driers, pulverising mills, storage bins, conveyors and feeders.

**Coal pulverising mills:** requirement for this kind of mills are drying of coal, grinding, separation based on size, creating proper fuel air ratio and uitabel control for all theses equipments.

**Pulverized fuel burners:** It has an arrangement to supply proper amount of fuel- air ratio to the furnace. Based on type of fuel burners are used such as gas burner, coal burner, pulverized burner. It can be further classified as long flame, turbulent, tangential and cyclone burners.

**Automatic Combustion control:** as load on generator changes demand for steam also changes. Automatic controller will change the steam as quick as possible and will maintain constant steam pressure and combustion condition. This avoids manual labour. The parameters to be controlled with variation in load are steam, water, fuel and air.

### 2.5.4 Ash Disposal and Dust Collection

## Module – 2(a) Steam Power Plant

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### 1. Ash Handling Plant

In Thermal Power Plant's coal is generally used as fuel and hence the ash is produced as the ByProduct of Combustion. Ash generated in power plant is about 30-40% of total coal consumption and hence the system is required to handle Ash for its proper utilization or disposal.

*The steam power plant produces 5000 of tons ash daily ( 2000MW)*

The ash may be to types,

- Fly Ash ( Around 80% is the value of fly ash generated)
- Bottom ash (Bottom ash is 20% of the ash generated in coal based power stations.

#### **Fly Ash**

Ash generated in the ESP(electro static precipitator) which got carried out with the flue gas is generally called Fly ash. It also consists of Air pre heater ash & Economizer ash (it is about 2 % of the total ash content).

#### **Bottom ash**

Ash generated below furnace of the steam generator is called the bottom ash.

#### **The operation of ash handling plants is**

- Removal of ash from the furnace ash hoppers
- Transfer of the ash to a fill or storage
- and disposal of stored ash

#### **The ash may be disposed in the following way.....**

- Waste land site may be reserved for the disposal of ash.
- Building contractor may utilize it to fill the low lying area.
- Deep ponds may be made and ash can be dumped into these ponds to fill them completely
- When sea born coal is used, barrage may take the ash to sea for disposal into water grave.

#### **The modern ash handling system usually used in large steam power plants are**

- Belt conveyor system
- Pneumatic system
- Hydraulic system
- Steam jet system

## Module – 2(a) Steam Power Plant

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### **Belt conveyor system**

- In this system the ash is made to flow through a water seal over the belt conveyor in order to cool it down and then carried out to a dumping site over the belt.
- It can deliver 3 tons of ash per hour with a speed of 0.3m/minute.
- The life of belt is 5 years. it is used in small power plant

### **Pneumatic system**

- In this system air is employed as a medium to driving the ash through a pipe over along distance.
- This system can handle 5-30 tons of ash per hour
- This is used for disposal of fly ash

### **Hydraulic system**

- In this system a stream of water carries ash along with it in a closed channel and disposed it off to the proper site.
- It is of two types high pressure system and low pressure system.

### **Steam jet system**

- This system employs jets of high pressure blowing in the direction of ash travel through a conveying pipe in which ash from the boiler ash hopper is fed.
- It is employed in small and medium size plant
- Steam consumption is 110 kg per tons of material conveyed.

### **2.5.5 Draught System**

- The combustion in the boiler requires supply of sufficient quality of air and removal of exhaust gases
- The Circulation of air is caused by difference of pressure is known as draught. Thus draught is the differential in pressure between the two points.
- A draught tube may be
  1. Natural Draught
  2. Mechanical Draught

### 2.5.6 Natural Draught

- A natural Draught is provided by the chimney or stack.
- Natural draught has its limitation . Modern plants has high rate of heat transfer and Draught
- losses are very high. in view of this Natural draught is used only for small boilers.

