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Combined Cycle Power Plant and study of its working mechanisms.

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Abstract *: The combined cycle power plant or combined cycle gas turbine, a gas turbine generator generates electricity and waste heat is used to make steam to generate additional electricity via a steam turbine. The gas turbine is one of the most efficient one for the conversion of gas fuels to mechanical power or electricity. The use of distillate liquid fuels, usually diesel, is also common as alternate fuels. More recently, as simple cycle efficiencies have improved and as natural gas prices have fallen, gas turbine have been more widely adopted for base load power generation, especially in combined cycle mode, where waste heat is recovered in waste heat boilers, and the steam used to produce additional electricity.*

This system is known as a combined cycle. The basic principle of the combined cycle is simple burning gas in a gas turbine produces not only power which can converted to electric power by a coupled generator but also fairly hot exhaust gases. Routing these gases through a water cooled heat exchanger produces steam which can be turned into electric power with a coupled steam turbine and generator. This type of power plant is being installed in increasing numbers round the world where there is access to substantial quantities of natural gas. A combined cycle power plant produces high power outputs at high efficiencies(up to 55%) and with low emissions. In a Conventional power plant we are getting 33% electricity only and remaining 67% as waste. By using combined cycle power plant we are getting 68% electricity. It is also possible to use the steam from the boiler for heating purposes so such power plant can operate to deliver electricity alone or in combined heat and power mode.

The process :

The process for converting the energy in a fuel into electric power involves the creation of mechanical work, which is then transformed into electric power by a generator. Depending on the fuel type and thermodynamic process, the overall efficiency of this conversion can be as low as 30 percent. This means that two-thirds of the latent energy of the fuel ends up wasted. For example, steam electric power plants which utilize boilers to combust a fossil fuel average 33 percent efficiency. Simple cycle gas turbine (GTs) plants average just under 30 percent efficiency on natural gas, and around 25 percent on fuel oil. Much of this wasted energy ends up as thermal energy in the hot exhaust gases from the combustion process.

To increase the overall efficiency of electric power plants, multiple processes can be combined to recover and utilize the residual heat energy in hot exhaust gases. In combined cycle mode, power plants can achieve electrical efficiencies up to 60 percent. The term “combined cycle” refers to the combining of multiple thermodynamic cycles to generate power. Combined cycle operation employs a heat recovery steam generator (HRSG) that captures heat from high temperature exhaust gases to produce steam, which is then supplied to a steam turbine to generate additional electric power. The process for creating steam to produce work using a steam turbine is based on the Rankine cycle.

The most common type of combined cycle power plant utilizes gas turbines and is called a combined cycle gas turbine (CCGT) plant. Because gas turbines have low efficiency in simple cycle operation, the output produced by the steam turbine accounts for about half of the CCGT plant output. There are many different configurations for CCGT power plants, but typically each GT has its own associated HRSG, and multiple HRSGs supply steam to one or more steam turbines. For example, at a plant in a 2x1 configuration, two GT/HRSG trains supply to one steam turbine; likewise there can be 1x1, 3x1 or 4x1 arrangements. The steam turbine is sized to the number and capacity of supplying GTs/HRSGs.

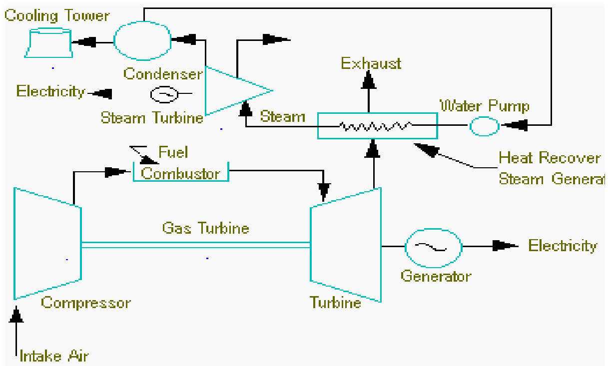

Figure 1.1 Working of combined cycle power plant

Combined Cycle Principles of Operation

The HRSG is basically a heat exchanger, or rather a series of heat exchangers. It is also called a boiler, as it creates steam for the steam turbine by passing the hot exhaust gas flow from a gas turbine or combustion engine through banks of heat exchanger tubes. The HRSG can rely on natural circulation or utilize forced circulation using pumps. As the hot exhaust gases flow past the heat exchanger tubes in which hot water circulates, heat is absorbed causing the creation of steam in the tubes. The tubes are arranged in sections, or modules, each serving a different function in the production of dry superheated steam. These modules are referred to as economizers, evaporators, super heaters / re heaters and pre heaters.

