Feasibility Study of IGCC Power Plant in Bangladesh

Ashab Uddin, Debangshu Barua, Md. Emran Husain, Md. Saiful Amin

Abstract— ***The integrated gasification combined cycle (IGCC) is one of the advanced clean coal power generation systems. It could replace many of the contractual high-cost rental power plants and small Industrial Power Plants which are being currently used to supply large amount of population and thereby secure the nation's energy supply well into the future. However, utility companies have been reluctant to make gasification a major component of their generation portfolio due to high capital costs and the lack of large-scale commercial application. To resolve some of the most pressing challenges preventing widespread implementation of IGCC technology, the government should support research and development efforts focusing on advanced gasification technologies to improve the efficiency and reduce capital costs simultaneously. IGCC technology already offers significant reductions in emissions of the major criteria air pollutants (NOx,SO2, particulate matter and CO) as compared to PC plants. It is already being considered as one of the most promising technologies in reducing the environmental consequences of generating electricity from coal.***

Index Terms- IGCC, Gasification, HRSG, Emission, Coal Gasification, Environment Friendly.

I. INTRODUCTION

Coal is the world's most abundant and widely distributed fossil fuel, with global proven reserves totaling nearly 1000 billion tons. Given these characteristics, coal has been a key component of the electricity generation mix worldwide. So power generation from coal is an essential need to meet world's energy demand. But there are two major challenges in coal-based power generation: improving the efficiency and reducing the emissions level. In fact, these challenges have been under research for a long time. Coal Gasification could be the solution to overcome these challenges. And Integrated Gasification Combined Cycle power (IGCC) plant could be a possible solution to meet the ever increasing demand for power. It could replace many of the contractual high-cost rental power plants and small Industrial Power Plants in Bangladesh.

II. IGCC

Integrated Gasification Combined Cycle (IGCC) is emerging as a best available technology to utilize low quality or contaminated energy resources, coal or oil. It can meet emission limits not achievable by other conventional or advanced competing technologies.

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In particular IGCC offers refiners the possibility of reducing to zero the production of residual fuel oil, an increasingly undesired product, while at the same time, co-producing electricity, hydrogen and steam. It also drastically cuts SO2 emissions.

A. How does IGCC work?

IGCC [1] is a combination of two leading technologies. The first technology is called coal gasification, which uses coal to create a clean-burning gas (syngas).The second technology is called combined-cycle, which is the most efficient method of producing electricity commercially available today.

B. Coal Gasification

Coal gasification [2,3] portion of the IGCC plant produces a clean coal gas (syngas) which fuels the combustion turbine. Coal is combined with oxygen in the gasifier to produce the gaseous fuel, mainly hydrogen and carbon monoxide. The gas is then cleaned by a gas cleanup process. After cleaning, the coal gas is used in the combustion turbine to produce electricity. Coal gas is rich in CH_4 and gives off up to 20.5 kJ per liter of gas burned. Coal gas or town gas, as it was also known became so popular that most major cities and many small towns had a local gas house in which it was generated, and gas burners were adjusted to burn a fuel that produced 20.5 kJ/L. A slightly less efficient fuel known as water can be made by reacting the carbon in coal with steam.

$C(s) + H_2O(g) \rightarrow CO\ (g) + H_2(g) \quad (\ H^o = 131.3\ kJ/mol_{rxn})$

Water gas burns to give CO_2 and H_2O, releasing roughly 11.2 kJ per liter of gas consumed. Note that the enthalpy of reaction for the preparation of water gas is positive, which means that this reaction is endothermic. As a result, the preparation of water gas typically involves alternating blasts of steam and either air or oxygen through a bed of white-hot coal. The exothermic reactions between coal and oxygen to produce CO and CO_2 provide enough energy to drive the reaction between steam and coal. Water gas formed by the reaction of coal with oxygen and steam is a mixture of CO, CO_2, and H_2. The ratio of H_2 to CO can be increased by adding water to this mixture, to take advantage of a reaction known as the water-gas shift reaction.

$CO\ (g) + H_2O(g) \rightarrow CO_2(g) + H_2(g) \quad H^o = -41.2\ kJ/mol_{rxn}$

The concentration of CO_2 can be decreased by reacting the CO_2 with coal at high temperatures to form CO.

$C(s) + CO_2(g) \rightarrow 2\ CO\ (g) \quad H^o = 172.5\ kJ/mol_{rxn}$

Water gas from which the CO_2 has been removed is called synthesis gas. Synthesis gas can also be used to produce methane, or synthetic natural gas (SNG).