### 2.5.7 Mechanical Draught

- Modern large size plants use very large size of boilers of capacity above 1000,000 kg per hour, such boiler needs tremendous volume of air (around 200000 m<sup>3</sup>) Per minute. A chimney provide this. Therefore mechanical draught is used.
- In a mechanical draught the system the movement air is due to the action of fan. A mechanical Draught consist of forced Draught or induced draught or both.
- In forced draught system the fan is installed near the boiler .the fan force the air through the furnace , economizer, air preheater and chimney. The pressure of air, throughout the system, is above atmospheric and air is forced to flow through the system
- In an induced draught system the , the fan is installed near the base of the chimney .The burnt gases are sucked out from the boiler , thus reducing the pressure inside the boiler. to less than atmosphere. this induces fresh air to enter the furnace.
- A mechanical Draught need additional capital investment and maintenance .But it required for proper operation of modern power plant. In super thermal power plant, each boiler may used two forced fans and two induced fan.

### 2.6 Feed Water

- Water contains many impurities it should be removed before it is fed to boiler.
- Every time water to be fed into a system due to losses as steam and leakage.
- Impurities in water are as follows: undissolved and suspended solid materials, dissolved salts and minerals, dissolved gases such as CO<sub>2</sub> and O<sub>2</sub>,oil,acids etc
- Operational troubles are caused due to impurities in water such as scale formation, corrosion, priming, forming, and carry over , caustic embrittlement.
- There are different types of feed water treatment are mechanical, thermal and chemical treatment.

## Module – 2(a) Steam Power Plant

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- Evaporators are used for supplying pure water to boilers. And are condensed using a pure water .
- Feed water heater are used to heat feed water before supplied to boiler. They are 2 types of heaters open and closed types of heater.

### 2.6.1 Turbo Alternators

- Turbo alternators in central power stations are usually 2 pole, 50Hz, 3000RPM.
- Their size vary upto 1000MW.
- The rotor and stator of a turbo alternator are cooled by air upto 40MW greater than that hydrogen cooling is used.
- Turbo alternator are rated for 11, 12, 22 -33KV. But higher voltages are not suggested because site, transmission problem, etc.
- Have 0.8 PF lag, 230 V. and can be overloaded 20% of rated PF.

### 2.7 Steam Station Control

- Control are provided at boiler, turbine and generator for best operating condition.
- We use automatic combustion control for best boiler efficiency.
- Turbine governing is effected in 2 ways in case of small turbine single inlet valve and large turbine more number of nozzles. These nozzles to be maintenance at proper vacuum, enough circulating water , water pumps oil pressure control circuits, feed water control , steam control etc.
- Generator increases in increase in load which Result in frequency reduction , load on change in generator is adjusted by change in speed of generator.
- In modern steam station boiler and turbine is controlled at turbine room and the generator and feeder at control room, in some case all may be centralized at one place in control room.
- Most of the control are automatic.
- A number of annunciation and indicating instruments helps in controlling the operation of steam station very effectively.

### 2.8 Outcome

Students have studied and understood

- The working principle and operation of steam power plant
- Various Equipments used in plant
- Ash and Dust Handling
- Steam station control

### 2.9 Further Readings

- <http://nptel.ac.in/courses/108105058/8>
- Pressurized Water Reactor (PWR) Systems, Reactor Concepts Manual, USNRC Technical Training Centre Publications (Available at [http://mitnse.files.wordpress.com/2011/03/pwr\\_plant\\_04.pdf](http://mitnse.files.wordpress.com/2011/03/pwr_plant_04.pdf))

## **Module – 2(b) DIESEL POWER PLANT**

### **Structure**

2.0 Introduction

2.1 Objective

2.2 Merits and Demerits

2.3 Selection of Site for Diesel Plant

2.4 Elements of Diesel Power Plant

2.5 Applications

2.6 Course Outcome

2.7 Further References

### **2.0 Introduction**

A generating station in which diesel engine is used as the prime mover for the generation of electrical energy is known as Diesel power station. Diesel power plant is more efficient than any other power plant of a same size. In a diesel power station, diesel engine is used as the prime mover. The diesel burns inside the engine and the products of this combustion act as the working fluid to produce mechanical energy. The diesel engine drives the alternator which converts mechanical energy into electrical energy. As the generation cost is considerable due to high price of diesel, therefore, such power stations are only used to produce small power. Initial cost of a plant is less and can be started very quickly as a result there will be very less standby losses. Diesel station can be used as central station, stand by plant, peak load plant, emergency plant, mobile plant, nursery station, small supply units for cinemas, hospitals and municipalities.