The economizer is a heat exchanger that preheats the water to approach the saturation temperature (boiling point), which is supplied to a thick-walled steam drum. The drum is located adjacent to finned evaporator tubes that circulate heated water. As the hot exhaust gases flow past the evaporator tubes, heat is absorbed causing the creation of steam in the tubes. The steam-water mixture in the tubes enters the steam drum where steam is separated from the hot water using moisture separators and cyclones. The separated water is re circulated to the evaporator tubes. Steam drums also serve storage and water treatment functions. An alternative design to steam drums is a once-through HRSG, which replaces the steam drum with thin-walled components that are better suited to handle changes in exhaust gas temperatures and steam pressures during frequent starts and stops. In some designs, duct burners are used to add heat to the exhaust gas stream and boost steam production; they can be used to produce steam even if there is insufficient exhaust gas flow.

Saturated steam from the steam drums or once-through system is sent to the super heater to produce dry steam which is required for the steam turbine. Pre heaters are located at the coolest end of the HRSG gas path and absorb energy to preheat heat exchanger liquids, such as water/glycol mixtures, thus extracting the most economically viable amount of heat from exhaust gases.

The superheated steam produced by the HRSG is supply to the steam turbine where it expands through the turbine blades, imparting rotation to the turbine shaft. The energy delivered to the generator drive shaft is converted into electricity. After exiting the steam turbine, the steam is sent to a condenser which routes the condensed water back to the HRSG.

Working principle of CCTG plant

First step is the same as the simple cycle gas turbine plant. An open circuit gas turbine has a compressor, a combustor and a turbine. For this type of cycle the input temperature to turbine is very high. The output temperature of flue gases is also very high.

This is therefore high enough to provide heat for a second cycle which uses steam as the working medium i.e. thermal power station.

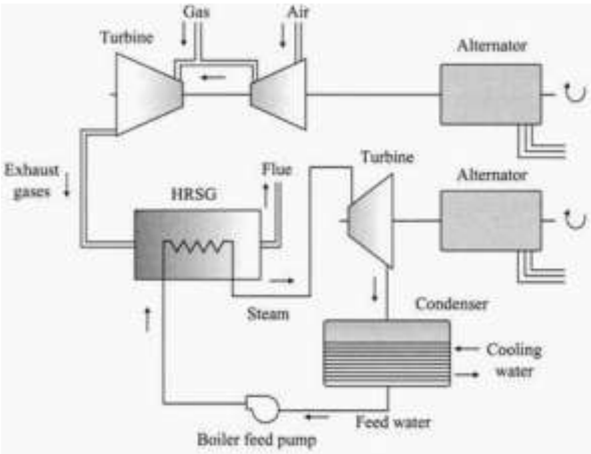

Figure - Working principle of combined cycle gas turbine (CCTG) plant

Air Inlet

This air is drawn though the large air inlet section where it is cleaned cooled and controlled. Heavy-duty gas turbines are able to operate successfully in a wide variety of climates and environments due to inlet air filtration systems that are specifically designed to suit the plant location.

Conclusions

The combined-cycle generation system features high thermal efficiency, low installed cost, fuel flexibility
with a wide range of gas and liquid fuels, low operation and maintenance costs, operating flexibility at
base, mid-range and daily start, high reliability and availability, short installation times and high efficiency in small capacity increments. In particular: 87

1. Combined cycles boost power output and efficiency to levels that are considerably above those of steam power plants.
2. Repowering, when converting an existing steam plant to combined cycle, offers savings in capital cost as compared to new construction.
3. Combined cycle, when integrated with coal gasification, holds promise in converting coal into electric power in an efficient, economical and environmentally acceptable manner.
4. The air-bottoming cycle (ABC), chemically recuperated gas turbine, compressed air energy storage (CAES) and compressed air storage humidification (CASH) are among advanced concepts with promise for combined cycle applications.

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