

## Current Trends in Integrated Gasification Combined Cycle Power Plants

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**Abstract:** Conventional Thermal Power Plants have technologically proven systems and worldwide are used for power generation. The coal based plants have the disadvantage of pollution because of ash handling problems wherever the power plants are located. The overall cycle efficiency of standalone thermal power plants are limited to around 40 percent. In order to improve over all plant efficiency combined cycle power plants have been found to give a shape world over. As many Natural Gas resources have been discovered world over, they have been considered as a commercial fuel in many applications. The utilization of Natural gas in a topping gas turbine cycle followed by a steam turbine cycle using a waste heat recovery boiler has been found to improve the efficiency of the overall power plants. These kind of combined cycle power plants have been installed and are in operation.

India has abundant coal reserves but when utilized in power plants create pollution problems. The conversion of coal into gas has been in the research area and is successful in developing large sized gasification plants using different technologies. This has resulted in generation of SYNGAS through pollution free green coal technology. This SYNGAS can be successfully used in gas turbines after purification. This paper gives the current technological innovations towards this type of "Integrated Gasification Combined Power Plants". This technology has potential to become popular in countries like India where the quality coal is inferior and utilization of these coals without pollution is a major advantage. In addition to it the efficiency improvement of overall power plant is an attraction towards commercial exploitation of such technology.

**Keywords:** Gasification, syngas, gasifier, combined cycle, gas turbine, waste heat recovery, steam turbine

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### I. Introduction

Integrated Gasification Combined Cycle (IGCC) power plants have high efficiency compared with conventional pulverised coal (PC) fired power plants. In IGCC power generation technology the coal of inferior quality, like the one which is available in India can be gasified to produce the fuel ('syngas') for a high efficiency gas turbine. The exhaust of Gas turbine, which has higher thermal potential is used to generate steam in a waste heat recovery boiler and this steam is expanded in a steam turbine cycle. This combined power generation results in higher efficiency of the overall cycle.

Some comprehensive advantages of IGCC Plants are:

- Pollution is reduced to a large extent as Coal gasification and Coal clean up process of the plant ensures low CO<sub>2</sub> per unit of generated power. Emissions of SO<sub>x</sub>, and particulates are also reduced by the requirement of clean Syngas fuel for the trouble free operation of the gas turbine.
- Water Consumption in IGCC plants are less as 60% of its power is produced from an air-based Brayton cycle thereby reducing the load on the steam turbine condenser to about 40% of that of an equivalent rated conventional coal fired power plant.
- It is estimated that IGCC generation efficiency based on coal gasifier is in the range of 46–47% net, where as the conventional pulverized Power Plant has a maximum efficiency of about 38 to 40 percent. [1]

IGCC plants have so many better features but have the disadvantage of high initial cost of the power plant. Hence the commercial operation worldwide is yet to pick up the required momentum.

### II. Coal Gasification Technologies:

India has 70 Billion tons of Coal Reserves, and ranks the world's 3<sup>rd</sup> largest source. The coal is mostly fall under the category of Sub bituminous coal followed by bituminous and Lignite type. But the Indian Coals

have high ash percentage falling between 20 to 40 percent, where as the imported coal from other countries falls between 5 to 15 percent only. The calorific value of Indian coal falls in the range of 3800 to 4300 Kcal /kg , where as imported coals are having an average calorific value of is about 7000 K cal/Kg [2]. The use of Indian coals have its own problems in pulverised coal fired plants and hence most of the power plants blend Indian and imported coal for their regular operation.

It is technologically advantages to use the poor quality Indian coals for producing Syngas , through coal gasifiers.

Coal gasification process can be carried out using a) Fixed Bed Gasifier b) Fluidized Bed gasifier and c) Entrained Bed Gasifier.

Fig 1 Shows the different type of gasifiers and its feed sizes. It has been found that for Indian coals Fluidized bed gasifiers are most suited as the efficiency of conversion is higher compare to other types. Also throughput of coal is much higher and out put of gas is also correspondingly higher and hence it is preferred to select these plants to the power cycle operations.