### **2.1 Objective**

After studying this unit, students will be able to

- Understand the working of diesel engine power plant and Applications of diesel engine power plant

## **2.2 Merits and Demerits**

### **Merits:**

1. Simple design & layout of plant.
2. Occupies less space & is compact.
3. Can be started quickly and picks up load in a short time.
4. Requires less water for cooling.
5. Thermal efficiency better than that of Steam Power plant of same size.
6. Overall cost is cheaper than that of Steam Power plant of same size.
7. Requires no Operating staff.
8. No stand-by losses.
9. Free from ash handling problem
10. Located near the plant.
11. Can use different types of fuel.

### **Demerits:**

1. High running charges due to costly price of Diesel.
2. Plant does not work efficiently under prolonged overload conditions.
3. Generates small amount of power.
4. Cost of lubrication very high.
5. Maintenance charges are generally high.
6. The plant does not work satisfactorily under overload conditions for a longer period.
7. The plant can only generate small power.

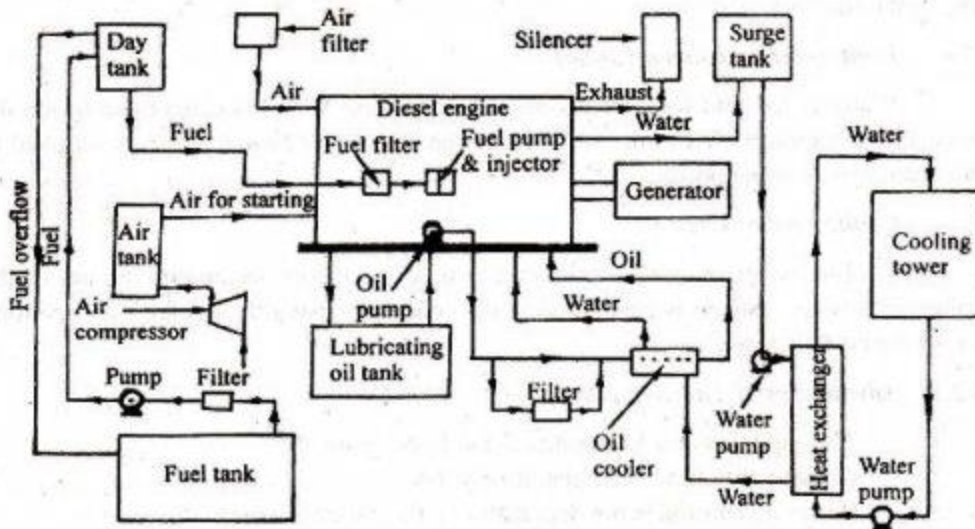
## **2.3 Selection of Site for Diesel Plant**

- Distance from load center



- Availability of land and water
- Foundations
- Transport of fuel
- Local conditions
- Neighborhood noise and nuisance

## 2.4 Elements of Diesel Power Plant



- **Fuel supply system:** It consists of storage tank, strainers, fuel transfer pump and all day fuel tank. The fuel oil is supplied at the plant site by rail or road. This oil is stored in the storage tank. From the storage tank, oil is pumped to smaller all day tank at daily or short intervals. From this tank, fuel oil is passed through strainers to remove suspended impurities. The clean oil is injected into the engine by fuel injection pump.
- **Air intake system:** This system supplies necessary air to the engine for fuel combustion. It consists of pipes for the supply of fresh air to the engine manifold. Filters are provided to remove dust particles from air which may act as abrasive in the engine cylinder.
- **Exhaust system:** This system leads the engine exhaust gas outside the building and discharges it into atmosphere. A silencer is usually incorporated in the system to reduce the noise level.
- **Cooling system:** The heat released by the burning of fuel in the engine cylinder is partially converted into work. The remainder part of the heat passes through the cylinder

walls, piston, rings etc. and may cause damage to the system. In order to keep the temperature of the engine parts within the safe operating limits, cooling is provided. The cooling system consists of a water source, pump and cooling towers. The pump circulates water through cylinder and head jacket. The water takes away heat from the engine and itself becomes hot. The hot water is cooled by cooling towers and is re-circulated for cooling.

