

Case Study of Thar Coal Electric Power Generation and Calculation (By Underground Coal Gasification)

Sifat Shah and Zulfiqar Khattak Jamil Ahmad Khan

Department of Electrical Engineering, COMSATS, Abbottabad, Pakistan

Abstract: Underground coal gasification (UCG) is a technique that is used in those areas where we cannot get coal by mining. Those coal reserves having a water layer cannot be extracted by mining easily. So this technique is used where we convert coal in to gas called syngas. This is an atmosphere clean process to reduce 90% sulphur and carbon dioxide in the air called green technology. Thar Desert (Pakistan) has world's 2nd largest coal reserve of 175 billion ton. In this paper energy scarcity issue in Pakistan has been addressed with focus on thermal electricity of Thar coal reserves. Also the paper presents a case study for utilization of coal reserves for electrical power generation through UCG to provide an alternative source for existing fossil fuel power plants in Pakistan.

Key words: Syngas • Gasification • Gasifier • Lignite coal

INTRODUCTION

Among the developing countries, the Pakistan is one of the countries, which tried to achieve its goals for energy sector through hydal. According to latitude and longitude, Pakistan lies in that region of the world, which is blessed with abundant natural resources and hilly areas, which is more suitable for hydro electricity generation. From last few decades Pakistan intended to utilize its natural resources for the generation of energy, especially in power generation sector. Many of hydro electricity generation projects such as Mangla, Terbel, ghazi brotha etc and many others on small and large scale has been installed and produced about 14000MW up to year of 2002. Most of the hydro power generation projects are under construction and some projects which were intended to start had run out in to political snag. As the installation cost of hydal projects is very high and huge patch of land is required for construction of dam. These are very severe problems which are being faced by Pakistan for installation of additional hydro power generation projects to meet the load demand of the country [1]. A couple of years ago, it is decided to install additional power generation projects to meet the growing demand of power sector through thermal, nuclear, fossil fuel etc. A nuclear power plant was installed in Chashma of about 300 mega watt. Again the installation cost of

nuclear power generation projects is also very high and enough crew members are required to run the nuclear power plants which is very infeasible for the country like Pakistan. Energy produced by fossil fuel was in very small scale and also causing environmental hazards [2].

Most of the thermal power generation was installed with natural gas and furnace oil as primary fossil fuels but Pakistan was unable to produce furnace oil indigenously as well as imports of oil on large scale, that's why the electricity produced through furnace oil was very costly. Thermal power plants using natural gas (Sui gas being explored from Baluchistan) being run from a decade to meet the load demand of the country. All thermal units are being run on the principle of single steam turbine, which gives the efficiency of about 27%.with such low efficiency and ever growing shortage of supplies, attention has been diverted towards exploration of new fossil fuels for these plants.

Methodology: Pakistan is blessed with immense resources of coal in the desert of THAR, 410 km from the Karachi, Sindh. Coalfields are located between latitude 24°15 North to 25°45 North and longitude 69°45East to 70°45 East in southern region of the Province of Sindh, Pakistan. The Thar coal field is a part of Thar Desert of Pakistan and it is almost 9th largest desert of the world. it is bounded in the north, east and south by India. According to

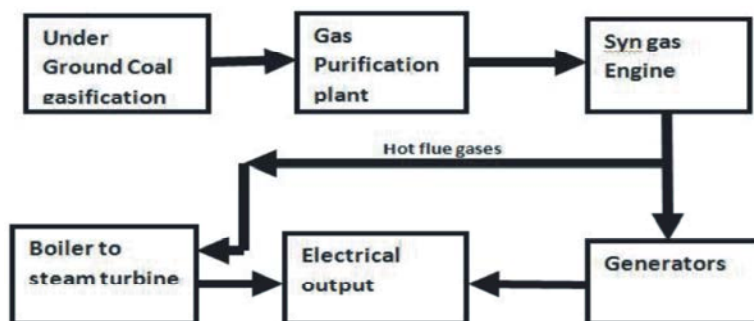


Fig. 1: Integrated Gasification Combine Cycle (IGCC)

