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

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***Abstract*: Sanjay Gandhi thermal power station, Birsinghpur is situated in the district of Umaria (M.P). The total Capacity of the plant is 1340MW (4X210MW+1X500MW). The purpose of the project is to assess the major power consumption by auxiliaries and suggesting cost saving alternatives in terms of energy saving. In this study the Energy audit of unit -3 along with Coal Handling Plant have been conducted for main auxiliaries of thermal power plant like Boiler, Turbine, Condenser vacuum system, Coal handling plant, performance evaluation of Air preheater, DM water consumption. Various parameters from Control room and Chemical wings has been taken and it was found that the efficiency of boiler is 87.51% which we can improve up to 89.63% by reducing dry flue gas losses. There is a lot of wastage of DM water in the plant, There is a huge amount of water passing in Boiler Feed Pump recirculation line, after carrying out the various calculation on Boiler Feed Pump, it is observed that the anticipated saving of approximately Rs. 27.30 Lakhs per year with an investment of Rs.5.0 Lakhs by replacement of valves. Motor Driven Boiler Feed Pump is the main power consuming auxiliaries in thermal power plant; it takes 3.5 MW per Boiler Feed Pump. We can replace Motor Driven Boiler Feed Pump by Turbo Driven Boiler Feed Pump and approximately we can save 2772 Lakhs per year with an investment of Rs. 1000 Lakhs. In Coal Handling Plant most of the motors (Conveyers and Crushers) are running under low load and a lot of power is wasting. Therefore by adopting some precautions and recommendations we can reduce the power consumption. The total anticipated saving will be 4108 Lakhs. per annum with an investment of Rs.2592 lakhs and payback period is 7.5 months. The study conducted clearly shows that the preventive maintenance, overhauling and re-assessment of operating conditions of aging plant imparts a major role in keeping a power plant an energy efficient utility.**

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

I- INTRODUCTION OF UNIT 3 (SGTPS)

The unit-3 of Sanjay Gandhi Thermal Power Station (SGTPS) is provided with Natural Circulation membrane tube water-cooled, radiant type two passes opposed fired with provision of gas recycling furnace. The live steam condition at inlet to ESV is 627 T/hr, 535ºC temperature and 150 kg/cm^2 pressure. The turbine has total three cylinders. It is reaction type, throttle governing and is provided with regenerative feed water heating system. There are six extractions and 60% HP/LP bypass. After conducting walkthrough audit of unit-III it is observed that there is a lot of potential available to save energy with a little bit investment. Then detailed energy audit have been conducted of various auxiliaries of unit-III which have the energy saving potential like minimization of dry flue gas losses in boiler, reduction in DM water consumption, replacement of MDBFP by TDBFP, prevention of air leakage etc.

Table 1.1 Overview of Unit

Unit	4
Insatted Capacity	210 MW
Make TG	BHEl
Design	KWU
Date of Commissioning	23/11/1999

Table 1.2 OPERATING PARAMETERS OF 210 MW (UNIT-III)

PARAMETER	UNIT	DESIGN	OPERATING
LOAD	MW	210	206
DRUM PR.	Kg/Cm^2	170.4	167
MS PR.	Kg/Cm^2	150	147
MAIN STEAM TEMP.	ºC	535	537.8
MAIN STEAM FLOW	T/Hr	627.3	690
1ST STAGE PR.	Kg/Cm^2	132.6	130.5
CRH PR.	Kg/Cm^2	38.1	38

CRH TEMP.	^{o}C	334.8	361.3
CRH FLOW	T/Hr	565.8	631
HRH PR.	Kg/Cm2	34.3	36.3
HRH TEMP.	oC	535	530
COND. VACUUM	Kg/Cm2	0.091	0.051
WIND BOX PR.	mmwc	74	70
FEED FLOW	T/Hr	700	680
SH ATTMP. FLOW	T/Hr	0	45
RH ATTMP. FLOW	T/Hr	0	24
FURNACE PRESSURE	*mmwc*	*-3*	*-10*
FLUE GAS O/L TEMP. At BOILER EXIT	oC	135	120

