

Resource inventory of coal based Thermal Power Plant – A Case study

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ABSTRACT: Coal based power plant in India uses high ash, low sulfur content coal having low calorific value. Due to low sulfur content and low calorific value, the ash generation for unit power generation for Indian coal is very high. The technology used for dust control in TPP is mostly electrostatic precipitator (ESP), the technology of which is borrowed from the west. Thus there is a challenge in making borrowed technology compatible with properties of Indian coal. It is not easily possible to carry out independent research on dust control for TPP using Indian coal and therefore, regular data collection and analysis may yield some insight into the design aspect of Indian TPP. This paper discusses the resources required in TPP using Indian coal, the need for database creation. The utility of database is discussed for a TPP having three different units like 210 MW old technology unit, 210 MW new technology unit and 500 MW latest technology unit.

KEYWORDS: Resource Inventory, Thermal Power plant, Coal consumption, Emission rate, Ash content, sulphur content.

I. INTRODUCTION

Discovery of alternating current by Nicola Tesla and its ability of transmission initiated the installation of pit head thermal power plants (TPP) near coal mines. TPP emit large quantity of suspended particulate matter (SPM) and gaseous pollutants in the coal mine environment. Since the coal mine area in the remote places is inhabited by lesser number of people of low income group, the need for air pollution control was of lesser importance. However, over time, population growth, urbanization, the need to use home appliances, lighting, and to operate machines in industries resulted in increased dependence on electrical energy particularly in urban area. Realization of transmission loss over large distance made it necessary to plan for installation of power plants near the urban centres or electrical load centres. Subsequently large TPP started coming up near urban area.

Thermal power plant (TPP) using Indian coal has to deal with high ash content of more than 40%. This puts pressure on the emission control side. The technology for control of pollution are borrowed from western countries and USA. The borrowed technology was initially meant for coal found in their countries, which is mostly low ash, high sulphur content coal with relatively high calorific value. The dust control technology adopted by them is ESP having 3 or 4 electrical fields. The same technology when transferred to India, the dust control system would require 8 or 9 electric fields in ESP to clean the gas. The low sulphur content of Indian coal reduces the conductivity of fly ash, and high dust load increases the size of ESP. As per an estimate of CENPEEP [1] for same amount of power generation, Indian TPP require 6.5 times bigger ESP compared to US/European coal. A detailed account of fly ash control in Indian coal based TPP is given by George et al. [2]. TPP in India is experimenting with Indian coal and imported dust control ESP [3,4,5,6] technology over the last 60 years and is a continuous process. The data of performance of control technology (ESP) is collected and documented by various Government agencies [7,8], which is then used in formulating the regulatory guidelines. For example, CPCB has recommended an emission rate of 150 mg/Nm³ [9] for old coal based thermal power plant, which is later changed to 50 mg/Nm³ in order to improve the ambient air quality for new

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 1, January 2017

technology power plant of 500 and 660 MW. Due to low sulphur content of Indian coal, there is no provision of SO₂ control at source, however, for effective dispersion and dilution of SO₂, the flue gas is released at higher elevation with sufficient exit velocity. The higher release height is ensured by providing tall stacks, the design of which is provided by CPCB [10]. Based on micrometeorology, the minimum stack for different region is designed by George et al. [11,12]. All these information are limited to control equipment or stack. Other information like coal quality, feed rate for different capacity plant, ash generated, collected etc. are usually ignored and there is a void of documentation of these data. The knowledge gained over the last six decades can help in planning efficient power plant, however, there seems to be no digital data bank of the past. This paper discusses the environmental issues that can be documented and used in decision making so as to create a healthy and sustainable environment near TPP. The data generated towards turbine for power generation process is excluded in this paper and data relevant to flue gas, dust control and emission characteristic is considered for analysis. Data generated in Sanjay Gandhi Thermal Power Station (SGTPS), Birsinghpur is shown as an example.

