A Review on "Performance Analysis of Thermal Power Plant for getting Maximum Efficiency"

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Abstract: **About 70% of India's energy generation capacity is from fossil fuels, with coal accounting for 40% of India's total energy consumption followed by crude oil and natural gas at 24% and 6% respectively. India is largely dependent on fossil fuel imports to meet its energy demands by2030; India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. In 2009-10, the country imported 159.26 million tonnes of crude oil which amounts to 80% of its domestic crude oil consumption and 31% of the country's total imports are oil imports. The growth of electricity generation in India has been hindered by domestic coal shortages and as a consequence, India's coal imports for electricity generation increased by 22% in 2015. In view of this situation, the project seeks to increase output from the Power Stations (PS) in the process closing down on the power shortages now and in the future through effective and efficiency improvement. This paper presents a review of the methodology to evaluate the performance of coal based thermal power plant. The main aim of the study is to identify areas where energy losses are occurring and develop them for efficient and effective improvement in a thermal power station.**

Keywords: **Energy audit, Thermal power station, efficiency, losses, combustion.**

1.1 Introduction

About 70% of energy generation capacity is from fossil fuels in India. Coal consumption is 40% of India's total energy consumption which followed by crude oil and natural gas at 24% and 6% respectively. India is dependent on fossil fuel import to fulfil its energy demands. The energy imports are expected to exceed 53% of the India's total energy consumption. In 2009-10, 159.26 million tons of the crude oil is imported which amounts to 80% of its domestic crude oil consumption. The percentage of oil imports are 31% of the country's total imports. The demand of electricity has been hindered by domestic coal shortages. Cause of this, India's coal imports is increased by 18% for electricity generation in 2010. India has one of the world's fastest growing energy markets due to rapid economic expansion. It is expected to be the second largest contributor to the increase in global energy demand by 2035. Energy demand of India is increasing and limited domestic fossil fuel reserves. The country has ambitious plans to expand its renewable energy resources and plans to install the nuclear power industries. India has the world's fifth largest wind power market and plans to add about 20GW of solar power capacity. India increases the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9%.

Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Given India's growing energy demands and limited domestic fossil fuel reserves, the country has ambitious plans to expand its renewable and nuclear power industries. India has the world's fifth largest wind power market and plans to add about 20GW of solar power capacity by 2022. India also envisages increasing the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9% within 25 years. The country has five nuclear reactors under construction (third highest in the world) and plans to construct 18 additional nuclear reactors (second highest in the world) by 2025.

1.1.1 Total Installed Capacity (September 2015)

The installed capacity in respect of various resources is as on 30.06.2015 from the Ministry of Renewable Energy. Note: The Hydro generating stations with installed capacity less than or equal to 25 MW are indicated under RES.

Table 1.1 Total Installed Capacities on Fuel Based (September 2015)

Source	Total Capacity (MW)	Percentage
Coal	134,388.39	58.75
Hydroelectricity	39,788.40	17.39
Renewable energy source	28,184.35	12.32
Natural Gas	20,380.85	8.91
Nuclear	4780	2.08
Oil	1,199.75	0.52
Total	2,28,721.73	

Table 1.2 Total Installed Capacities on Sector Based (September 2015)

Sector	**Total Capacity (MW)**	**Percentage**
State Sector	90,062.14	39.37
Central Sector	65,732.94	28.73
Private Sector	72,926.66	31.88
Total	2,28,721.73	

1.2 To increase the Efficiency of the Power System: Energy Audit a Tool

Energy audit is an engineering technique used for accounting of energy used by a particular plant, process, system or sub system. By applying the techniques of energy audit, it is possible to know whether energy is being used efficiently or not. Results of energy audit studies also identify the problem areas of the process or equipment under study and quantify the energy losses. It also identifies the potential areas for energy conservation. The technique is used to:

- Establish the pattern of energy use
- Obtain information about the level of operating efficiency
- Identify where and how losses are occurring
- Identify the generic design deficiencies.
- Identify performance deterioration and damaged plant or machine parts
- Suggest appropriate techniques to conserve energy along with economic implications.