1.3 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

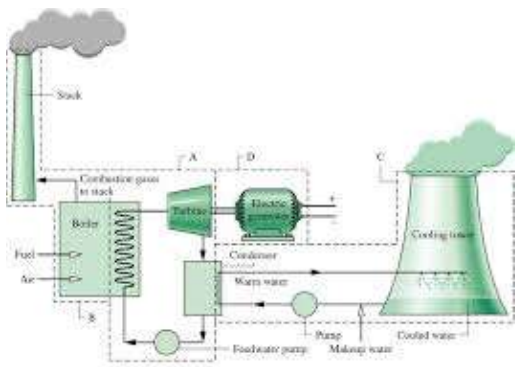

Fig 1.1 Working Cycle of Typical Coal Fired Power Station

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 calculationIt 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.

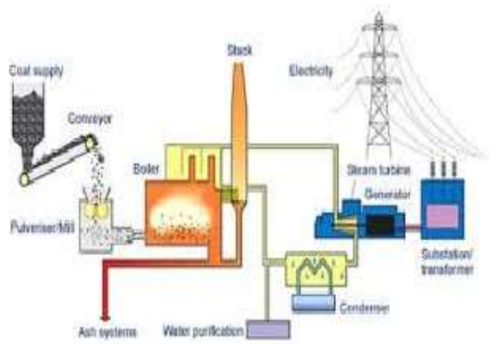

Fig 1.2 Typical layout of thermal power plant

II- LITERATURE REVIEW

2.1 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.

2.2 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.

2.3 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.

III-Research methodology

This causes the boiler to be extremely dangerous equipment that must be treated with utmost care. The process of heating a liquid until it reaches its gaseous state is called evaporation. Heat is transferred from one body to another by means of
(1) Radiation, which is the transfer of heat from a hot body to a cold body without a conveying medium,
(2) Convection, the transfer of heat by a conveying medium, such as air or water and
(3) Conduction, transfer of heat by actual physical contact, molecule to molecule.
Fuel analysis comprises of "proximate" and "ultimate".

(A)Proximate analysis:
In the proximate analysis, moisture (M), Ash (A) and volatile matter (VM) are determined. Fi xed carbon
(FC) is obtained from the following equation:
$FC = 100 - (\%M + \%A + \%VM)$…….. (3.1)

(B) Ultimate Analysis
Ultimate Analysis The main chemical elements in coal (apart from associated mineral matter) a re C, O, H, N and S. The chemical analysis is very important to calculate material balance ac curately and calorific value of coal.For the ultimate analysis C,H,N and S are determined by chemical analysis and expressed as a moisture free basis. Ash is determined as in proximate analysis and is calculated in moisture free basis.
Then
$\%O = 100 - (\%FC + \%H + \%N + \%S + \%Ash)$ ……….. (3.2)

3.1.1 Conversion from proximate analysis to ultimate analysis:
$\%C = 0.97FC + 0.7(VM + 0.1A) - M(0.6 - 0.01M)$ …….. (3.3)
$\%H_2 = 0.036FC + 0.086(VM - 0.1A) - 0.0035M^2(1 - 0.02M)$ ….. (3.4)
$\%N_2 = 2.1 - 0.02VM$ ….. (3.5)

3.2 Basically Boiler efficiency can be tested by the following methods:
1) *The Direct Method*: Where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.
2) The Indirect Method: Where the efficiency is the difference between the losses and the energy input.

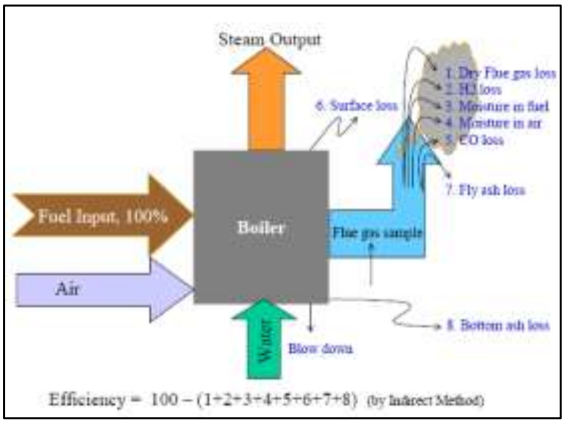

Fig.3.1 Boiler Efficiency by Indirect Method

IV-RESULTS AND ANALYSIS

4.1. ESTIMATING BOILER EFFICIENCY

Unit-3 is provided with boiler manufactured by M/s ABL. Maximum Continues Evaporation of the boiler is 680 T/hr& maximum working pressure is 184 kg/cm^2 . The boiler efficiency of the Unit-4 was evaluated by loss calculation method. During the time of site measurement parameters like O_2, CO_2 and CO in the flue gas were measured.