II. DATABASE GENERATION

For a power plant, the data generation starts from coal mining (or import). The final cost of coal at mine site gets enhanced as it move towards the TPP. In case of load centre power plant, the cost of transportation and lost during transportation gets added. At the coal handling plant of TPP, the cost is further altered by its washing, blending to improve the calorific value and reducing the ash content. The cost of coal at the entry of furnace of TPP is an important data and should be retained for further analysis. Therefore, two data generated is the unit cost of coal at the exit of coal mine and at the entry of TPP. Kindly refer **Fig. 1 (a)** to realize the coal mining, transportation and TPP in the overall mechanism.

III. DATABASE OF THERMAL POWER PLANT

The important units at TPP are Forced draft (FD) fan, air pre-heater, boiler-furnace assembly, steam super heater, re-heater, economizer for water heating, electrostatic precipitator, induced draft (ID) fan and stack. **Fig. 1(b)** shows only some selected units in TPP. Since power generated is a direct function of heat energy input i.e. coal quality and quantity and therefore, power generated should be recorded along with the coal consumed. The first waste emission is from furnace where bottom ash is generated. The amount of bottom ash generated should be quantified based on its outward flow rate and documented electronically for each batch of coal, and at regular interval.

The ESP consumes electrical power for charging the particulate matter (PM) and removes PM through its bottom hoppers. Thus the electrical power consumption at each electrical field, corresponding quantity of fly ash collected and properties of collected fly ash (particle size distribution at each field) needs to be recorded regularly in electronic form for use in future.

The power required by ID fan depends on the head loss generated in the previous units like ESP or any other dust control device. The ESP should be designed in such a way that the head drop should be minimum. The power required in pushing the flue gas emitting from ESP up to stack top at an exit velocity of more than 20 m/s by induced draft (ID) fan should be recorded.

The electrical power consumption by various utilities including ESP, office & plant auxiliary consumption should be recorded along with the power output, its transmission and distribution losses so as to determine power production efficiency and its comparison with other modes of power generation like hydro-electrical, nuclear and solar etc.

The most important data that a power plant should record during its lifetime is the pressure profile along various units. This data is useful in re-designing different units to improve the overall efficiency. For example, if a multiclone as a pre-cleaner or a wet scrubber after ESP is to be proposed, the pressure variation needs to be known. For an overall good

International Journal of Innovative Research in Science, Engineering and Technology

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efficiency, the positive pressure should be equal to the negative pressure. **Fig. 1(c)** shows the pressure profile along different units of power plant. In general, the following parameters are required to be recorded

- Cost of coal at pit head
- Cost of coal at entry of TPP
- Quality of coal at Furnace inlet
- Quantity of bottom ash
- Power consumption in each electric field of ESP
- Electrical Power generated & distributed at consumer end.
- Fly ash collected in each hopper of ESP
- Particle size distribution of fly ash collected at each electric field
- Power consumption by FD fan
- Pressure profile along different units of TPP
- Flue gas characteristic (PM emission rate, Temperature, exit gas temperature, flue gas velocity)
- Utility power consumption in the TPP

