Diesel Power Generating Plants

Introduction

Steve Mackay

- Dean of Engineering
- Worked for 30 years in Industrial Automation
- 30 years experience in mining, oil and gas, electrical and manufacturing industries
Learning Objectives

- Energy sources
- The choice between AC and DC power
- Single phase vs. three-phase AC power
- Prime movers used for power generation
- Power plant components/types
- Types of engines used in power generation
- Diesel engine and its advantages in power generation applications

Energy Sources

- Conventional energy sources
  - Involves a combustion process
  - Depletion of natural resources like coal, Oil, etc
  - Major Air Pollution contributors
- Non conventional/Renewable energy sources
  - Combustion process not a must
  - Use Sun, wind, etc directly to produce power
  - Bio degradable wastes also can be used
  - Air pollution is avoided
Energy Sources- Calorific Values

- Calorific value decides the efficiency of an energy source per unit weight
- Typical calorific values in kilo calories per kg

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Calorific Value (kCal/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffin</td>
<td>10,400</td>
</tr>
<tr>
<td>Diesel Petroleum</td>
<td>9,800</td>
</tr>
<tr>
<td>Charcoal</td>
<td>7,100</td>
</tr>
<tr>
<td>Dried Wood</td>
<td>4,700</td>
</tr>
<tr>
<td>Lignite</td>
<td>4,000</td>
</tr>
<tr>
<td>Wood (25-30% Moisture)</td>
<td>3,500</td>
</tr>
</tbody>
</table>

AC and DC Power

- Flow of electrons decide the type
- Initial inventions were based on DC
- AC power gained importance with
  - Invention of transformers
  - Advantages in Long distance transmission
  - Can easily be converted to DC
- Generators comprise of conductors and magnetic field with relative motion that results in current flow in conductors
Three phase and single phase AC

- Three phase help in carrying more power compared to single phase
- Today’s AC generation beyond a few kilowatts is in three phase
- Prime mover is used to rotate a generator which produces three phase power in three sets of conductors used in the generator
- Alternator is the common term for AC generators
Capacity of generator

- Normally given in kVA
- Useful power kW = kVA × power factor
- Diesel generators rated for 0.8 lagging power factor
- Engine capacity limits the maximum kVA that can be drawn from the generator
- Power plant incorporate multiple generators.
- Capacity of a power plant is given by the total kW or MW produced by all the generators.
- Voltage rating limited to around 25kV due to practical limitations
AC Generator Components

• Stator – Incorporate the main windings that ultimately carry the load current
• Rotor – Coupled to prime mover to convert mechanical energy to Electrical energy transferred through the stator and the speed of rotation decides the output frequency
• Exciter / Field – Exciter Provides DC supply to the field windings that are responsible for a rotating magnetic field cutting across stator windings
Prime Movers

- **Internal combustion and External combustion**
- **Internal combustion:** Fuels combusted internal to prime movers
  - Diesel engines
  - Gas Turbine
- **External combustion:** Fuels burnt external to prime movers
  - Steam Generators

### Prime Mover Features

<table>
<thead>
<tr>
<th>Type</th>
<th>Output Range</th>
<th>Typical Fuels</th>
<th>Typical Heat to Power Ratio</th>
<th>Heat Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Turbine</td>
<td>0.5MW to 600MW</td>
<td>Any, but used for producing steam</td>
<td>3:1 to 10:1</td>
<td>Medium</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>0.5MW to 250MW</td>
<td>Natural gas, Liquified Gas, Biogas, Mine gas</td>
<td>1.6:1 up to 5:1 with after firing</td>
<td>High</td>
</tr>
<tr>
<td>Compression ignition engines</td>
<td>Upto 20 MW</td>
<td>Natural gas with diesel oil, Heavy fuel oil</td>
<td>1:1 to 1.5:1 up to 2.5:1 with after firing</td>
<td>Low and High</td>
</tr>
<tr>
<td>Spark Ignition</td>
<td>Up to 4MW</td>
<td>Natural gas, Landfill gas, Biogas, Mine gas</td>
<td>1:1 to 1.7:1</td>
<td>Low and High</td>
</tr>
<tr>
<td>Heat Recovery gas turbines</td>
<td>1MW to 100MW</td>
<td>Same as gas turbine</td>
<td>Down to 0.7:1</td>
<td>Medium</td>
</tr>
</tbody>
</table>

www.eit.edu.au
Prime Mover Choice

- Heat to Power Ratio
- Quality of heat requirement at power plant location
- Higher heat demand in industry may tilt in favour towards gas turbines
- Utility companies – Heat requirement is minimal and hence combined cycle plants may be preferred
- Diesel Engine power plants limited in size.