The Energy Conservation Act 2001 has made it mandatory for many types of industries to operate at prescribed energy efficiency. Thus it formalises the concept of energy conservation by making it mandatory (through legislation) to consume energy at prescribed efficiency levels or better. Under this act Govt. of India prescribes the standards and directs the consumers on ways and means of efficient utilisation of energy with a view to improve productivity, enhance operating efficiency, reduce operating costs, and minimise pollution. Power Stations are coming under Energy Conservation Act as designated consumers. The parameters, which will come under the ambit of the act, are:

1. Unit Heat rate
2. Auxiliary Power
3. Specific Oil consumption
4. Plant load factor

As per the Energy Conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption".

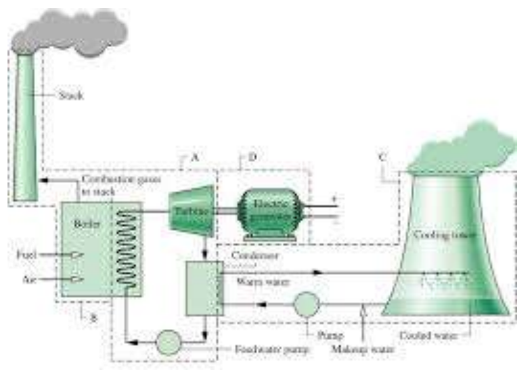

Fig 1.1 Working Cycle of Typical Coal Fired Power Station

Boiler is a most useful device for any developing industries to process & production. Boiler is a steam generating device, which produce steam with burning of fuel. Basically coal is used as fuel in boiler. If the fuel has higher gross calorific value, than it is able to produce more heat per kg of fuel. It is directly proportional to the efficiency.

Efficiency of the boiler should be calculated by two method, direct method and indirect method. It required various parameters for calculating the efficiency.

These parameters are chemical analysis result of coal, feed waters analysis, coal feeding rate, steam pressure, steam generation per hour, flue gas analysis, and weather any heat recovery devices are attach or not, if attach, than its data, fuel consumption rate per hour, humidity factor etc. These all are related to each other and required for calculation. It is necessary to optimized good boiler efficiency. Boiler efficiency can be measured by two method, direct method and indirect method. Both methods give a different result.

Direct method did not include any losses for calculating boiler efficiency, while indirect method includes all the heat losses from a system to find boiler efficiency. In their study they simulate the efficiency with various values of fuel GCV. GCV of fuel indicate the heating value of fuel. As the heating value is high, efficiency is also increased with the higher GCV coal.

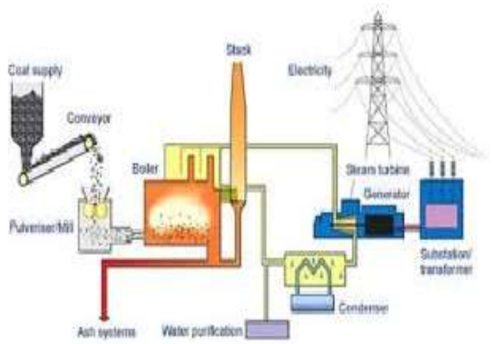

Fig 2 Typical layout of thermal power plant

2. Literature Based on Various Case Studies of Different Thermal Power Plants:

Chetan T. Patel, Dr.Bhavesh K. Patel, Vijay K. Patel in their investigation "Efficiency With Different GCV of Coal And Efficiency Improvement Opportunity In Boiler" compare the different GCV of coal to find out the proper fuel selection of fuel. There are different parameters regarding to the boiler system which helps to improved boiler efficiency.Here calculation has been done for the 40THP FBC boiler used in the L & T Industries, fuel having GCV of 5800 kcal/kg and 4300 kcal/kg respectively for semi bituminous coal and Indian lignite coal. Both coals have a different chemical composition and properties.

