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Mitigation of Emission in Thermal Power Plant Using Conventional and Non-Conventional Fuel

H.Chandra[1], S. Paliwal[2] and A. Tripathi[3]

[1]*Bhilai Institute of Technology, Durg (CG) India*
[2]*Research Scholar, Singhania University, Jhunjhunu (Rajasthan) India*
[3]*Jaypee University of Engineering and Technology, Guna (M.P.) India,*

ABSTRACT: *Modeling and analysis on the basis of conventional and non-conventional fuel has been carried out for a gas based combined cycle, coal based thermal power plant situated in and around Delhi, India; and same type of analysis is considered when biomass fired power plant is considered. It is shown that significant improvement in thermal efficiency and environment advantages may be obtained for a gas based combined cycle power plant and the reverse is the case with the biomass fired thermal power plant. The results shows that the percentage reduction in CO_2 emission by combined cycle power plant as compared to coal fired thermal power plant is 65% while 20% excess emission of CO_2 if biomass is considered as fuel for power plant.*

Keywords – *Conventional and non conventional Thermal Power Plants, modeling, emissions.*

I. INTRODUCTION

The power plays a very vital role for development of any Nation and having its importance in overall GDP growth. Day by day the gap between demand and supply of power is increasing. This gap can be met out with more power generation with high capacity plants. The major portion of power generation worldwide is through Coal. Coal is depleting fossil fuel and having environmental issues with its use. The economic use of coal can be done through efficient newer techniques of power generation with minimal environmental impact. Main emissions from coal fired and lignite based thermal power plants are CO_2, NO_x, SO_x, and air-borne inorganic particles such as fly ash, carbonaceous material (soot), suspended particulate matter (SPM), and other trace gas species. Thermal power plants, using about 70% of total coal in India (Garg et. al., 2002), are among the Large Point Sources (LPS) having significant contribution (47% each for CO_2 and SO_2) in the total LPS emissions in India.

Energy consumption per capita is now an accepted indicator of the level of development of a country, which continues to be quite low for India, which had 62,534 MW as installed generation capacity of the utilities at the end of 1989-90 (Mudgal S., 1996). According to Central Electricity Authority (CEA), of a total installed capacity of over 1,04,917 MW in India, over 72,000 MW is accounted for by thermal power plants, the hydel sector accounts for another 25,000 MW, with nuclear and wind power accounting for the rest of power (Power Line, 2002). Thus almost 72% of the installed power capacities are likely to be in thermal power generation. Coal, gas and diesel are contributing 84 %, 13 %, and 3 % of the thermal power generation respectively. The share of hydroelectric generation is likely to remain around 25-30% while rests of the requirements are likely to be met by nuclear power ($\cong$ 3-5%).

A combination of population growth, improved standard of living and increased industrial activities mean an inevitable increase in energy demand. The country requires additional power capacities of 11,000 MW to be added per year in order to meet the growing demand by 2020 (Chandra A., 1997).

It is in this context that there has, of late, been a growing world opinion in favor of looking at alternatives to fossil fuels that would insure Eco-friendly sustainable development on the one hand and energy security on the other hand. Indicative of this thinking is the series of global meetings held in the last decade of the 20th century starting and culminating in Kyoto with a protocol, which commits nations to pursue vigorously the goal of environmentally sustainable development. The protocol was followed by the launch of clean development mechanism (CDM) envisaging technology transfer and financial assistance from the developed to the developing countries to promote systems that would help reduce green house gas emissions. In these circumstances, renewable sources of energy have emerged as a viable option to achieve the goal of sustainable development. India produces huge quantities of agro-residues and agro-industrial wastes. The national productivity council (NPC) survey on Dec.31, 2000 sponsored by Ministry of Non-Conventional Energy Sources (MNES) revealed that about 321 million tonnes of crop residue and 50 million tonnes of agro-industrial wastes are generated annually. It is presently estimated that India produces 400 million tonnes of agricultural wastes every year (Ministry of Power, Annual Report 2012-13).