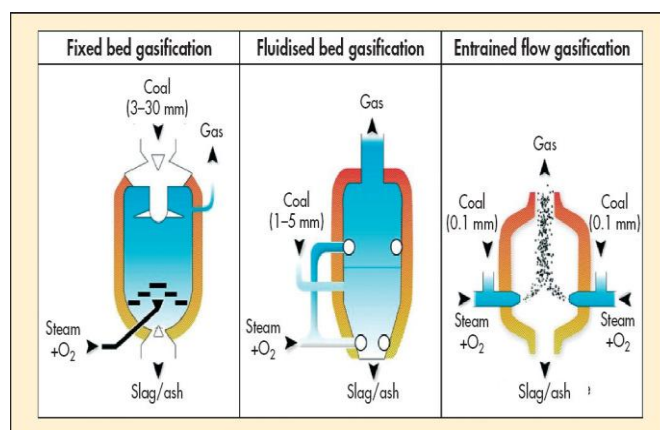


Fig 1. Types of Gasifiers

## 2.1 Coal Gasification Process

The fluidized-bed gasifiers has lower operating temperature in the range of 900–1000°C compared with fixed-bed and entrained-flow gasifiers. [3] This results in lower oxygen consumption thereby reducing sensible heat losses in the gas and also increases the refractory life . When high-ash coal is used the ash discharge rate of bed is higher and the lower temperature of operation prevents clinker formation . The disadvantage of fluidized-bed gasification compared with fixed-bed and entrained-flow gasifiers is that the carbon conversion is lower. This is generally taken care in the design of the gasifier by having adequate retention time of coal movement.

Coal, air, and steam are the input streams to the process, which produces the output streams: gas and ash. Coal with a particle size of 1 to 5mm is fed into the gasifier by means of a screw conveyor at appropriate height above the distributor. The coal particles are in suspension in the air steam mixture, which provides better surface contact with reactants and the chemical reactions are improved to yield good gas output. Required quantity of steam generated in the waste heat recovery boiler and air from the compressor of the gas turbine of the power plant is used as input streams for the gasifier. Pressurized bed gasifiers are the current technology which improves the throughput and increases the SYN gas output, there by increasing the operational efficiency.

## 2.2 PROPERTIES OF SYNGAS

The Syngas, the gasifier output after clean up system may have the following chemical composition range based on Volume percentage [4] : H<sub>2</sub> – 25 to 30; CO – 30 to 40; CH<sub>4</sub> – 0 to 5 ; N<sub>2</sub> – 0 to 3; H<sub>2</sub>O – 15 to 25. The Lower Heating Value (LHV) is in the range of 7 to 10 MJ/ Nm<sup>3</sup> .

It may be noted that the LHV of Natural Gas is in the range of 38 to 45 MJ/ Nm<sup>3</sup>. The low heating value of the Syngas necessitates that the gas turbine and combustor design have to be different from the normal natural gas fired gas turbines. GE of US has already started commercializing these type of gas turbines.

### III. Combined Cycle Power Plants

Combined Cycle Power Plants are commercially established worldwide and India too. These plants have natural gas as fuel for the gas turbine cycle. Fig 2 shows a typical lay out of a combined Cycle Power Plant. The topping cycle here is a gas turbine cycle which uses Natural gas as its fuel. The exhaust of the gas turbine passes through Heat Recovery Steam Generator ( HRSG) and the the flue gas is exhausted through a stack. The steam so produced is used in a steam turbine to generate power. This kind of combined cycle has better efficiency than conventional pulverised fuel power plants.

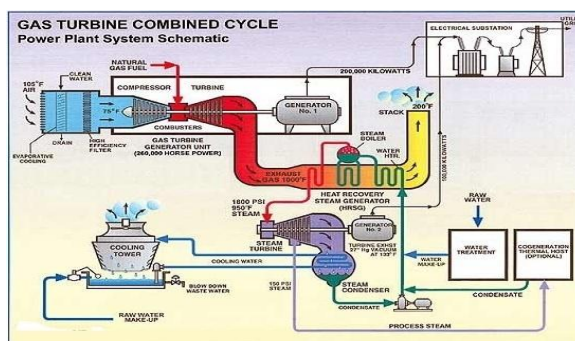


Fig 2. Typical Gas Turbine Combined Cycle

#### 3.1 Combined Cycle Power Plants in India

Many operating plants using available Natural gas as the resource are operational in India. Table 1 gives a glance of these plants.

Table-1 – List of Combined Cycle Power Plant

Name Of The Plant	Location	Fuel Used	Power Generated
Dabhol	Maharastra	Naptha & Natural gas	3X695 MW
Dadri	Uttar Pradesh	Natural Gas & oil	2X409 MW
HPL; Co Gen	West Bengal	Napta & Natural Gas	110 MW
Karuppur	Tamil nadu	Natural Gas	120 MW
Kattalguri	Assam	Natural Gas	3X97 MW
Kayamkulam	Kerala	Natural Gas	360 MW
Regency	Tamil nadu	Natural Gas	59 MW
Tanirbavi	Karnataka	Naptha	220 MW
Uran	Maharastra	Natural Gas & Oil	2X336 MW
Valuthur	Tamilnadu	Gas	95 MW

### IV. Integrated gasifier combined cycle power plants

It is evident from the earlier sections that Gasifier Technology and Combined cycle technology are well developed and now the power sector industries have some ambitious program for combining these two product for commercial exploitation. Lot of research work has been carried out by Bharat Heavy Electricals Limited for the development of Integrated Gasifier combined Cycle Power Plant. This has been successfully demonstrated by a 6.2 MW plant located at their works at Trichy Plant.