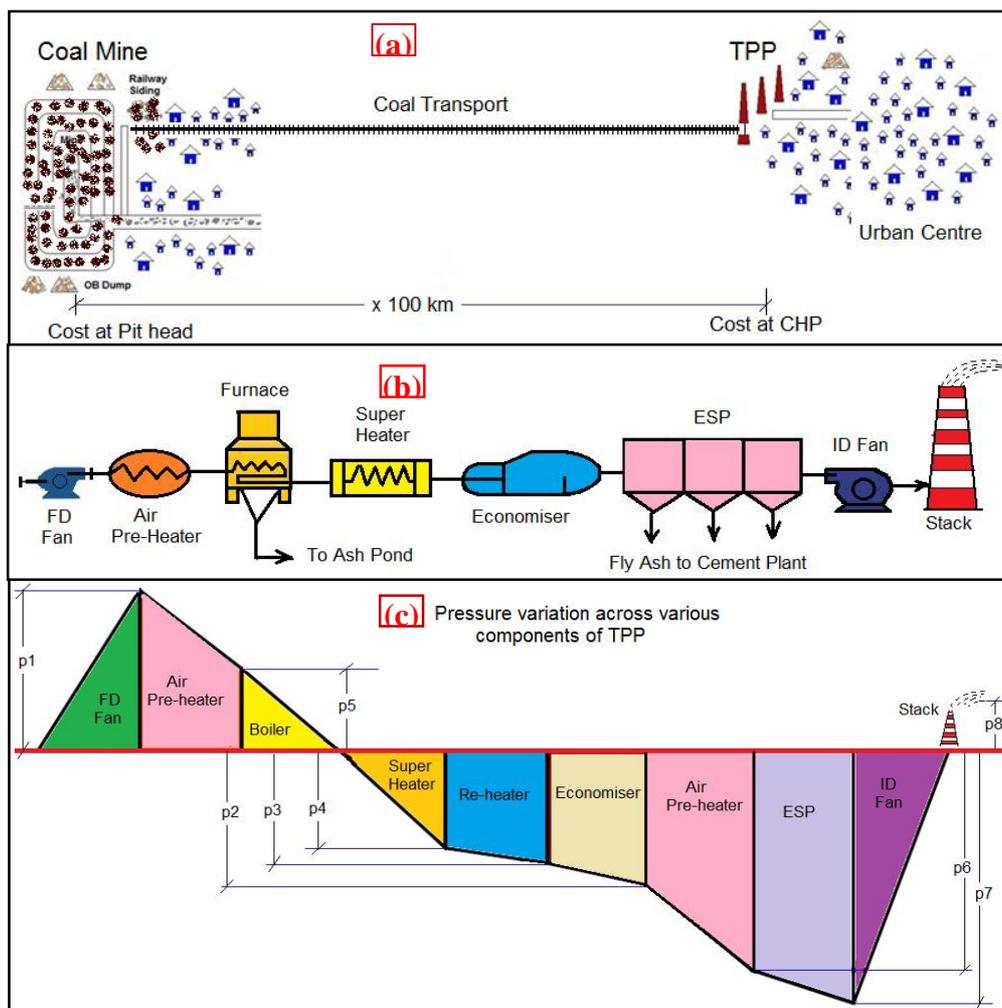


Fig. 1: Schematic diagram of overall TPP (a) Cost involved in coal mining, transportation up to urban center (b) main components of a TPP (c) pressure variation from FD fan to stack exit that needs to be recorded.

International Journal of Innovative Research in Science, Engineering and Technology

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IV. ANALYSIS RESULTS

Data generated at Birsinghpur TPP is used for demonstration of data utility in decision making for better power plant design. Coal consumption, air pollutant emission and power generation data from different units of TPP is gathered for analysis. Birsinghpur TPP stores data in hard copy paper format, which is then converted to digital form by entering them in MS Excel file for subsequent analysis.

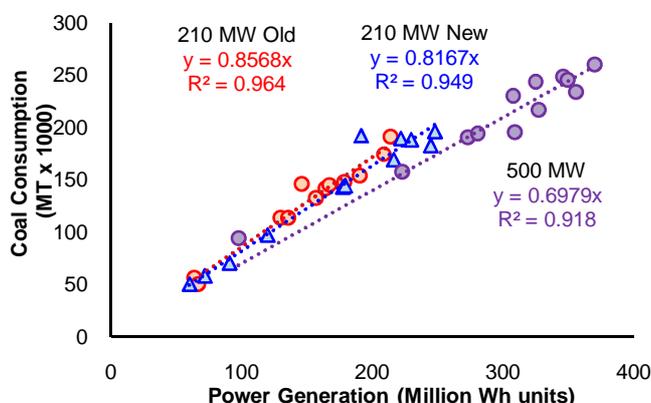


Fig. 2: Coal consumption for unit power generation by TPP units of different capacity.