The ultimate and proximate analysis of coal used for the calculation of boiler efficiency is calculated below and obtained from the laboratory of SGTPS on the same day of testing. During the test period blow down and soot blowing was terminated. The losses considered for calculation of boiler efficiency are given below:

1. Dry flue gas loss
2. Loss due to moisture in fuel
3. Loss due to Hydrogen in fuel
4. Moisture in combustion air loss
5. Loss due to unburnt Carbon
6. Radiation loss
7. Un-accounted loss

4.1 Boiler Heat Balance

Table 4.1 Heat Balance Sheet

SL.NO.	LOSSES (%)	DESIGN	PRESENT
1.	DRY FLUE GAS	3.85	3.6
2.	MOISTURE IN FUEL	1.607	1.4
3.	H_2 IN FUEL	3.144	2.9
4.	MOISTURE IN AIR	0.094	0.11
5.	UNBURNT CARBON	0.9303	0.10
6.	RADIATION	1.5	1.5
7.	UNACCOUNTED	1.362	0.76
8.	TOTAL LOSSES	12.49	10.37
9.	EFFICIENCY (%)	**89.63**	**87.51**

Boiler efficiency by method of losses = 87.51%

- Comparisons of different losses and gross efficiency between the design and current values have been given in the above table.
- Current dry flue gas loss is 3.85%, compared to the design value of 3.6%.
- Higher dry flue gas loss is due to the lower CO_2 and air leakage across APH. Percentage of air leakage across APH is;
  APH-L=46.01
  APH-R= 40.015
- Decrease of excess air quantity, performance improvement of APH (discussed in APH section), controlling tramp air leakage from ash hopper seals/doors, grit hoppers, duct opening, air heater air bypass dampers passing, etc. will bring dry flue gas loss down to design value. The exercise will also improve the boiler efficiency. The saving potential that can be achieved is calculated and given below.

4.1.8 Saving Potential-
Boiler Efficiency = 87.51%
Coal flow rate at 207 MW = 150 TPH
(Considering 0.25% improvement in efficiency by bringing down dry flue gas loss.)
Fuel Saved @ 0.25% = 0.366 TPH
Total fuel Saved/Year = 2635.2 T
(Considering 24 hrs and 300 days of operation)
Amount Saved per Year @ Rs. 1800/T of coal = Rs. 47.43 Lakh
Investment Required (Approx.) = Rs. 20 Lakh
(Expenditure incurred during APH overhauls- Rs.5 Lakhs, Basket replacement- 10 Lakhs, replacing worn out gasket-Rs.2 Lakhs seals and bellow scaffolding-Rs.3 Lakhs)
Payback Period = 5 months

4.2 APH Performance Analysis

The performance evaluation of APH (BI-SECTOR RECUPERATIVE) was evaluated based on the measurements taken during the energy audit study.

The following observation has been carried out after the analysis of air pre heater

- Oxygen percentage in outlet of APH-L(4.5),APH-R(4.9) are very high.
- Percentage of air leakage in APH-L(23.09),APH-R(26.15) are very high .It is due to increase in clearance in axial, radial, circumferential seals. This is the main cause of Dry Flue Gas losses of boiler.
- Effectiveness of all the air heaters is at 62%. It indicates that the hot end, cold end Baskets are in good condition.

4.3Air Pre Heater Tramp Air Leakage

Boilers are sometimes operated with considerable quantities of air in leakage. The detailed calculations to find the quantity of tramp air are given below.

