Diesel, Gas Turbine, combine cycle power plant.

Introduction:

Diesel electric plants in range of 2 to 500 mw are used as central stations for small supply authorities to supplement hydroelectric or universally adapted to supplementing thermal power stations where they are stand by generating units for starting from cold or under emergency condition.

Plant are essential for starting from cold or under emergency condition.

Application of Diesel Engines in Power Field

Peak Load Plants:

Diesel Plant can be used in combination with thermal or hydro plant as peak load units. They can be easily started or stopped at a short notice to meet peak demand.

Mobile Plants:

Diesel Plants mounted on trailers can be used temporarily or emergency purpose.

Stand by units:

Main unit fails so cannot cope with demand. This Plant can supply.
Emergency Plant:
During power interruption in a vital unit like a key industrial plant or a hospital, a diesel electric plant can be used to generate the needed power.

Nursery Station:
- In absence of main grid, diesel plant can be installed to supply power in small town.
- In course of time when electricity from main grid becomes available in the town, diesel unit can be shifted.

Starting Station:
- Diesel units used to run auxiliaries for starting large steam power plant.

Central Station:
- Used as central station where capacity required is small.

Advantages of Diesel Plant:
- Easy to design.

Disadvantages
- occupy less space
- located near load center
- easier lubrication system
- no ash handling problem

Disadvantages:
- high operating cost
- high maintenance
- noise problem
- cannot supply over load.

Types:
- Air is compressed to high pressure x small volume at which hot air temp is more than self ignition temp of oil, which is atomized form. The combustion product expand sprayed in to compressed air in fine atomized form. The combustion product expand doing work on piston Linn exhaust valve open.

Exhaust of product Linen Lake place.

There is no spark plug. Fuel oil spray burns in hot compressed air. Hence diesel engine also called compressed ignition.
Brayton cycle:

Brayton cycle used for analysis of gas turbine plants.

With reference to Brayton cycle:

Heat supplied \( Q_1 = m \cdot c_p \cdot (T_3 - T_2) \)

\( m \) = mass of air

Heat rejected \( Q_2 = m \cdot c_p \cdot (T_4 - T_1) \)

\[ \frac{T_{2s}}{T_1} = \frac{T_3}{T_4} \]

\[ = \left( \frac{P_2}{P_1} \right)^{\gamma-1/\gamma} \]

\( \gamma_p \) = pressure ratio \( P_2/P_1 \)

\[ h_c = \frac{T_{2s}}{T_2} - \frac{T_1}{T_1} \]

Turbine isentropic efficiency

\[ \eta_t = \frac{T_3 - T_4}{T_3 - T_{4s}} \]

\[ T_1 - T_{2s} - T_3 - T_{4s} - T_1 \]
\[ \eta_{\text{cycle}} = 1 - \frac{1}{\frac{V_p}{V}} \]
\[ = 1 - \frac{T_1}{T_{45}} \]

- \( V_p \) increases, \( \eta_{\text{cycle}} \) increases
- \( \text{Eim} \) cannot cycle

\[ V_p \text{ max} = \sqrt{\frac{T_3}{T_1}} = \sqrt{\frac{T_{\text{max}}}{T_{\text{min}}}} \]

\[ \omega_{\text{net}} = \omega_1 - \omega_c \]
\[ = \omega_1 - \omega_2 = \omega_1 - \omega_c \]
\[ = \omega_1 \max \left( \frac{T_3 - T_{45} - T_{45} + T_E}{2(\omega_1 - \omega_c)} \right) \]

\[ \text{Differentially, } \omega_{\text{net}} \text{ with respect to } V_p \]

\[ \frac{d\omega_{\text{net}}}{dV_p} = 0 \]

\[ (V_p)_{\text{opt}} = \frac{T_{\text{max}}}{T_{\text{min}}} \frac{y}{y-1} \]
\[ (V_p)_{\text{opt}} = \left( \frac{T_{\text{max}}}{T_{\text{min}}} \right) \frac{y}{y-1} \]

\[ \omega_{\text{net}}(\max) \]

\[ V_p \]
\[ V_p(\max) \]
Variation of net cycle work

\[(V_p)_{opt} = \sqrt{(V_p)_{max}}\]

On substituting

\[\text{Wnet} = \text{max} CP \left( T_{\max} - T_{\min} \right)^2\]

\[\text{\(\eta_{\text{max power}} = 1 - \frac{T_{\min}}{T_{\max}}\)}\]

If compressor = turbine, efficiency are

Considered

\[\text{\(V_p\)}_{opt} = \left[ \frac{5C_{\eta \tau}}{T_3 - T_1} \right] \frac{T_2}{2(\gamma - 1)}\]

\[\text{\(V_p\)}_{max} = \frac{T_3 - T_1}{1 + \left( T_3 - T_1 \right) - \frac{T_1}{\gamma c_{\eta \tau} T_1}}\]

\[\frac{c_p}{T_1} = \frac{\text{Wnet}}{c_p} \left( T_3 - T_1 \right) - \frac{T_1}{\gamma c_{\eta \tau} T_1}\]

\[= 1 - \frac{T_1}{T_3} \frac{V_p}{\gamma - 1}\]

Effect of regeneration

\[\varepsilon = \frac{\text{Actual temp rise of air}}{\text{Max. temp rise possible}}\]

\[= \frac{T_5 - T_2}{T_4 - T_2}\]
Let us consider two cyclic power plants coupled in series, the topping plant operating at bottom cut.