Bio-Power resources are renewable. When biomass is used to produce power, the carbon dioxide released at the power plant is recycled back into the re-growth of new biomass. This renewable and recycling process makes it possible to generate power without adding to air emissions. Biomass can be grown as bio-energy crops or gathered from forests, mills and landfills as a byproduct. Growing bio-energy crops has important land, habitat and soil conservation benefits. Producing energy from residues in forests, mills and landfills avoids the release of methane into the atmosphere from decomposition of unused wood and agricultural wastes. The key to successful biomass power development is to use the resource efficiently in modern conversion systems that maximize the energy produced and minimize the byproducts of conversion processes. Until the 20th century, in most parts of the world including the U.S., using biomass to generate heat or to drive steam engines was the most common way to produce energy. However, historical methods of burning wood, field residues, or wood wastes and byproducts have tended to be less efficient than modern conversion systems currently available and in development. In modern times, the combination of improved technological efficiencies, scientific advances, increased environmental awareness, and environmental protection regulations have turned biomass conversion into a cleaner, more efficient process (Chakraborty et al., 2008).

This paper presents modeling and analyses of thermal power plants to mitigate the air pollutants emitted by using the conventional fuel (coal) and non conventional fuel (bio mass), by considering case studies of actual power plants situated in India.

II. MATERIALS AND METHODS

For analysis of thermal efficiency and pollutant emission, data have been collected for the year 2012 for all the power plants located in the vicinity of Delhi. These power stations are Gas Turbine Power Station (G.T.P.S.), Delhi Vidut Board (D.V.B.), Indra Prastha (I.P.) Estate, New Delhi; Badarpur Thermal Power Station (B.T.P.S.), Badarpur, New Delhi; and National Capital Power Station (N.C.P.S.), Dadri, Uttar Pradesh. G.T.P.S. is natural gas-fired combined cycle power plant, under D.V.B., while, B.T.P.S. & N.C.P.S. are coal-fired thermal power plants under National Thermal Power Corporation (N.T.P.C.) an apex body in India for power production.

2.1 Conventional Fuel Data Collection

Data collected from G.T.P.S., B.T.P.S. and N.C.P.S. respectively are the following:

2.1.1 G.T.P.S. Technical data

Following data have been collected from G.T.P.S.-

(a) Fuel composition

Type: Natural Gas, Calorific value = 9186.8 cal/m^3=38.58 × 10^6 J/ m^3.

Obtained from: Hazira-Bijapur-Jagdishpur (HBJ) pipeline, Jagdishpur laboratory. Composition: It is given in table 1.

(b) Number of Power Generation Units = 3,Each Unit Contains = 2 GT (Gas Turbine) and 1 ST (Steam Turbine),So Total Number. of GT= 6, Total No. of ST= 3.

(c) Capacity of Each GT Unit = 30 MW, Capacity of Each ST Unit = 34 MW,

So Total Capacity = (30×6) + (34×3) MW = 282 MW.

(d) Fuel Feed: Fuel Feed/day to six GT = 1.44 Million m^3/day

(e) Gas Exhaust Flow (in tph) Measured in 3 consecutive day at the same time: 505.3 t/hr, 485.9 t/hr, and 418.9 t/hr.

Net GT Exhaust Flow Rate = (505.3+485.9+418.9)/3 = 470.033 t/hr

(f) GT Exhaust Composition Measured at 3 Consecutive Day at the same time (% weight) is given in table 2.

Table 1. Composition of natural gas used in G.T.P.S.

Element	Content in volume %
C_6	0.06
N_2	0.10
CH_4	83.70
CO_2	3.03
C_2	7.48
C_3	3.90
n C_4	0.78
ISO C_4	0.65
n C_5	0.12
ISO C_5	0.14

Table 2. Gas Turbine exhaust composition obtained from G.T.P.S.