- **Lubricating system:** This system minimizes the wear of rubbing surfaces of the engine. It comprises of lubricating oil tank, pump, filter and oil cooler. The lubricating oil is drawn from the lubricating oil tank by the pump and is passed through filters to remove impurities. The clean lubricating oil is delivered to the points which require lubrication. The oil coolers incorporated in the system keep the temperature of the oil low.
- **Engine starting system:** This is an arrangement to rotate the engine initially, while starting, until firing starts and the unit runs with its own power. Small sets are started manually by handles but for larger units, compressed air is used for starting. In the latter case, air at high pressure is admitted to a few of the cylinders, making them to act as reciprocating air motors to turn over the engine shaft. The fuel is admitted to the remaining cylinders which makes the engine to start under its own power.
- **Diesel engine alternators:** The alternators are of rotating field whose capacities vary from 25-5000KVA at 0.8 p.f. lag. Generally they have a rating of 3 phase 440V. The alternators are directly coupled to engine special attention to be taken to avoid vibrations. They have automatic voltage regulation which permit voltage regulation and parallel operation. Each alternator will have its own exciters of voltage rating 115V or 230V and power rating of 2-3% of alternate rating.
- **Instruments:** Thermometers, pressure gauges, wattmeters, voltmeters ammeters, synchronising equipments, alarms etc.
- **Switchgear control equipments:** bus bars, station transformer, CB, UVR,OVR, lamp indicators will indicate the position of CB or whether the bus bar is alive or dead. The engine governing can be controlled from the switch board.

## 2.5 Applications

- **Emergency plants:** Many industries all over the world have installed diesel plant in their premises as a backup when supply from grid is disconnected.
- They are used for starting auxiliaries in steam power stations.
- **Mobile plants:** They are mounted on a trailers are used for temporary and emergency purposes.
- **Peak load plant:** It can be started and loaded very quickly. As such these plants can be used as peak load plants.
- **Stand by plants:** When supply from a grid is not available it will be used as a standby plant.
- They can be used in remote location where supply from grid is not available.
- Used in steam and hydro plant at the construction level.

## 2.6 Course Outcome

- Understood the operation of diesel engine power plant and its applications

## 2.7 Further References

- <https://www.scribd.com/doc/41088831/Diesel-Power-Plant>
- <http://www.ignou.ac.in/upload/Unit-4-58>

### **Module – 2 (c) Gas Turbine Power Plants**

#### **Structure**

- 2.0 Introduction
- 2.1 Objective
- 2.2 Merits and demerits
- 2.3 Selection site
- 2.4 Fuels for gas turbines
- 2.5 Elements of simple gas turbine power plant
- 2.6 Methods of improving thermal efficiency of a simple steam power plant
- 2.7 Turbine Performance
- 2.8 Comparison of gas power plant with steam and diesel power plants.
- 2.9 Advantages of Gas power plant
- 2.10 Disadvantages of Gas turbine Power Plant
- 2.11 Applications
- 2.12 Outcome
- 2.13 Further Readings

#### **2.0 Introduction**

Gas turbines are one of the most widely-used power generating technologies. Gas turbines are a type of internal combustion (IC) engine in which burning of an air-fuel mixture produces hot gases that spin a turbine to produce power. It is the production of hot gas during fuel combustion, not the fuel itself that gives gas turbines the name. Gas turbines can utilize a variety of fuels, including natural gas, fuel oils, and synthetic fuels. Combustion occurs continuously in gas turbines, as opposed to reciprocating IC engines, in which combustion occurs intermittently.