$CO\ (g) + 3\ H_2(g) \rightarrow CH_4(g) + H_2O(g)$

$2\ CO\ (g) + 2\ H_2(g) \rightarrow CH_4(g) + CO_2(g)$

An important area of IGCC technology improvement is the optimization of the design and integration among the various components of the complex. Integration means recovery of the waste energy available, improvement of the efficiency and, where possible, reduction of the investment cost. There are potential benefits of integrating two major components of the IGCC: the gas turbine and the air separation plant. There are several possible degrees of integration between the air separation plant and the gas turbine. In the case of total integration, 100% of the air required by the air separation is supplied by bleeding some of the air from the discharge of the gas turbine compressor. Depending on the gas turbine frame this air is available at 10-15 bar, therefore the air separation plant is a high-pressure type, delivering oxygen and nitrogen at 3-4 bar. Oxygen is recompressed and used in gasification, while nitrogen is recompressed and re-injected into the syngas to replenish the mass deficit caused by the air bleeding, and, at the same time, reduce N0x formation during combustion by lowering the flame peak temperature.

C. Figures

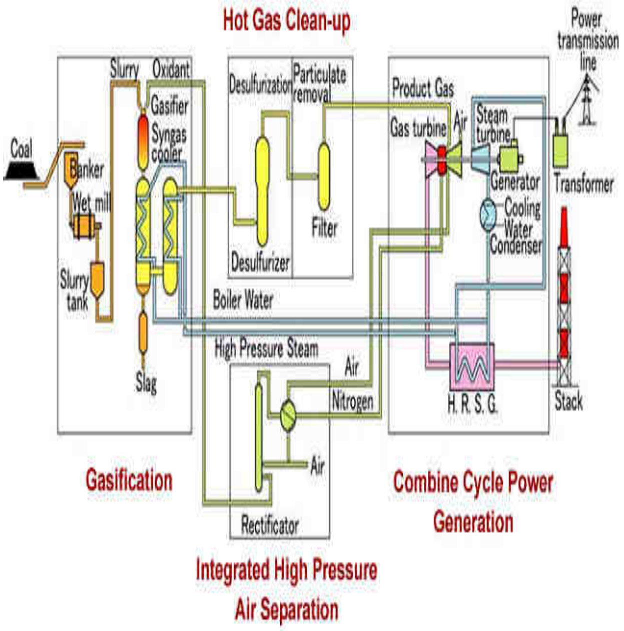

Fig 1: IGCC power plant process diagram[3]

III. WHY IGCC OVER PC AND NGCC

A. Energy and Energy analysis:

Sue and Chuang [4] performed exergy analysis based on load variation. The exergy loss at 50%load is three times that of 100% load due to the lower steam pressure in the HRSG. Therefore, the plant selected combined cycle plant operating efficiency at 100% load is 2.4% higher than at 50% load. Khaliq and Kaushik [5] presented second-law efficiency of gas fire thermal power plant varying the number of reheat process and compression ratio in gas turbine. The first-law efficiency of the adiabatic turbine increases with the increase in pressure ratio. The second-law efficiency decreases with the pressure ratio, but increases with the cycle temperature ratio since a greater proportion of the available work lost at the higher temperature may be recovered. The exergy destruction in the reheat turbine increases with the pressure ratio, the number of reheat stages and the pressure drop in each re-heater first-law and second-law efficiencies of the combined cycle increases up to the pressure ratio of 32, and then they start decreasing with increases in the pressure ratio. But it is interesting to note that the second-law efficiency of the combined cycle is greater than that of the first-law efficiency for same pressure-ratio. If the pressure ratio is too low, then the gas-turbine cycle and combined-cycle efficiencies and their specific work-outputs drop, whereas the steam cycle work-output increases due to the high gas-turbine exhaust temperature. If the pressure ratio is too high, the compressor and turbine works increase but their difference, the net gas-turbine work output drops. Franco and Russo [6] analyzed the heat recovery steam generator (HRSG), as a first step in the analysis of the whole plant. They handle this problem adopting both a thermo- dynamic and a thermo-economic objective function instead of the usual pinch point method. Thermodynamic optimization has the purpose to diminish energy losses, expressed on exergy basis, while the aim of the thermo-economic optimization is the minimization of the cost function associated with the system/plant, sum of the cost of exergy inefficiencies and the cost of the HRSG. Pro- posed methods have been applied to some HRSG configurations, including some present commercial plants. The results of the application of the thermo-economic optimization lead to a meaningful increase of the thermal efficiency of the plant that approaches the 60%. Reddy and Mohamed [7] determined gas turbine main combustion chamber as the major source of exergy destruction rate. The exergy destruction rate in the main combustion chamber is found be very high as compared to other parts of the system. Whereas the higher pressure ratio, results in an increase in exergy destruction rate in the gas turbine cycle components [8,9]. For the same pressure ratio, the combined cycle net work output increases with higher turbine inlet temperatures. The exergy destruction rate in the combustion chambers and the gas turbine cycle components reduces with higher gas turbine inlet temperature. Dincer et al. [10] reported energy and exergy assessments of integrated power generation using solid oxide fuel cells (SOFCs) with internal reforming and a gas turbine cycle. The other main exergy destruction is attributable to electrochemical fuel oxidation in the SOFC. The energy and exergy efficiencies of the integrated system reach 70–80%, which compares well to the efficiencies of approximately 55% typical of conventional combined-cycle power generation systems. Variations in the energy and exergy efficiencies of the integrated system with operating conditions are provided, showing, for example, that the SOFC efficiency is enhanced if the fuel cell active area is augmented. The SOFC stack efficiency can be enhanced by reducing the steam generation while increasing the stack size