Composition	% Weight
CO_2	3.1129
Water Vapor	9.9989
O_2	13.7351
N_2	72.2824
Argon	0.8708
SO_2	Nil

2.1.2 B.T.P.S. Technical data

FOLLOWING DATA HAVE BEEN COLLECTED FROM B.T.P.S.-

(a) Coal composition

Since the composition of coal vary day by day, so the coal composition is given by the average value of Proximate and Ultimate analysis of the coal used for producing heat in plant.

(i) Proximate Analysis (% by mass): Moisture = 2.81, Ash = 45.25, VM = 16.54, FC = 35.40, GCV = 3550 kcal/kg

(ii) Ultimate or Total Analysis (% by mass): Ash = 46.56, C = 39.81, H = 3.35, S = 0.50, N_2 = 0.78, O = Remainder

(b) Coal feed

(i) Coal Source =Jharia Coal Fields, Dhanbad, Jharkhand, India

(ii) The coal feed for each unit is tabulated in table 3.

(c) Capacity of power production of each unit

Capacity of 1^{st}, 2^{nd}, and 3^{rd} units are 100 MW each (actual power produced at present is 95 MW per unit). All these three units are connected to one chimney. Capacities of 4th & 5th units are 210 MW each and these two are connected to second chimney. So total power produced by B.T.P.S. = (3 × 100) MW + (2 × 210) MW = (300 + 420) MW = 720 MW.

(d) For Fourth Unit of BTPS

Emission Rate of Total Fly Ash varies between 150 to 700 mg/Nm^3. Capacity of Fourth Unit = 210 MW. Average Flue Gas Flow Rate varies between 160 Nm^3 /s to 215 Nm^3 /s at 155 ^{0}C.

Table 3. Coal feed for each unit of B.T.P.S.

Unit No.	Coal feed mt/day
First	1664
Second	1692
Third	1640
Fourth	3193
Fifth	3036
Total	11225

2.1.3 N.C.P.S. Technical data

FOLLOWING DATA HAVE BEEN COLLECTED FROM N.C.P.S., WHICH IS SITUATED IN GAUTAM BUDH DISTRICT OF UTTAR PRADESH-

(a) Coal composition and Coal Qualities (% by weight): Ash = 45.41, C = 38.61, H = 3.25, S = 0.5, N= 0.74, O =11.48, Fly Ash = 90%

(b) Coal feed: Coal Source: Piparwar Mines, Jharkhand, Coal Feed = 140 t/hr

(c) Capacity of power production: Total no. of Units = 4, Capacity of Each Unit = 220 MW, Total Capacity = 4×220 = 880 MW

2.2 Non-conventional Fuel Data Collection

2.2.1 6MW Rice Husk fired Plant (Pandey et al., 2012; Gidde and Jivani, 2007)

Fuel used:	Rice Husk
Steam capacity:	30 ton/hr
Steam pressure:	66 Kg/cm^2
Steam temperature:	490^{0}C
Feed water temperature:	115^{0}C

Since the rice husk is granular type of fuel the AFBC boiler is selected to get better efficiency.

Ambient air temperature:	35^0C
Moisture in air, M, kg/kg of dry air:	0.0219
RH:	60%
Excess air % :	20%
Fuel properties:	
Constituent	Fraction
C	36.67%
H	4.57%
O	32.89%
S	0.18%
N	1.25%
Moisture	9.44%
Ash	15%

a) Gross calorific value of fuel used = 3275 kcal/kg

Fuel feed = 7926.82 kg/hr

2.2.2 6MW Cotton Stalk fired Plant (Tandon and Sundarmoorthy, 2009)

Fuel used:	Cotton stalk
Steam capacity:	30 ton/hr
Steam pressure:	66 Kg/cm^2
Steam temperature:	490^0C
Feed water temperature:	115^0C

Since the rice husk is granular type of fuel the AFBC boiler is selected to get better efficiency.