Mr. M. G. Poddar and Mrs. A. C. Birajdar has done a case study of thermal power plant, Unit-I Parli (V) Maharastra for energy audit and found out that the efficiency boiler is 79.69% at 85% BMRC against the guaranteed value of 86.20% at 100%.The major reasons for having lower efficiency are poor quality of coal and air leakages. Efficiency of the boiler is increased by 0.27% by reducing air leakage about 6% in air heater.Excess air leakage of about 31% in to the system at AH outlet against designed value of 5-to15%.The annual cost saving in auxiliary power consumption of (PA+FD) and ID fans can be reduced to Rs. 41.22 and 39.52 Lakhs respectively.

Ch. Kiran Kumar and G.Srinivasa Rao made a performance analysis from the energy audit of Kothagudem thermal power station, Andhra Pradesh. A detailed analysis of the effect of the fuel on the boiler efficiency, the dry and the wet flue gas loss, combustion characteristics, the start-up and the shut-down losses, the radiation losses and the heat losses due to hydrogen in fuel, moisture in fuel, carbon monoxide in fuel are explained. They also presented the factors leading to the deterioration of the boiler efficiency by direct method and indirect method and evaporation losses and blow down losses of cooling tower.

Vikrant Bhardwaj, Rohit Garg, Mandeep Chahal, Baljeet Singh presented an energy audit of 250MWPower Plant (PTPS, Panipat) (Coal – based) at different loads. In thermal power station approximately 90% of thefuel i.e. Coal alone. In my work the overall plant efficiency observed 33.67% (210MW), 35.89% (232MW) and36.74% (250MW). The component efficiencies found 85.23% (Boiler), 41.19% (Turbo-Gen.) and 53.33%(condenser) at full load.

Ravi prakash kurkiya, and Sharad chaudhary reported Energy analysis of a thermal power plant. They provide the basis to understand the performance of a fluidized bed coal fired boiler, feed pump, turbine and condenser. MATLAB 2008 a computer programming is used for the analysis. The energy balance sheet shows that theoretical losses in various component of boiler. It provides information for selection of the components which has maximum losses so, that optimization techniques could be used to make it more efficient. The various energy losses of plant, through different components are calculated which indicates that maximum energy losses occur in turbine.

3. Literature based on coal quality improvement

India ranks third in world coal production, producing 407 million metric tons (mt) of coal in 2006. The majority of this production, approximately 85%, is used for thermal power generation. Electricity from coal currently accounts for 71% of India's total 67 giga watts of power generated.

Total power generation for coal is projected to increase to 161 gigawatts by 2030, with an associated projected increase in coal production to 750 mt. With a growing concern over energy security and sustainability coupled with concerns about climate change and greenhouse gas emissions from coal combustion, the long term generation of coal-based thermal power by India will require the use of cleaner coal and clean coal technologies (CCT).

Indian coals are of poor quality and often contain 30-50% ash when shipped to power stations. In addition, over time the calorific value and the ash content of thermal coals in India have deteriorated as the better quality coal reserves are depleted and surface mining and mechanization expand. This poses significant challenges.

A low-quality, high-ash coal also creates problems for power stations, including erosion in parts and materials, difficulty in pulverization, poor emissivity and flame temperature, low radiated transfer, and excessive amounts of fly ash containing large amounts of unburned carbons. On the other hand, the benefits of using beneficiated coal are well documented and include reductions in erosion rates and maintenance costs in power plants, and increases in thermal efficiencies and reduction in CO_2 emissions. Further, if IGCC or supercritical PCC is used in the future, the thermal efficiency can be further increased resulting in even greater GHG reductions.

However, use of these state-of-the-art technologies requires consistent supply of clean coal to achieve the maximum overall thermal efficiencies. Even fluidized bed combustors (FBC), which are capable of burning lower grade coals, would operate more efficiently with higher-grade coals.