Fig 3 shows the efficiencies of different kinds of Power Plants

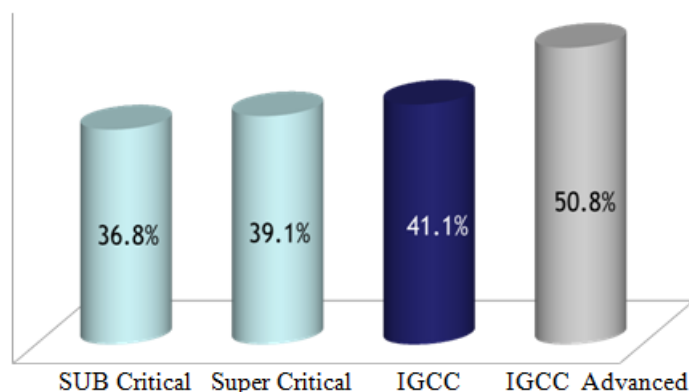


Fig 3- Efficiencies of different Power Plants

( SOURCE : DOE/NETL, USA-2007/1281)

Fig 4 shows a block diagram of Integrated Combined Cycle Power Plant.

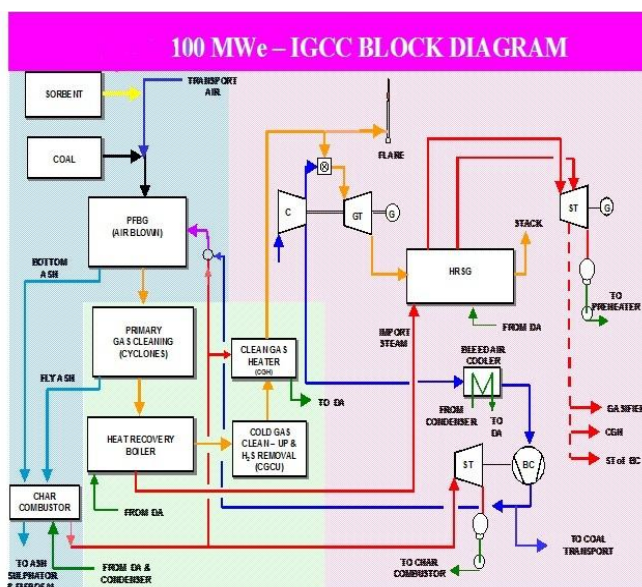


Fig 4 Block diagram of combined cycle power plant

The output of the plant is 100 MW in the ratio of 60MW by GT and 40 MW by Steam Turbine. Here the gasifier planned is Pressurized Fluidized type with Hot Gas clean up system. The Syn gas so cleaned up is fed into the combustor of the gas Turbine.

General Electric gas turbines (Model GE 7FA) are selected for such power plants since General Electric has the design capability to modify their combustor to suit the Syn gas, which has a lower calorific value than that of typical Natural Gas. Siemens Gas turbines also may be considered with modified combustors. Other systems like HRSG (Heat Recovery Steam Generator) and the steam turbines are within the capability of Indian Power Equipment Manufacturers like Bharat Heavy Electricals Limited and L&T.

Table 2 shows the major plants under operation worldwide. The operational experiences are encouraging and many plants are being set up presently. India is yet to get a plant of this type even though negotiations are in progress.

Table 2: Major Gasifier based combined power Plant under operation

Project/ Country	GT Make	Gasifier Make	Net Power (MW)	Start-Up Date
Nuon Buggenum, Netherland	Siemens V94.2	Shell (with Krupp Uhde)	253	Jan'94
Wabash River, US	GE 7FA	ConocoPhilips	262	Oct'95
Polk 1, US	GE 7FA	Texaco (GEE)	250	Sep'96
ELCOGAS, Puertolano, Spain	Siemens V94.3	Preflo (with Shell)	300	Dec'97

### V. Conclusions

There is no ultimate limit in the development in any field of engineering, which is applicable to power industries too. The research in power technology will lead to better products and will improve the efficiency levels. Coal reserves in India are the third largest in the world. But the quality of coal is sub-bituminous type with

high ash content of around 40 percent. Pollution control is also an important factor as for as India is concerned. The gasification of coal and integrated combined cycle power plants effectively addresses all the problems cited. In addition to that about 40 percent water consumption is also saved. Considering day to day operation it is enormous saving on the onset of evident water problems in future. The only huddle is the high initial cost of such plants. India is poised to adopt this technology in near future as concerned government agencies and power industry are looking for implementation of IGCC soon.

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