Ambient air temperature: 35^0C

Moisture in air, M, kg/kg of dry air: 0.0219

RH: 60%

Excess air %: 20%

Fuel properties:

Constituent	Fraction
C	38.38%
H	5.82%
O	40.55%
S	0.31%
N	0.12%
M	11.38%
A	3.44%

Fuel feed = 6660.92 kg/hr

2.3 Theoretical Background

Analysis of different data collected for power plants are based on certain well-established relationships (Sarkar Samir, 1998, and Horlock J. H., 1995).

(a) Quick Combustion Relationships (Sarkar Samir, 1998):

Where C, and S are carbon and sulphur in % by weight of coal composition.

$$\textbf{Volume of } CO_2 \textbf{ emitted} = \alpha = \frac{22.4}{100}\left(\frac{C}{12}+\frac{S}{32}\right) Nm^3/\text{kg of fuel} \quad (1)$$

Mass of CO_2 produced per kg of fuel = w = M. (PV/RT), where P = atmospheric pressure, M= molecular

$$\textbf{Theoretical Air Required} = A_0 = \frac{22.4\times 4.76}{100}\left(\frac{C}{12}+\frac{H}{4}-\frac{O}{16}+\frac{S}{32}\right) Nm^3/\text{kg of fuel} \quad (2)$$

weight, V= volume of gas, R= characteristic gas constant, T= temperature in Kelvin

Where C, H, O and S are carbon, hydrogen, oxygen and sulphur in % by weight. of coal composition

Volume of NO_2 emitted = $\gamma = 0.79\, A_0 + [(N\times 24) / (28\times 100)]$ **(3)**

Volume of flue gases = $\alpha+\gamma$ Nm^3/kg of fuel, and, **(4)**

Inlet Dust Concentration = (Power capacity × Fly ash content × Coal feed (t/hr/MW) × Ash content × 10^6) / (Average flue gas flow rate × 3600) gm/m^3 **(5)**

(b) Relations for energy analysis (Horlock J. H., 1995):

Overall efficiency of combined cycle power plant = [Net Output/{v_f × (CV of fuel)}] × 100 %

Where, v_f = fuel feed (m^3/s), CV = calorific value of fuel (J/m^3) **(6)**

Overall efficiency of coal based thermal power plant is ={(Output power)/(Input power)} × 100 %

Where, Input Power = Coal feed × Calorific Value (CV) of fuel **(7)**
CV of fuel can be calculated by using Dulong's formula (Sarkar Samir, 1998), which is: CV of fuel = 80.8 C +345 {H- (O/8)}+22.2 S, in kcal/kg, **(8)**
Where C, H, O and S are carbon, hydrogen, oxygen and sulphur in % by weight. of coal composition.

III. RESULTS AND DISCUSSIONS

The data of thermal power plants are analyzed in terms of conventional fuel and non conventional fuel in previous section and the results are shown in Figures 1-2.

- Rate of CO_2 emission of combined cycle power plant (Indra Prastha State) = 0.3113t/hr/MW
- Rate of CO_2 emission of (NTPC) Badarpur Coal based thermal power plant = 0.9523t/hr/MW
- Rate of CO_2 emission of (NCPS) Dadri coal based thermal power plant = 0.9017t/hr/MW

From the above results it is clear that the percentage reduction in CO_2 emission by combined cycle power plant as compared to coal fired thermal power plant is 65% is case of B.T.P.S., Delhi and 65.5% in case of NCPS, Dadri.

- Rate of CO_2 emission of biomass fired (Rice-husk) boiler is = 1.773 T/hr/MW
- Rate of CO_2 emission of biomass fired (cotton-stalk) boiler is = 1.678 T/hr/MW

From the above result we may conclude that there much higher CO_2 emission with biomass fired boiler as comparison to coal based and combined cycle thermal power plant.

- Energy efficiency of combined cycle power plant = 43.85%
- Energy efficiency of Badarpur Thermal Power Station (BTPS) = 33.025%
- Energy efficiency of National Capital Power Station (NCPS) = 35.85%
- Energy efficiency of biomass fired (Rice husk and cotton stalk) boiler are respectively 19.8% and 19.7%.