Steam Turbines

- Steam boiler is used to produce the high pressure steam to run the turbines.
- The plant may be based on coal, diesel, oil, nuclear, etc but all are used to exchange their heat to produce superheated steam
- Higher capital investment with cost becoming feasible for large size power plants
Gas Turbines

- Gas is internally combusted in a pressurized combustion chamber
- Air from atmosphere is compressed by integral compressor coupled to the prime mover flywheel
- Hot gases turn the turbine blades
- Increased natural gas findings have resulted in stand alone capacities to over 250 MW.
- Space requirements low but highly capital intensive.
- Operate at very high rpm with Generator coupled using a reduction gear box
Combined Cycle Plants

- Normally combination of gas turbine and comparatively a smaller capacity steam turbine.
- Hot exhaust gases are used to produce steam for running the steam turbines.
- Steam generator named as heat recovery steam generator (HRSG) and the plant is named combined cycle Gas turbine Plant (CCGT).
- Cogeneration plants are similar but use the recovered steam directly for process needs.
Reciprocating Engines

- Compression Ignition Diesel engines
- Spark Ignition Diesel engines
- The later type applied for smaller size engines in the order of tens of kilowatts
- The diesel power plants use compressed air to ignite the fuel which is sustained thereafter unless interrupted.
- Require planned maintenance which can ensure 90~95% availability.

Typical Diesel Generators
Power Plant Components

- Prime Mover
- Generator
- Fuel storage and handling system
- Cooling system
- Exhaust system
- Electrical substation and control

Power Plant Types

Normally named after the prime over.

- Gas Turbines
- Steam Turbines
- Hydel Turbines
- Diesel Engines
- Wind Turbines
- Gasoline Engines
- Heavy fuel engines, etc.
Coal Based Power Plants

Advantages
• Economical
• Good availability in many countries

Drawbacks
• Not economical for smaller sizes
• Calorific values differ
• CO2, Ash and sulphur issues

Natural Gas Power Plants

Advantages
• Lower capital cost.
• Compact sizes.
• Lesser CO2 produced compared to coal or oil

Drawbacks
• Not economical for smaller sizes
• Location close to the source preferred.
Oil Based Power Plants

Advantages
- Lower cost
- Compact Generators
- Produces less CO2 than coal

Drawbacks
- Limited oil reserves.
- Oil spills, especially at sea, cause severe pollution
- Sulphur and Acid rains

Diesel Power Plants

Advantages
- Small in size
- Relatively low cost
- Portability
- Faster installation time

Drawbacks
- Major noise and CO2 producers.
- Fuels availability limitation
Solar Power Plants

Advantages
- Abundant source
- Non polluting
- More useful for isolated locations

Drawbacks
- Higher capital cost
- Mainly DC power and smaller size units.
- High area requirements for large capacities.
- Alternate power during nights and no sun days

Diesel Engines

Main Types
- Spark ignition Otto-cycle engine
- Compression ignition Diesel – cycle engine.

Main Differences
- Method of combustion
- Spark ignition types limited for smaller sizes
- Lower Compression ratio for spark type
Spark Ignition Engines

- Natural Gas based engines
- Main Types
  - Lean Burn
  - Rich Burn
- Lean Burn Type preferred because of
  - Greater fuel efficiency
  - Lower emissions
  - Higher power density

Engine Components

Major Components

- Drive Train – Pistons, rods, etc
- Valve Train – Camshaft, valves, etc
- Governor – Speed controller
- Turbocharger – Centrifugal compressor used to compress the intake air for better combustion
- After cooler – To reduce turbocharger output air temperature
Diesel Power Plants

Support Systems
- Generator
- Fuel oil system
- Lube oil system
- Intake air system
- Cooling system
- Control and Instrumentation
- Exhaust and ventilation systems

Typical Operation procedures
- Lube oil system startup and ensure proper pressure
- Engine started without any load on alternator
- Bring up to full speed and start applying loads
- Ensure minimum loading of 50% to avoid carbon formation and maintenance issues
- Idle run is recommended before shutdown of engine
Diesel Plant Advantages

• Faster installation time
• Quick start up when needed
• Follow the load with governor control
• Good part-load efficiencies
• Higher reliability and availability.
• Easier maintenance
• Comparatively lower capital cost
• Adaptability to different fuel including bio fuels

Review

• Three Phase AC generation is the most common
• Conventional and non conventional types of power generation
• Comparison of different generating types
• Spark Ignition and Compression Ignition engines
• Diesel Power Plant components
• Advantages of diesel power plants