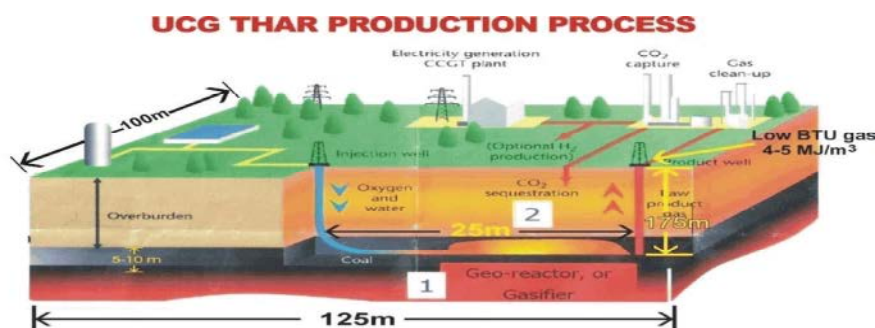


Fig. 2: UCG Thar Production Process

geological survey and drill well shows the presence of three likely Aquifer zones at various depths: (i) above the coal zone Ranges between 50meter to 90 meters depth.(ii) With in the coal zone at 120 meters depth: and there thickness up to 7o meters and (iii) below the coal zone. At 200 metes depth: thickness up to 47 meters. 86 wells are drilled at a distance of 25 meters from each other for conversion of coal into syngas by underground coal gasification. According to the geological survey report of Pakistan 2008 on Thar coal reservoir it has been discover with estimated of 175 billion tons of pure lignite coal, which is spread over an area of more than 9100 square kilometers with dimensions of 140 km (north-south) 65 km (east west). This coal can easily converted into syngas through some chemical process, the process is called underground coal gasification (UCG). In this process the bothering of mining is being avoided that syngas can be converted into furnace oil through a chemical process. It is more feasible to run the units on the principle of Integrated Gasification Combined Cycle (IGCC).

In this process the gases and steam which comes out from single steam turbine at highly temperature will be given to another boiler to run a small turbine (which is directly coupled to electrical generator) for the generation of extra power. The both units combine will give the efficiency of about 57%. The cost of generation through

thermal using IGCC will become half as compared with the conventional power plants employing single turbine principle.

Underground Coal Gasification Process: Underground coal gasification (UCG) technique is only solution for those coal reserves which are sandwiched between water beds. Before the invention of the underground coal gasification technique the coal reserves which were present below the water ground level, was useless.[3] Because preceding mining techniques were failed due to presence of water bed above the coal seams. Now due to this technique (UCG) it becomes possible to use the coal which is below the water bed.

In underground coal gasification process vertically holes are being drilled up to the coal seams with regular distances.[4] Then hot compressed air with steam is being injected in to the well (in case of lignite coal steam can be avoided) in the presence of hot compressed air the coal start burning in the bottom of well. Due to injected pneumatic pressure a channel is formed between two wells and gas starts coming out from next hole.

The gas collected from collection well will be mixture of carbon mono oxide, carbon dioxide, methane, nitrogen and steam (CO , CO_2 , CH_4 , N_2 and steam). After collection this mixture of gasses being passed through a gas

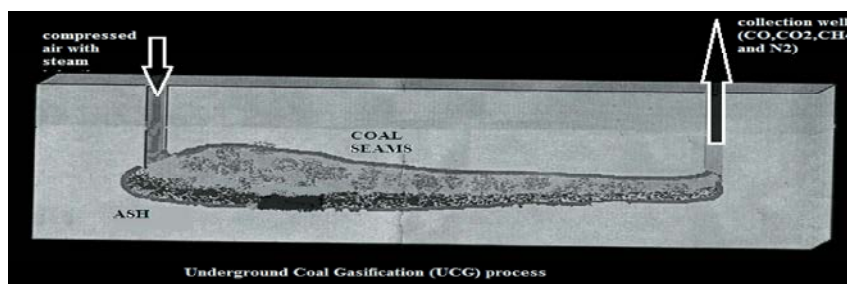


Fig. 3: Underground Coal Gasification process

cleaning plant to capture carbon dioxide CO_2 . After capturing CO_2 , it is again being injected into gassifire to use in chemical process, so that it can be avoided to release carbon dioxide in to the air for clean environment [5]. After cleaning the gas it is given to the syngas engine for the generation of electricity through (IGCC) process.

Chemical Reaction Zones in UGC: The chemical reaction involved in Underground Coal Gasification (UCG) is divided in to

Three different zones are (a) Oxidation zone (b) Reduction zone (c) Drying zone

Oxidation Zone: Oxidation means addition of oxygen or removal of hydrogen. In this zone we injected hot compressed air at high pressure through injecting well. The temperature of this zone is about 900°C . When oxygen react with coal carbon dioxide (CO_2), carbon monoxide (CO) and water (H_2O) is formed. Carbon dioxide (CO_2) is harmful for environment so it is captured by purification plant.

Reduction Zone: Reduction means addition of hydrogen or removal of oxygen. The temperature of this zone ranges between 500°C to 900°C . In this zone carbon monoxide (CO) and water (H_2O) react to formed carbon dioxide (CO_2) and water (H_2O). This reaction is reversible (means carbon monoxide and water can also be formed by the reaction of carbon dioxide and water) CO_2 is again captured. Finally CO and hydrogen (H_2) react to form methane (CH_4) gas.