- Coal Beneficiation

A cost-effective and significant step toward improving power plant efficiency and reducing the GHG emissions from the coal-fired power plants in India would be to increase the availability of clean beneficiated coals using appropriate beneficiation technologies. Coal beneficiation (or cleaning) is widely viewed as the lowest-cost option for India to address these goals. According to IEA reports, increasing the quality of coal is an essential step toward the deployment of the state-of-the-art Clean Coal Technologies (CCTs) in India.

The advantages of using beneficiated (washed) coal have been proven through their increasing use in thermal power stations throughout the USA, Europe and other countries. These advantages are numerous, ranging from purely economic savings to environmental benefit.

Craig D. Zamuda, Ph.D. U.S. Department of Energy and Mark A. Sharpe, PE Sharpe *International LLC* had done a significant research to determine the beneficial results of using lower ash coals in Indian thermal power plants. They concluded that, although coal washing increases the upfront cost of coal, in general the cost of electricity from coal fired power generation using clean coal will be less, when all the plant costs associated with using unwashed coal are included. The economic benefits of using clean coal include:

(1) Fewer tons of coal handled reducing the transportation costs;
(2) Less abrasive coal product used in power plant;
(3) increase in mill capacity;
(4) Reduction in ash deposit formation;
(6) increased plant efficiencies;
(7) Higher unit availability and capability
(8) Reduction in tube failures;
(9) Lower maintenance costs;
(10) Reduction in auxiliary power consumption;
(11) Improved ESP performance;
(12) Less particulate emissions;
(13) Lower sulphur emissions; and
(14) Less ash to dispose.

In addition, other significant benefits will arise from using washed coal that have not been addressed in this paper, including the benefits to human health from reduced atmospheric emissions.

Dr.Samsher investigated the effect of coal quality and air leakage on requirement of total air and generation loss. Coal based power stations contribute about 55% of total installed power capacity in India. These power plants are designed to burn a particular grade coal and accordingly the manufacturer provides the operating guidelines to keep the performance at its highest point. This investigations deal with requirement of air for proper combustion which may be far away from the manufacturer data due to wide variation in coal quality over the years or sometimes coal is taken from different mines having different characteristics. Air leakage from Air Pre-heater (APH) is another problem which can be minimized by placing the Forced draft (FD)/ Primary Air (PA) fans after the air preheated; hence the air side pressure is reduced to sub-atmospheric level and causing less air leakage. The reduction in air leakage can also be tried with using trough type circumferential seals.

2.2 Literature based on improvement of boiler efficiency

Tai Lva, LinghaoYua, and Jinmin Song made a Research of Simplified Method in Boiler Efficiency Test. It is needed to make ultimate analysis of coal when testing boiler efficiency by traditional method. However, it is so costly and so long that it is impossible to test boiler efficiency frequently. However, it is much easier to make proximate analysis of coal, and most enterprise may operate. In this paper, a mathematics model has been established based on proximate analysis so as to replace ultimate analysis of coal in boiler efficiency testing. Theoretical air requirement, heat loss due to exhaust gas, and heat loss due to unburned gases were compared by this new model. Errors are no more than 5%, and it shows that the method is feasible and valid.

Rahul Dev Gupta, Sudhir Ghai, and Ajai Jain made a case study for Energy Efficiency Improvement Strategies for Industrial Boilers. The findings of boiler house efficiency improvement study carried out in a large boiler house unit of a pulp and paper mill has presented. The causes of poor boiler efficiency were various heat losses such as loss due to unburnt carbon in refuse, loss due to dry flue gas, loss due to moisture in fuel, loss due to radiation, loss due to blow down, and loss due to burning hydrogen, etc. The various heat losses were analyzed and a set of recommendations were made to the plant management for implementation, so that efficiency of boiler can be increased. Five important recommendations were implemented by plant management, and it has been seen that there is tremendous increase in boiler efficiency. Economic analysis reveals that the expenditure on the proposed system will be recovered in a short span of time.

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