#### **2.1 Objective**

Explain the arrangement and operation of gas turbine power plants and working of major equipment in the plants.

#### **2.2 Merits and Demerits**

##### **2.2.1 Advantages of Gas Turbine Power Plant**

1. They are small in size, weigh less and have low initial cost per unit output.
2. They are easy to install within short periods.
3. They are quick-starting and smooth running.
4. They offer flexibility by supplying electricity for power generation as well as by supplying compressed air for process needs.
5. They are capable of using a range of liquid and gaseous fuels including synthetic fuels.
6. They are subjected (put) to fewer environmental restrictions than other prime movers.
7. Water consumption is less compared to steam power plant.

### **2.2.2 Disadvantages**

1. An electric motor or an I.C. engine is necessary for starting the plant. The starting motor must bring the compressor well towards the operating speed. So, starting is not simple as in the case of other power plants.
2. Gas turbine plants have less vibrations when compared with reciprocating engines of the same speed. However the high frequency noise from the compressor is objectionable.
3. High temperatures impose severe restriction on the servicing conditions of the plant.
4. Overall efficiency is low since two-thirds of the total power output is used for driving the compressor.
5. The blades of the turbine require special cooling methods due to the severity of operating temperatures and pressures. In practice, the temperatures at the entry of the turbine are as high as  $1100^{\circ}\text{C}$  -  $1260^{\circ}\text{C}$ . Hence they should be made of special metals and alloys.

### **2.3 Selection of site**

The factors to be considered for site selection of gas turbine power plants are distance from load centre, availability of land at reasonable rate, availability of fuel at reasonable rate, availability of transportation facilities, distance from populated area and type of land (land should be of high bearing capacity).

### **2.4 Fuels for gas turbines**

One further advantage of gas turbines is their fuel flexibility. They can be adapted to use almost any flammable gas or light distillate petroleum products such as gasoline (petrol), diesel and kerosene (paraffin) which happen to be available locally, though natural gas is the most commonly used fuel. Crude and other heavy oils and can also be used to fuel gas

turbines if they are first heated to reduce their viscosity to a level suitable for burning in the turbine combustion chambers.

### 2.5 Elements of Gas Turbine power plant

The major components are

- Regenerator
- Combustion chamber
- Compressor
- Alternator
- Starting motor
- Gas turbine

- Compressor:

The compressor used in gas power plant is rotating type. The air at atmosphere pressure is drawn by the compressor through a filter which removes the dust. The rotary blades in the compressor push the air through the stationary blades to raise its pressure. Thus air with high pressure is available at compressor output.

- Regenerator:

A regenerator is a device which recovers the heat from the exhaust gases to heat the air from the compressor. The exhaust is passes through regenerator before releasing it to the atmosphere. Several numbers of tubes are nested in a shell of the compressor. The compressed air passes through these tubes and exhaust gases from the gas turbine passes through the shell side which transfers heat to the compressed air. In this way compressed air heated by the exhaust gases which is an effective usage of waste gasses.

- Combustion chamber:

This is one of the important components of the gas power plant where the high pressure air from the compressor is entered in it via regenerator. The air from regenerator is quietly heated which is not adequate to drive the gas turbine. Only hot air with high pressure can only drive the gas turbine. So in combustion chamber the compressed air is heated up to high temperature (3000 F). The heat is added to the air by burning oil which is injected through a burner in to the chamber at high pressure. The heated air with high pressure is then applied to gas turbine after it attains suitable temperature.

- Alternator:

Alternator is directly coupled with the gas turbine same as in the case of steam power plant. Alternator converts the mechanical energy of the turbine in to electrical energy. The output generated electrical energy is then passed to the grid through a generator transformer, isolators and circuit breakers.

- Starting motor:

The starting motor is placed to start the compressor before starting the plant. This works as the initial driving component for the compressor. The starting motor is coupled to the same shaft of the gas turbine for this purpose. Once the gas turbine starts rotating, some part of the mechanical energy is used to drive the compressor and the starting motor is turned off. The starting motor is driven by the batteries.