Drying Zone: The temperature of this zone ranges between 200°C to 500°C . Methane gas formed in reduction zone includes moisture. This moisture is removed from gas at drying zone and finally we obtained methane (CH_4) gas, water (H_2O), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen (H_2), carbon(C) and hydrocarbons from burning of coal.

Hydrocarbons Types and Their Uses: Hydrocarbons are chemical compounds consisting entirely of carbon and hydrogen. They are a subset of organic compounds. Hydrocarbons range from methane, which is just one carbon atom bonded to four hydrogen atoms, to polymers such as polystyrene, which consists of thousands of carbon and hydrogen atoms. As carbon-carbon bonds are the strongest in all of chemistry, long chains with carbon backbones are extremely durable and seem to have a practically unlimited extent. Hydrocarbons come in a variety of forms. They may be gases (methane and propane), liquids (hexane and benzene), waxes (paraffin wax), or polymers (polyethylene and polystyrene).

There are four main types of hydrocarbons: (1) Saturated hydrocarbons, consisting of only single bonds between carbon atoms; (2) Unsaturated hydrocarbons, with double or triple bonds (3) Cycloalkanes, with consist of hydrogen bonded to carbon rings (4) Aromatic hydrocarbons, which contain a chemical structure known as an aromatic ring, for example benzene. The use of hydrocarbons depends on the number of carbon atoms which are shown in Table 2.

Tariff Comparison for Electricity Generation: The bar chart shows that comparisons among the different source of power plant in rupees per kilowatt hours. This graph shows only running charges per kilowatt hour.

Thar Coal Reserves (Sind, Pakistan): In the Thar coal field reserves about 175 billion tons coal has been estimated, which is world's 2nd largest coal reserves at single geographical contained area, spreading over the area of about 9100 sq.km. Coal seams present at Thar field are of about 0.20 to 22.81 meters. The heating value of Thar coal which is pure lignite coal is between 6200 to 11000 Btu/lb. If Pakistan utilizes its Thar coal reserves for next 100 years, then about 1.74 billion tons can be used per annum [2].

Table 1: Schematic Chemical Processes Involved in UCG

Temperature 200-550C	Temperature 550 -900 C	Temperature more than 900C
Draying and pyrolysis Zone	Reduction Zone	Oxidation Zone
Coal \rightarrow CH ₄ + H ₂ O	C + H ₂ O \rightarrow CO + H ₂	C + O ₂ \rightarrow CO ₂
Co + CO ₂	CO ₂ + C \rightarrow 2CO	C + ½ O ₂ \rightarrow CO
H ₂ + C	Co + H ₂ O \rightleftharpoons CO ₂ + H ₂	CO + ½ O ₂ \rightarrow CO ₂
Hydrocarbons	Co + 2H ₂ CH ₄	Coal + O ₂ \rightarrow CO ₂ + CO + H ₂ O

Table 2: Carbon Content in Hydrocarbons

No of carbon atoms	Application	Matter Form
1—4	Heating and cooking fuel (CH ₄)	(gas)
6—18	Gasoline (C ₈ H ₁₈)	(Liquid)
12--24	Jet fuel and camp stove fuel (C ₁₂ H ₂₆)	(Liquid)
18--50	Diesel fuel, heating oil and lubricants	(Liquid)
50+	Petroleum jelly, paraffin wax, tar and asphalt	(solid)

Tariff Rs Comparison Per KWh

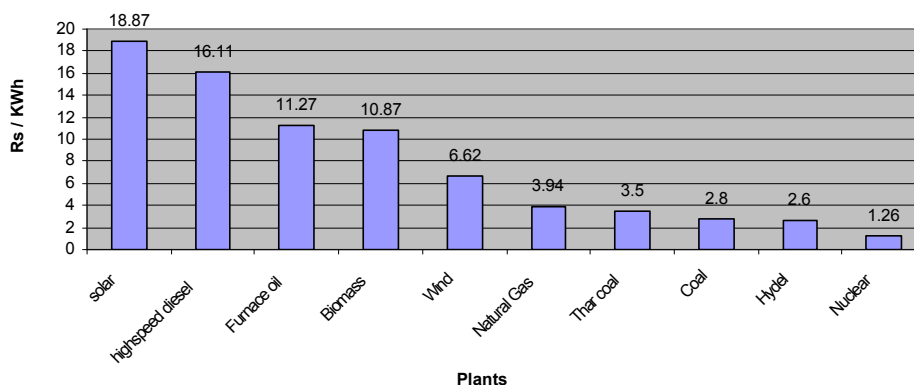


Chart 01: Tariff Comparison

Table 3: Comparison of calorific value

S.NO	Particular	Calorific value
1	Solid fuels	
	(i) Lignite	5,000 kcal / kg
	(ii) Bituminous coal	7,600 kcal / kg
	(iii) Anthracite coal	8,500 kcal / kg
2	Liquid fuels	
	(i) Heavy oil	11,000 kcal / kg
	(ii) Diesel oil	11,000 kcal / kg
	(iii) Petrol	11,110 kcal / kg
3	Gaseous fuels	
	(i) Natural gas	520 kcal/m ³
	(ii) Low BTU gas from Thar By UCG	7895 cal / m ³