The steam gas was working fluid in the topping plant at water in bottom.

\[ h = h_1 + h_2 - h_1 \rho_2 \]

\[ w_f = w_i - w_c \]

Not to lose two plant in series, in previous section it was assumed that all heat reject.
by topping plant is absorbed by bottom

However there is always some heat loss & heat absorbed always less than heat rejected.

Heat loss in blue two plants in series.

\[ h = w_1 + w_2 \]
\[ h_1 = \frac{w_1}{\eta_1} \]
\[ h_2 = \frac{\eta_2}{\eta_3} \]
\[ \theta_3 = \theta_2 - \theta_1 = \eta_3 (1 - h_1) - \omega_1 \]
\[ h = h_1 + h_2 \]
\[ \frac{\eta_3}{\omega_1} = h_1 + h_2 \left[ 1 - h_1 \right] - \frac{\omega_1}{\omega_2} \]
\[ \frac{\eta_8}{\omega_2} = 1 - \frac{\omega_1}{\omega_2} \]
\[ h = \frac{w_1 + w_2}{2} = \frac{w_1 + w_2}{a_2 + a_4} = \frac{h_1}{2} + \frac{h_2}{2} \]

\[ = h_1 x_1 + h_2 (1-x_1) \]

\[ = h_1 x_1 + h_2 - h_2 x_1 \]

\[ = h_2 + x_1 (h_1 - h_2) \]

\[ x_2 = \frac{a_4}{a_2 + a_4} = \frac{1-x_2}{a_2 + a_4} \]

Series - Parallel Plant

\[ h_1 (1-x_2) + h_2 \left( \frac{a_4 + a_3 - a_2}{a_2 + a_4} \right) \]
\[ \eta_1 = (1 - \eta_2) + \eta_2 (\lambda_2 (1 - \eta_1)) (1 - \eta_2) - \eta_2 \]

\[ \eta_2 = \eta_1 \eta_2 - \eta_2 \]

\[ \eta_B = \frac{\eta_5}{\omega_5 + \omega_1} = 1 - \frac{\eta_1 \omega_6}{\omega_4 \omega_3 - \omega_4 + \omega_6} \]

\[ \eta_5 = 1 - \frac{\eta_6}{\omega_2 + (\omega_2 - 1) + (1 - \eta_5)} \]

\[ \eta_6 = \eta_1 + \eta_2 + \eta_1 \eta_2 - \eta_2 (1 - \eta_6) \frac{(\lambda_2 + (1 - \lambda_2) (1 - \eta_6)) - \lambda_1 \eta_2 (1 - \eta_6)}{\lambda_2 + (1 - \lambda_2)} \]

\[ \eta = \eta_1 + (\eta_0) \eta_2 (1 - \eta_1) = \eta_1 (\eta_0) - \eta_1 (\eta_0) \eta_2 \]

The same can be derived earlier.
components to layout of Diesel Engine Power Plant

Essential components are

- Diesel Engine
- Air Intake System
- Fuel System
- Cooling System
- Lubricating System
- Exhaust System

Starting of Engine

Exhaust lines

Fuel Tank

Air Filter

Air Compressor

Fuel Filter

Fuel Injector

Oil Filter

Oil Pump

Exhaust

Swage Tank

Engine:

Main component of diesel Power Plant.

Directly coupled to generator

Air Intake System:

The fresh air is trapped from atmosphere.

It is filtered to remove dust and solid.

Particulate which cause wear to engine.

This air is compressed with help of

Super charger to increase the output of engine.
Exhaust System:
- Used to discharge engine's gas to the atmosphere. The exhaust main fold collects the exhaust of each cylinder to guide it to the exhaust pipe. There gases are released to the atmosphere through muffler.
- Reduce the pressure of the gases to reduce the noise.

Fuel System:
- Fuel injection system is the heart of the engine. Lower speed engines have simpler combustion chambers that promote good mixing of fuel and air.
- The fuel injection system performs the following:
  1. Fills the fuel
  2. Monitors and corrects the quantity of fuel
  3. Timing of injection process
  4. Regulates fuel supply
  5. Fine atomization of fuel oil
  6. Distributes the atomized fuel properly inside the combustion chamber.
Cooling System:
- The combustion of air to fuel mixture take place inside cylinder.
- Temperature of gas inside cylinder may be high 2700°C. There is no external cooling. Cylinder walls will be at high temp 1000°C to 1500°C.

(a) Avoid determination of lubricating oil.
(b) To avoid damage due over heat of piston.
(c) Avoid uneven expansion which result in cracking.
(d) Avoid pre-ignition to detonation or knock.
(e) Reduction in volumetric efficiency.