- Gas Turbine:

This is heart component of the gas power plant. The hot air with high pressure and temperature is passed through gas turbine. The gases are expanded on the gas turbine blades which causes the rotation of blades to the intended mechanical work. After expanding, the exhaust gases with the temperature about 900 F are applied to the regenerator.

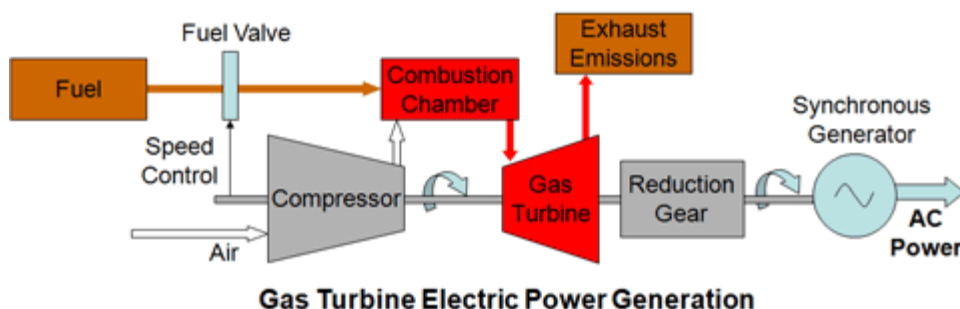
### Electrical Power Generation

In electricity generating applications the turbine is used to drive a synchronous generator which provides the electrical power output but because the turbine normally operates at very high rotational speeds of 12,000 r.p.m or more it must be connected to the generator through a high ratio reduction gear since the generators run at speeds of 1,000 or 1,200 r.p.m. depending on the AC frequency of the electricity grid.

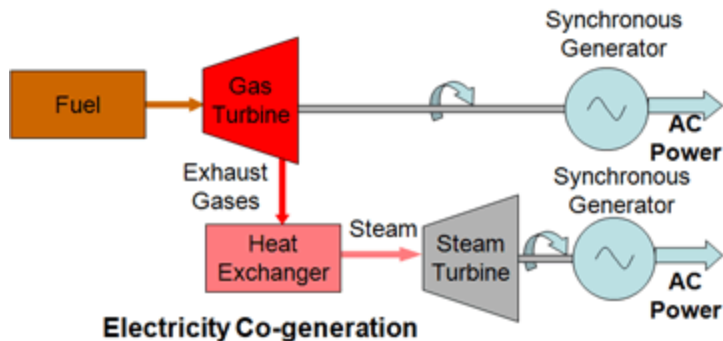
## 2.6 Methods of Improving Thermal Efficiency

Gas turbine power generators are used in two basic configurations

Simple Systems consisting of the gas turbine driving an electrical power generator.



Combined Cycle Systems which are designed for maximum efficiency in which the hot exhaust gases from the gas turbine are used to raise steam to power a steam turbine with both turbines being connected to electricity generators.



### 2.7 Turbine Performance

#### Turbine Power Output

To minimise the size and weight of the turbine for a given output power, the output per pound of airflow should be maximised. This is obtained by maximising the air flow through the turbine which in turn depends on maximising the pressure ratio between the air inlet and exhaust outlet. The main factor governing this is the pressure ratio across the compressor which can be as high as 40:1 in modern gas turbines. In simple cycle applications, pressure ratio increases translate into efficiency gains at a given firing temperature, but there is a limit since increasing the pressure ratio means that more energy will be consumed by the compressor.

- **System Efficiency**

Thermal efficiency is important because it directly affects the fuel consumption and operating costs.

- **Simple Cycle Turbines**

A gas turbine consumes considerable amounts of power just to drive its compressor. As with all cyclic heat engines, a higher maximum working temperature in the machine means greater efficiency (Carnot's Law), but in a turbine it also means that more energy is lost as waste heat through the hot exhaust gases whose temperatures are typically well over 1,000°C. Consequently simple cycle turbine efficiencies are quite low. For heavy plant, design efficiencies range between 30% and 40%. (The efficiencies of aero engines are in the range 38% and 42% while low power microturbines (<100kW) achieve only 18% to 22%).