Analysis is carried out for comparing coal consumption per unit of power generation for different technology. Analysis of stored long term data helps in quantification of coal consumption per unit power generation and help realize the efficiency of power production of different technology. Three technology are considered: 210 MW old technology, 210 MW new technology and 500 MW latest technology. A scatter plot of coal consumption and power generation (million units) is plotted, followed by fitting a linear regression line. Fig. 2 shows the scatterplot and regression line of coal consumption and power generation. The option of zero intercept is chosen so that the slope of regression line directly indicates the coal consumption for unit power generation. The coal consumption data analysis reveals that 858 MT coal is required for one million unit power generation with older technology 210 MW. At the same time, 818 MT of coal is required for 210 MW new technology power plant. As the units power generation capacity increases, the coal consumption for unit power generation reduces as seen from 500 MW power plant, which requires only 703 MT coal for same amount of power generation. Thus the realization that smaller units will require more coal compared to bigger units, the unit capacity of power plant can be decided. Such analysis has led to the design of new plant of 660 MW. Since these data are related to economics of power generation, such data analysis is carried out regularly by those handling power plant. However, air pollution emission parameters, which do not appear to be directly related to cost of power generation are seldom analysed. Total ash generation, fly ash emission, suspended particulate matter (SPM), sulphur dioxide (SO₂) are some of the parameters, which also needs to be analysed viz.a.viz power generation so as to realize the pollution potential of different units.

Total ash generated in TPP can be determined from the ash content of the coal used in furnace. Heaviest part of the total ash is removed in the furnace, called bottom ash, which is transported to the ash pond by mixing it with water and can be quantified. Quantification of bottom ash helps in determining the quantity of total fly ash in coal. A part of fly ash gets removed in ESP, which is then collected through its hoppers and transported by trucks to nearby cement plant for mixing due to its cementing property. If TPP can keep record of fly ash collected in hoppers, the amount of fly ash released from stack top can also be determined. Maintaining record of ash removal from TPP is not a routine practice in Indian TPPs. In this study, ash content is considered as 40% and of this total ash, 20% is assumed as bottom ash and remaining 80% is the fly ash allowed to pass through ESP. The efficiency of ESP for 210 MW old technology TPP is considered as 99.5%, for 210 MW new technology is considered as 99.75% and for 500 MW latest technology it is

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(An ISO 3297: 2007 Certified Organization)

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considered as 99.9%. With such efficiency the remaining fly ash that can pass through ESP and move out of stack is estimated and used in subsequent analysis. Scatter plot of power generation with coal consumption, total ash generation and fly ash generation along with regression line is shown in Fig. 3. The vertical distance between coal consumption and total ash generation is the useful coal that is used in power generation. As the power generation increases, the fraction of useful coal relative to total ash increases suggesting that it is advantageous to install higher capacity units in place of smaller TPP units.

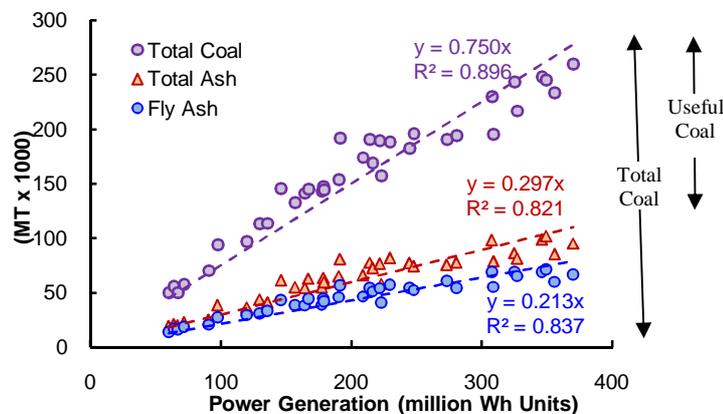


Fig. 3: Coal consumption, total ash and fly ash generation for varying power generation.