From the above results we may conclude that energy efficiency of combined cycle power plant is around 20-25% more than both coal-fired thermal power plant and energy efficiency of biomass fired power plant can be improved by proper boiler design, fuel feed systems, combustion equipment.

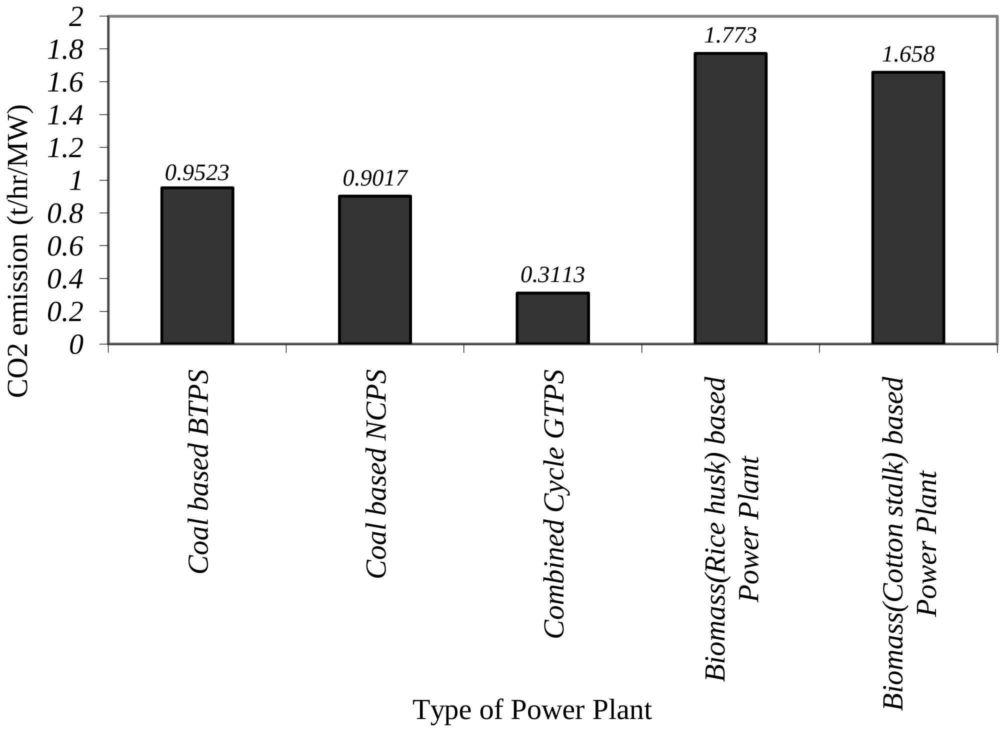

Fig. 1 Carbon Dioxide emission from different types of power plant

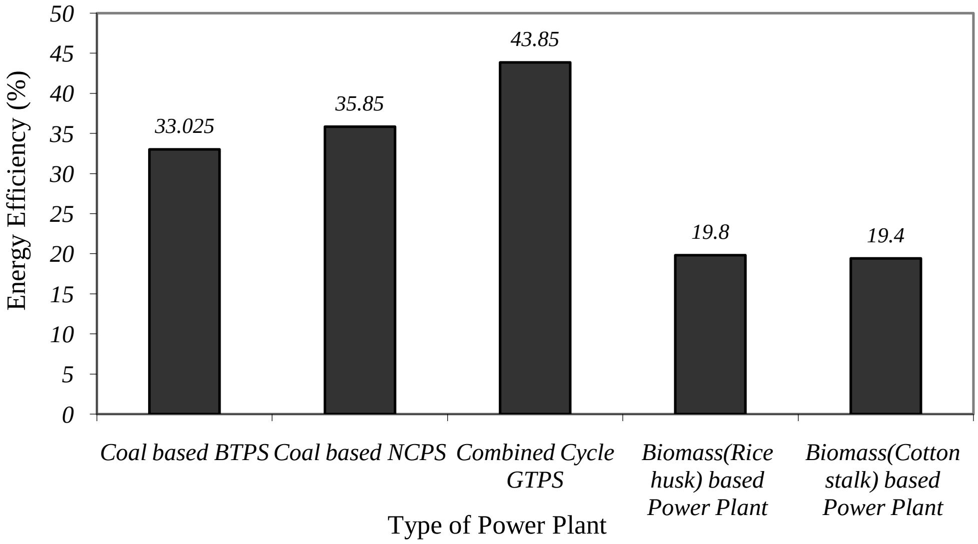

Fig. 2 Energy efficiency of different types of power plant

IV. CONCLUSIONS

Due to rapid industrialization, the demand for power generation is increasing day by day. In India, coal is the primary source for power generation and about 70% of total generation (nearly 10700 MW) is based on the coal. Though a number of control techniques are already been implemented, coal based power units emit tonnes of emission into the air and thus polluting our environment.

Biomass fired power plant using rice husk and cotton stalk as fuel has been also considered, these plants are having much lower efficiency than coal based power plant. Therefore, there is need to improvement in overall efficiency of biomass fired thermal power plant by proper improvement in the design boiler, heat transfer surfaces, fuel field systems, combustion equipment and by improving the fuel qualities, in order to give sufficient rise in overall efficiency of plant.

REFERENCES

[1]. Garg, A., Kapse, M., Shukla, P.R., Ghosh, D., Large Point Source (LPS) emissions from India: regional and sect oral analysis, *Atmospheric Environment.* 2002, 36, 213-224.
[2]. Mudgal, S., Thermal power plant & the environment in India, *Proc. Of Power, Bangalore, India*, 1996.216-228.