Although increasing the firing temperature increases the output power at a given pressure ratio, there is also a sacrifice of efficiency due to the increase in losses due to the cooling air required to maintain the turbine components at reasonable working temperatures.

- **Combined Cycle Turbines**

It is however possible to recover energy from the waste heat of simple cycle systems by using the exhaust gases in a hybrid system to raise steam to drive a steam turbine electricity generating set. In such cases the exhaust temperature may be reduced to as low as 140°C enabling efficiencies of up to 60% to be achieved in combined cycle systems.

In combined-cycle applications, pressure ratio increases have a less pronounced effect on the efficiency since most of the improvement comes from increases in the Carnot thermal efficiency resulting from increases in the firing temperature.

Thus simple cycle efficiency is achieved with high pressure ratios. Combined cycle efficiency is obtained with more modest pressure ratios and greater firing temperatures.

### **2.8 Comparison of gas power plant with steam and diesel power plants**

1. It is smaller in size and weight as compared to an equivalent steam power plant. For smaller capacities the size of the gas turbine power plant is appreciably greater than a high speed diesel engine plant but for larger capacities it is smaller in size than a comparable diesel engine plant. If size and weight are the main consideration such as in ships, aircraft engines and locomotives, gas turbines are more suitable.
2. The initial cost and operating cost of the plant is lower than an equivalent steam power plant. A thermal plant of 250 MW capacity cost about Rs. 250 crores. Presently whereas gas turbines plant of that same-size cost nearly 70 crores.
3. The plant requires less water as compared to a condensing steam power plant.
4. The plant can be started quickly, and can be put on load in a very short time.
5. There are no standby losses in the gas turbine power plant whereas in steam power plant these losses occur because boiler is kept in operation even when the turbine is not supplying any load.
6. The maintenance of the plant is easier and maintenance cost is low.

7. The lubrication of the plant is easy. In this plant lubrication is needed mainly in compressor, turbine main bearing and bearings of auxiliary equipment.
8. The plant does not require heavy foundations and building.
9. There is great simplification of the plant over a steam plant due to the absence of boilers with their feed water evaporator and condensing system.

### **2.9 Advantages of Gas power plant**

- The design of gas power plant is simple compared to steam power plant as that it does not require boiler and its auxiliaries.
- Occupies less space and size compared to the steam power plants where the boiler and feed water arrangement is not needed.
- Initial and Operation costs are lower compared to all other plants.
- Gas turbines are simple in construction compared to steam turbines and the maintenance of them is also less.
- It requires less water compared to steam power plants where the condenser is required.
- It can be started with less time from cold conditions.

### **2.10 Disadvantages of Gas turbine Power Plant**

The efficiency and net output power is less because some amount of mechanical power is used to drive the compressor.

Initial external power is needed to drive the compressor until the plant starts generating.

### **2.11 Applications**

Gas turbines can be used for large scale power generation. Examples are applications delivering 600 MW or more from a 400 MW gas turbine coupled to a 200 MW steam turbine in a co-generating installation. Such installations are not normally used for base load electricity generation, but for bringing power to remote sites such as oil and gas fields. They do however find use in the major electricity grids in peak shaving applications to provide emergency peak power.

Low power gas turbine generating sets with capacities up to 5 MW can be accommodated in transportation containers to provide mobile emergency electricity supplies which can be delivered by truck to the point of need.

### 2.12 Outcome

Described about the working of Gas turbine power plants and state functions of major equipment of the power plants

### 2.13 Further Readings

- <https://energy.gov/fe/how-gas-turbine-power-plants-work>
- <https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact=8&ved=0ahUKEwic0q-s97bYAhXI6Y8KHS9fBq4QFghZMAQ&url=https%3A%2F%2Fwww.iitk.ac.in%2Freach%2F2008%2FEnergy%2FGas%2520Turbine%2520-AKushari.ppt&usg=AOvVaw1TOdqNNELcHINBiKH8PfFn>