Mathematical Analysis of Total Electricity Produced by THAR Coal Reserves:

Data For the under consideration Site “Thar”:

Reserves: 175 billion ton of lignite coal

Heating value: 6200-1100 Btu/lb

Total Area: 9100 Sq.km

Coal beds: 0.20 - 22.81 meters

Theoretical /Proposed Model for the Generation:

Thermal efficiency = 30% = (turbine + boiler)

Electrical efficiency = 92%

Heating value = 7000 Btu/lb

Data Analysis/Calculations for the proposed model:

The power can be calculated by hit upon the followings

- Heat of combustion
- Heat output
- United generated/annum
- Average load on station.

Hit upon Technique for Solution: For simplicity of calculation, the reserves suggested are 175 billion tons of coal in 100 years

$$\begin{aligned}
 \text{Coal used in 100 years} &= \text{Total reserves}/100 \\
 &= 175 \text{ billion ton}/100\text{years} \\
 &= 1.75 \text{ billion ton}/\text{years}
 \end{aligned}$$

For the 1.75 billion ton per year coal consumption, the produced power can be assessed as under.

Step 1: (Conversion of all the units in billion ton)

Heating value = 7000 Btu/lb

= Btu/kg 1kg=2.2045lb and 1 lb=453.6gm

= $700 \times 2.2045 (7000) (2.2045) (1000) \text{ Btu / ton } 1\text{ton} = 1000 \text{ kg}$

= $(7000) (2.2045) (1000) (1 \times 10^9) \text{ Btu / billion ton } 1 \text{ billion} = 1 \times 10^3 \text{ million and } 1 \text{ million} = 1 \times 10^6$

Step 2: (convert Btu/billion ton into Kcal / billion ton)

Calculating heat of combustion

$(7000) (2.2045) (1000) (1 \times 10^9) \text{ Btu / billion ton}$

= $1.54315 \times 10^{16} \text{ Btu / billion ton}$

= $(1.54315 \times 10^{16}) (252) \text{ Cal / billion ton } 1 \text{ Btu} = 252 \text{ calories}$

= $3.8887 \times 10^{18} \text{ Cal / billion ton}$

= $3.9 \times 10^{15} \text{ Kcal / billion ton.}$

Step 3: (Determination of All the Unknowns)

(i) Heat of combustion:

Heat of combustion = Coal used / annum \times Calorific value

= $(1.75 \text{ billion ton}) (3.9 \times 10^{15} \text{ Kcal / billion ton})$

= 6.825×10^{15}

(ii) Heat Output:

Heat output = overall efficiency \times heat of combustion

= $(0.30) (0.92) (6.82 \times 10^{15} 5)$

= $1.8837 \times 10^{15} \text{ Kcal}$

Units generated / annum:

Unit generated/annum = heat output / 860 Kwh 1kwh = 860 kcal

= $(1.8837 \times 10^{15}) \text{ kcal / 860}$

= $2.190 \times 10^{12} \text{ Kwh}$

= $219 \times 10^7 \text{ Mwh}$

Average load on station:

Average load on station = (units generated / annum) / (hours in year)

= $(219 \times 10^7 7) \text{ Mwh / } (365 \times 24)$

= 2, 50,000 MW

CONCLUSION

Pakistan has been facing shortage of energy crisis since the last few years. The scenario gets more worse during summers with load shadings of 10 to 12 hours per day. if THAR coal reserves are utilized, Pakistan can generate electricity of 2, 50,000 MW for 100 years. The maturity of the Thar resources would provide a positive contribution for long-term energy solution for Pakistan. The electrical energy generation capability of 100,000 MW based on expected consumption of 536 million tones of coal per year, could be a significant fuel resource used for provision of coal base load capacity in the system supplementing gas based capacity..

REFERENCES

1. Case study, 2008. Pakistan country report on Thar coal power project July 2008.
2. Principles of power system. 4th edition, by V.K. Mehta, Rohit Mehta.
3. The coal resources, comprehensive report of coal (world coal institute).
4. Friedmann, *et al.*, 2009. Prospects for underground coal gasification in carbon-costrained world. Energy Procedia, 1: 4551-4557.
5. Yang, *et al.*, 2008. Field test of large-scale hydrogen manufacturing from underground coal gasification (UCG). International Journal of Hydrogen Energy, 33: 1275-1285.