[3]. *Power Line*, Vol. 6, No. 9, 2002, 70-71.
[4]. Chandra, A., Environmental considerations in power plants, *Energy Opportunities,* 1997, 28-30.
[5]. Ministry of Power, Government of India, *Annual Report,* 2012-2013.
[6]. Chakraborty, N., Mukherjee, I., Santra, A.K., Chowdhury, S., Chakraborty, S., Bhattacharya, S., Mitra A.P., Sharma, C., Measurement of CO2, CO, SO2, and NO emissions from coal-based thermal power plants in India, *Atmospheric Environment.* 2008, 42, 1073-1082.
[7]. Horlock J.H., Combined cycle power plants-past, present and future, *Journal of Engineering for Gas Turbine and Power*, 117, 1995, 608-616.
[8]. Wunsch A., Highest efficiencies possible by converting gas turbine plants into combined cycle plants, Brown *Boveri Review*, 10, 1985, 455-463.
[9]. Sarkar Samir, Fuels and combustion, *Orient Longman Mumbai*, 1998..
[10]. Horlock J.H., Combined cycle power plants-past, present and future, *Journal of Engineering for Gas Turbine and Power*, 117, 1995, 608-616.
[11]. Tandon S.K. and Sundarmoorthy C.2009. Environmental Preservation through use of Cotton Stalks for Industrial Purpose. International Workshop on Utilization of Cotton Plant by Produce for Value Added Products, Nagpur. Nov. 9-11, 2009.
[12]. Gidde M.R. and Jivani A. P. 2007. Waste to Wealth-Potential of Rice Husk in India a Literature Review. *Proc. of International Conference on Cleaner Technologies and Environmental Management,* PEC Pondichery, India, January 4-6, 2007, 586-590.
[13]. Pandey R., Sar S.K. and Bhui A.K., Feasibility of Installing Rice Husk Power Plant in Chhattisgarh to meet Sustainable Energy Demands. *International Journal of Advanced Engineering Research and Studies,* Vol.1, Issue IV, 2012, 57-60.