In order to compare the overall efficiency of different units that includes coal combustion, heat abstraction (Boiler, economizer, air pre-heater) and pollution control device (ESP) the emission of different pollutant per unit MW installed capacity is estimated using measured emissions and plotted graphically. The estimated unit emission can also be called 'pollution potential' i.e. emission per MW of installed capacity. This is estimated by emission divided by the installed capacity in MW. Since there are two 210 MW old units, the emission from each is added and then divided by 420 MW. Similarly for new 210 MW, the emission is linearly added and the divided similarly. For 500 MW unit, the emission is directly divided by 500 MW to obtain the emission potential. Since the data is available for different months, maximum, average and minimum emission values of similar capacity units are linearly added for estimating pollution potential. This helps in providing a 'range' or 'uncertainty' of pollution potential. Fig. 4 shows the scatter plot along with the regression line for TPP of each unit type. From the slope of regression line, it is found that SPM emission for unit power generation for three different units is different. For 210 MW Old unit, the SPM emission rate is 0.238 g/s/MW, and similarly for 210 MW New technology plant and 500 MW plant, the same is 0.113 and 0.077 g/s/MW respectively.

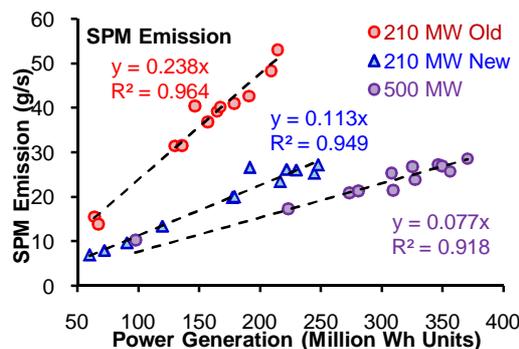


Fig. 4: SPM Emission for varying power generation.

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It can be seen that the SPM emission rate for old technology 210 MW is the highest compared to 500 MW and therefore it can be concluded that new technology, higher unit capacity power plants emits lesser particulate matter (PM) pollution compared to smaller size units.

Emission of SO₂ from stack is estimated using stoichiometric relation for which Sulphur content of 0.2% is assumed and the same is emitted through the stack without any control. **Fig. 5** shows the scatter plot of SO₂ emission with corresponding power generation. It can be seen that the latest technology, higher capacity (500 MW) unit emits relatively lesser SO₂ compared to older technology and smaller units (210 MW).

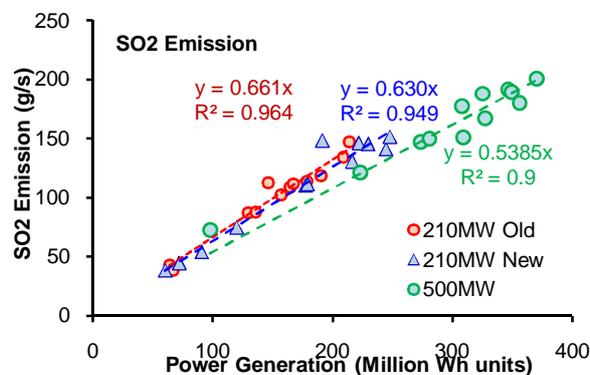


Fig. 5: SO₂ Emission for varying power generation.

V. CONCLUSION

The resource inventory data of Birsinghpur TPP is analysed and it is found that large size power generation units consumes relatively lesser amount of coal when compared to smaller units of older technology to generate same amount of power. Large size TPP generates lesser amount of pollution compared to smaller TPP. Designing TPP for using Indian high ash, low calorie coal would require data particularly the pressure profile along different units so that if a new device needs to be introduced, the corresponding pressure drop can be estimated for its appropriateness.

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