Table 4.4 Parameters measured for Air Leakage

S.N.	Measured Parameters	APH-L	APH-R
1.	Average current fuel analysis		
	H_2 (%)	5.972	
	M (%)	11.03	
	A (%)	33.46	
	GCV (kJ/kg)	18001.2	
2.	Conditions of Airpreheater		
	(a)Air inlet temperature	32.0	
	(b)Air outlet temperature	224	226
	(c)Gas inlet temperature	274	275
	(d)Gas outlet temperature	127	117
	(e)Gas inlet O2%	0.69	0.69
	(f)Gas Outlet O2%	4.5	4.9
3.	Theoretical air required = 3.27XGCV (kJ/kg) Fuel / 1000	5.886	
4.	LMTD at A/H = Ø1 – Ø2 / 2.3 log10 Ø1/Ø2 Ø1 = (2c) – (2b) Ø2 = (2d) – (2a) L.M.T.D.(°C)	50 95 70.18	49 85 65.43
5.	A/H Leakage % = 100 X (2f) – (2e) / 21- (2f)	23.1	26.1
6.	Excess air at A/H gas inlet = (2e) / 21 – (2e)	0.03	0.03
7.	Air required for gas inlet condition {1+(6)} X (3)	6.06	6.06
8.	Excess air at A/H gas outlet = 2(f) / 21- (2f)	0.273	0.304
9.	Air required for gas outlet condition ={1+(8)} X (3)	7.493	7.675
10.	Leakage air = (9)- (7)	1.433	1.615

Tramp air including air leakage as percentage of total air is

APH-L = 46.01%

APH-R = 40.015%

Possible sources of in-leakage for tramp air include:

1) Pressure type milling plant
2) Ash hopper seals
3) Ash hopper doors
4) Duct opening
5) Boiler roof seals defective
6) Air heater air bypass dampers passing
7) Attemperating air dampers passing

It is recommended to check above points for air leakage and take corrective action.

4.4 Economizer Performance Analysis

Table 4.5 Parameters Measured for Economizer

S.N.	Parameter	Unit	Design	Actual
1.	Flue gas I/L temperature	°C	423	419
2.	Flue gas O/L temperature	°C	343	272
3.	Draught at I/L of ECO	mmwc	-40.5	-18
4.	Draught at O/L at ECO	mmwc	NA	-33
5.	Feed water temperature at I/L Economizer	°C	245	221
6.	Feed water temperature at O/L Economizer	°C	277	315

4.5 Super Heater Performance Analysis-

The super heater in 210MW Boiler is present in three stages.

1. PSH (Primary super heater)
2. Platen Super Heater
3. Final Super Heater

Table 4.6 Parameters Measured for Super Heater

S.N.	Parameter	Unit	Design	Actual
1.	Flue gas I/L Temperature	°C	437	438
2.	Flue gas O/L temperature	°C	357	369
3.	Draught at I/L of PSH	mmwc	-28	-25
4.	Draught at O/L of PSH	mmwc	-36	-38
5.	Steam I/L temperature	°C	367	355
6.	Steam O/L temperature	°C	427	421

4.6 Final SH Performance-

S.N.	Parameter	Unit	Design	Actual
1.	Flue gas I/L temperature	°C	[illegible]	870
2.	Flue gas O/L temperature	°C	830	803
3.	Draught at I/L of Final SH	mmwc	-5	-8
4.	Draught at O/L of Final SH	mmwc	-8	-10
5.	Steam I/L temperature	°C	448	437
6.	Steam O/L temperature	°C	535	535

V Conclusion

The following observation can be concluded after the performance analysis:

By comparing the real values of the Boiler losses with the reference or design values it is clearly concluded that all the boiler losses are inside the limit apart from the heat loss due to Fly ash and Bottom ash present in the fuel. The major reasons for having lower efficiency are poor quality of coal and air leakages

Un-burnt coal with fly and bottom ash and un-burnt gas loss is reduced by supplying excess air but it is to be varied judiciously keeping in mind that an extra amount of excess air supplied takes huge amount of useful heat and passes through stack. On-line system should be developed to monitor the quality of coal as it varies continuously and accordingly amount of excess air and its location of supply should be decided. The coal particles size distribution in the pulverized coal should also be maintained properly to reduce the un-burnt loss. The leakage in the air pre-heater is another parameter which needs to be controlled and for this possibility of trough type circumferential seal and placing of FD and PA after APH can be checked and applied. After performing the energy audit of SGTPS (Unit-III) it was found that there is too much potential is available to save energy in various sections like Boiler, fuel quality.

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