B. Advantages of IGCC

Because of the drawbacks of PC and NGCC power plants and limited reserve of natural gas [11], the IGCC technology come front for future generation. The benefits of IGCC are:

1. Low Emissions and High Efficiency
2. Low Emissions from High Sulfur Coal
3. Lower Cost Mercury Removal
4. Lower Water Use
5. Lower Cost CO_2 Removal
6. Expect Less Resistance to Permitting
7. Raw material for SOFC
8. Most environment friendly technology

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C. Figures and Tables

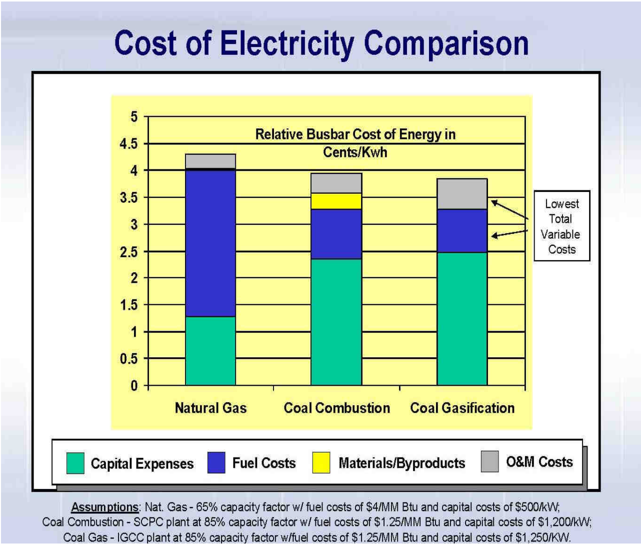

Fig 2: Cost of Electricity [11,15]

Table I: Gas Scenario of Bangladesh [12]

Total number of gas fields	23
Number of producing gas fields	17 (79 wells)
Extractable gas reserves (proven and probable)	20.5 TCF
Total consumption of gas up to April 2010	8.5 TCF
Total reserve remaining	12 TCF
Daily gas production	2000 MMCFD (approx.)

Table II: Comparison of emissions for IGCC versus a conventional pulverized coal plant with emissions controls.[13,15]

	IGCC	Pulverized Coal
Sulfur Dioxide (lb/MBTU)	0.08	0.3
Nitrogen Oxide (lb/MBTU)	0.06	0.09
Particulate Matter (lb/MBTU)	0.06	0.3
Water Consumption (gal/MWh)	440	640
Total Solids Generated (lb/MWh)	120	250

Table III: Cost of carbon capture from various generation technologies.[14]

	IGCC	Pulverized Coal	NGCC
CO_2 Created (kg/kWh)	6.64	7.66	3.37
Cost of Avoided CO_2 ($/tonne)	18	32	41
Incremental COE (cents / kWh)	1.04	2.16	1.23

IV. FEASIBILITY OF IGCC POWER PLANT IN BANGLADESH

For a feasibility study of IGCC plant some certain issues might be play a vital role. Those are sorted below**:**

A. Fuel Supply

The locations of coal mines found until now is being identified .So, any place near to those can be very much useful for the availability of coal.(Table I)

B. Water Supply

Water is the most available resource for IGCC**.** From the data & location analysis Khulna is mostly and some selective region from Rajshahi, Barishal, and Rangpur & Chittagong are very much suitable for IGCC water supply.

C. Land Scopes

Land is a critical requirement of this type of plant as it needed a huge area. And in Bangladesh there is hardly any free area to locate. So it can be associated with the water supply and fuel availability.

D. Availability of labor

Labor availability may not be a fact as Bangladesh is very much famous for its skilled manpower & its availability.

E. Electric Transmission

It might be easy to transmit the plant output to the desired grid if it located in proper location. It also can settle in a distant place where the electricity firstly met the local demand & then the grid.

