Integrated Gasification Combined Cycle Power Plant

An Online Continuing Education Course for Engineers

Course Number: O-4002

Credit: 4 Hours / 4 PDH / 4 CPD

Integrated Gasification Combined Cycle

Power Plants

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Note: The figure on the cover is courtesy of the National Energy Technology Laboratory.

Introduction

Integrated gasification combined-cycle (IGCC) systems combine a coal gasification unit with a gas fired combined cycle power generation unit. The first stage is a coal gasification process. The second stage takes the cleaned gas and burns it in a conventional combustion turbine to produce electrical energy, and the hot exhaust gas is recovered and used to boil water, creating steam for a steam turbine which also produces electrical energy. In typical plants, about 65% of the electrical energy is produced by the combustion turbine and 35% by the steam turbine.

An integrated gasification combined cycle (IGCC) is a power plant that uses synthetic gas as its fuel source. The synthetic gas, also known as syngas, is used to power a combustion turbine generator whose waste heat is then used to power a steam turbine. The gasification process can use coal, heavy petroleum residues, or biomass as the feedstock.

An integrated coal gasification combined cycle power plant is the most environmentally friendly coal-fired power generation plant available today. The plants can generate electric power with very little greenhouse gas emissions.

Coal gasification is the process of converting coal to a gaseous fuel through partial oxidation. The coal is fed into a high-temperature pressurized container along with steam and a limited amount of oxygen to produce a gas. The gas is consists mainly of carbon monoxide and hydrogen. The gas is cooled and undesirable components, such as carbon dioxide and sulphur are removed.

Coal and other hydrocarbons have been gasified for the production of chemicals, fertilizers, and synthetic fuels for more than half a century. However, it is only in the last 20 years that gasification has been used for the production of electricity using the Integrated Gasification Combined Cycle (IGCC) process. The figure shown below is a simple diagram of the basic components of an IGCC plant.

Integrated Gasification Combined Cycle Plant
Block Diagram

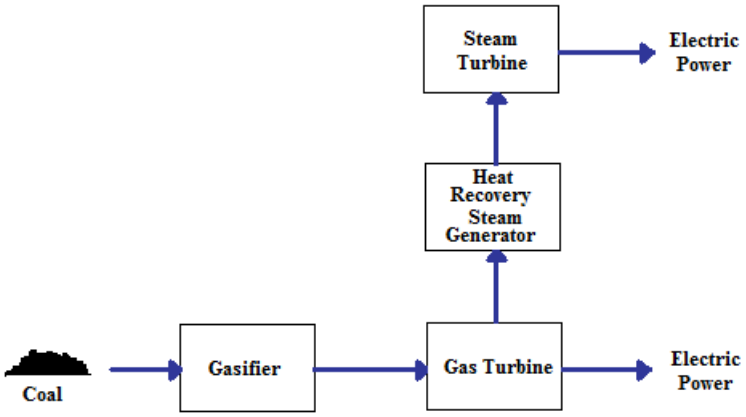

Figure 1

Looking at Figure 1 we see that an IGCC plant consists of a gasification plant, a gas-fired turbine, and heat recovery steam generator and a steam turbine.

A hydrocarbon feedstock, such as coal, is gasified in a high-pressure, high-temperature gasifier with either air or oxygen produced in an air separation unit (ASU). The resulting synthesized gas (syngas) is cooled, cleaned, and fired in a combustion turbine. The hot exhaust from the combustion turbine passes through a heat recovery steam generator (HRSG) where it produces steam that drives a steam turbine. Electric power is produced from both the gas and steam turbine-generators.

By removing the emission-forming constituents from the syngas under pressure before combustion in the power block, an IGCC power plant produces very low levels of air pollutants (NO_x, SO_2, and PM) and volatile mercury.

IGCC uses a combined cycle format with a combustion turbine driven by the combusted syngas, while the exhaust gases are heat exchanged with water/steam to generate superheated steam to drive a steam turbine. Using IGCC, more of the power comes from the combustion turbine. Typically 60-70% of the power comes from the combustion turbine with IGCC, compared with about 20% using pressurized fluidized bed combustion (PFBC.)

In general the advantages of IGCC are:

- Theoretically an IGCC can achieve up to 50% thermal efficiency (In practice, the initial plants have fallen far short of this level.)
- It produces about half the volume of solid wastes as a conventional coal power plant.
- It uses 20-50% less water compared to a conventional coal power station.
- It can utilize a variety of fuels, like heavy oils, petroleum cokes, and coals.
- Carbon capture is easier and costs less than capture from a pulverized coal plant.
- A minimum of 95% of the sulphur is removed.
- Nitrogen oxides (NO_x) emissions are less than most types of existing coal-fired generating units.

IGCC will compete directly against other clean coal technologies such as the supercritical pulverized coal (SCPC) design. Presently, IGCC plants cost 20 to 25 percent more than a comparable SCPC power plant at any given site.

In the first section of this course we will look at the primary feedstock for IGCC power plants – coal. Subsequent sections will go into more detail about the gasification process and combined cycle power plants.

I. Fuel Source

Coal is a fossil fuel formed from plant remains that were preserved by water and mud from biodegradation. Coal is a readily combustible black or brownish-black rock. It is composed primarily of carbon and hydrogen along with small quantities of other elements, notably sulfur. Coal is extracted from the ground by coal mining, either underground mining or open pit mining.

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the most advanced units reaching about 35% thermodynamic efficiency for the entire process, which means 65% of the coal energy is waste heat that is released into the surrounding environment. Older coal power plants are significantly less efficient and produce higher levels of waste heat.

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Approximately 40% of the world electricity production uses coal. It is estimated that the total known coal deposits recoverable by current technologies might be sufficient for around 300 years' use at current consumption levels.

Types of Coal

We use the term "coal" to describe a variety of fossilized plant materials, but no two coals are exactly alike. Heating value, ash melting temperature, sulfur and other impurities, mechanical strength, and many other chemical and physical properties must be considered when matching specific coals to a particular application.