Two methods in cooling engine.
1. Air cooling
2. Water cooling.

- Air cooling - Small engines.
- Big diesel engines always water cooled.

The cylinder & its head are enclosed in a water jacket which is connected to a radiator.
b. Lubrication System:

- Lubrication is flow of oil between two surfaces having relative motion.

- The important functions are:
  a. Lubrication: To keep moving parts to slide freely.
  b. Cooling: To keep surface cool by taking away heat.
  c. Cleaning: To keep bearing oil piston rings clean of products of combustion by washing them away.
  d. Sealing: To form a good seal between cylinder wall and piston ring.
  e. Reducing noise:

Various types of lubrication used in IC engine:

1. Mist lubrication
2. Wet sump lubrication
3. Dry sump lubrication
Component of Gas Turbine Power Plant:

- Economics of P.G. by gas
- Turbine is quite attractive due to low cost
- High reliability and flexibility, quick start
- Using wide variety of fuel from natural gas
- To residual oil. Due to better materials used
- Inlet gas temp to gas turbine blade now exceed 1200°C result over all η% of GT

- About 35%.
  - Because of low weight/unit produce
- Gas turbine is exclusively used to drive aviation
- System of all kind of aircraft
- Used in buses & trucks

- Closed cycle x Open cycle Plant
- Components of GT are Compressor
- Combustion chamber x Turbine cycle of GT plant
- Air standard cycle (open or closed)

Brayton cycle

Fuel supply

Combustion chamber

Generator

Compressor

Turbine
GT Plant open or closed.

(air, helium, argon, CO₂ etc) is externally heated.

So cooled to operate in closed cycle.

Advantages:
- Warm up time
- Low weight & size
- Fuel flexibility
- Floor space
- Startup & shut down
- High efficiency
- Combined cycle mode
- Cooling water
- Ash disposal.
- Transmission loss
- Cost of installation
- CO₂ generation
- Low cost
Gas turbine, like steam turbine, gas turbine also has a axial flow type. The basic requirement of turbine are light weight, high efficiency, reliability in operation, long working life. Large work output can be obtained per stage with high blade speeds when blades are designed to higher stress.
combined cycle plants.
The maximum steam temp in a power cycle does not exceed 600°C. Although the temp in dry bottom pulverized coal furnace is 1300°C, there is great thermal irreversibility in a decrease of availability because of heat transfer from combustion gases to steam through such a large difference.
By superposing a high temp power plant as a topping unit to a steam plant, power plants are classified as combined plants.

(i) Gas turbine - steam turbine plant
(ii) MHD - steam plant
(iii) Thermo electric - steam plant

Gas turbine - steam turbine power plant.

The air standard cycle for a gas turbine power plant is the Brayton cycle.

Gas turbine power plant also consists of two reversible Rankine cycles, one adiabatic to the other.
A gas turbine plant can be either open or closed. Simple open gas turbine plant is shown below. The product of combustion is working fluid which produce power by doing work on blade of gas turbine. It is an internal combustion plant.

(i) Large compressor work i/p, since power required by a pump for same pressure rise the compressor thus consumes large part of work produced by turbine.

(ii) Large exhaust loss since exhaust gas temp is quite high so also mass flow rate is large.
Machine inefficiency since with time in compressor efficiency work input to the compressor increase with decrease in turbine efficiency. The work output from turbine decreases. At certain value of, h₁, h₂, efficiency due to large low cycle efficiency, compressor work to exhaust loss, large machine inefficiencies.

Machine is costly. Fuel since cost of kerosene much higher than coal.

1. Less installation cost
2. Less installation time
3. Quick start up stop
4. Fast response to load change
5. So gas turbine plant often used as peak unit for certain energy demand when steam plant designed

Hours of day is high to meet peak loads and operate at economic load factor.
Natural gas combined cycle power system with biomass as supply.
Integrated gasification combined power plants:

- In combined cycle power plants, natural gas based (NGCC) or coal based (IGCC) supplementary firing of fuel can augment total power output of plant.

By injecting low cost limestone in to CFB boiler, scrubber effect is removed.

- By capture of sulfur in low combustion temperature to staged combustion minimize NOx formation. By injecting ammonia, NOx can be further reduced by half. PC boilers can excellently burn high grade coals,

- But need to be equipped with selective catalytic reduction.

Some investigators studied the effect of supplementary firing of biomass on performance of NGCC & IGCC power plants.
An additional case of burning natural gas alone in SFC was undertaken to compare the influence of biomass on the amount of natural gas saved to the reduction in CO2 gas emission to the environment.

High temp SFC gas flow through high temp steam which two phase to generate steam which two stage turbins in bottom cycle. In topping cycle the high temp preheated gas expand in two stage reheat in condenser in boiler.

A system of a two stage similar to that proposed by De x Nag.

but with a PCFB, the production of steam as well as power out is greatly improved.

with h' reaching 45%.

It is seen that full gasification of coal with syngas as fuel, the improvement in specific as well as CO2 emission in process plant.