E. Co-Production

The co-production elements can be harmful to life, so the power plant must locate in a certain distant place from the Populated area. Besides that, some of the by products can be used for fertilizer production, so anywhere near the cultivable lands (Rajshahi, Rangpur) can also be useful for farming.
After analyzing all these related issues, we may detect 3 preferable location for IGCC. Those are:

1. Khulna Division
2. Rajshahi Division
3. Rangpur Division

G.Tables and Figures

Table IV: Coal reserve in Bangladesh [12]

Location & Year of Discovery	Depth (Meter)	Mine area (Sq. km.)	Estimated Reserves (Million Ton)
Boropukuria, Dinajpur (1985)	119-506	6.88	390
Khalashpur , Rangpur (1995)	257-483	12	143 (GSB)
Fhulbaria, Dinajpur (1997)	150-240	30	572
Jamalganj, Bogura (1965)	900-1000	16	1050
Dighipara, Dinajpur (1995)	327	Not Available	200 (Partial Evaluation)

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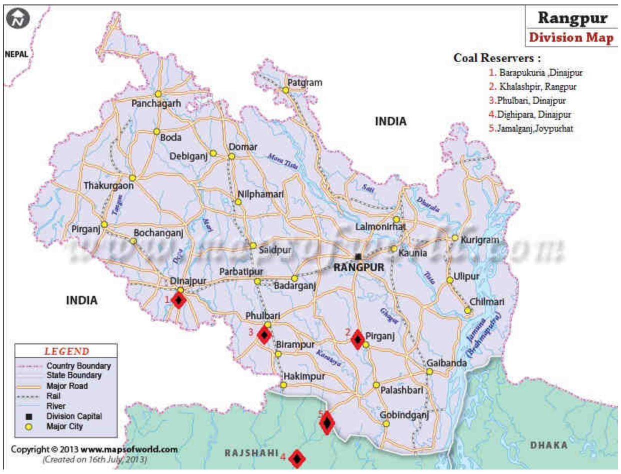

Fig 3: Coal Resources in Geological position of Bangladesh

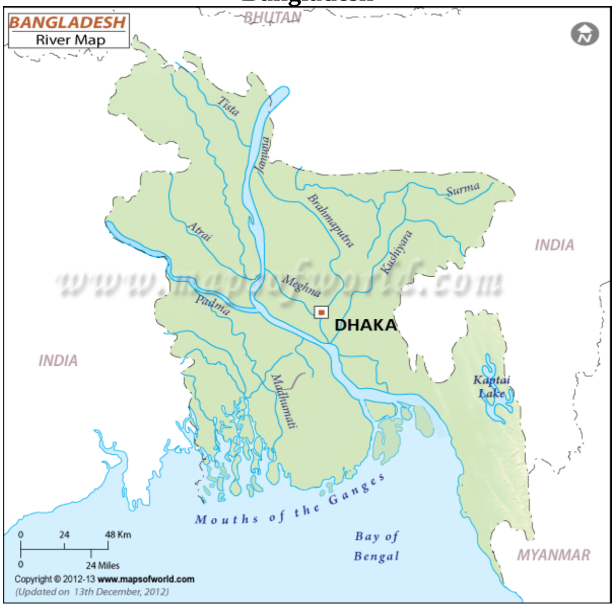

Fig 4: Water Resources in Geological position of Bangladesh

V. CONCLUSION

It is the cleanest coal technology …

– Inherently lower SO_X , NO_X , and PM
– Lowest collateral solid wastes and wastewater
– Potential for lowest cost removal of mercury and CO_2

It is a proven technology …

– 20 years of successful commercial operation at Eastman
– Multiple commercial IGCC's (e.g., TECO Polk, Wabash)

It is becoming increasingly competitive …

– Capital cost at parity with other clean coal and dropping
– Lowest variable cost of all fossil fuel technologies

It is gaining acceptance …

– Gaining support of environmental groups (e.g., NRDC, CATF)
– Numerous state and federal initiatives and incentives

It provides great promise for the future …

– Flexible feedstock, process options, and products
– Opens new markets for coal (synfuels, chemicals, fertilizers)
– It provides the only feasible bridge from coal to hydrogen (directly converts coal to hydrogen)

From the above discussions, it can be concluded that the coal and other fossil energy resources are likely to remain the key fuel for electricity generation. At the same time, the need to reduce anthropogenic emissions of CO_2 to avoid the substantial negative impacts of climate change is pressing. This combination of circumstances strongly promotes the business case for large-scale IGCC power plant with carbon dioxide capture. Large-scale capture of CO_2 by means of physical absorption in power plants is however not a commercially available concept. While the concept is likely to have a large potential, it remains to be proven that it in application will work within acceptable ranges of quality, reliability and cost.

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