Energy Audit Of A Boiler- A Case Study Thermal Power Plant, Unit-Iii Parli (V) Maharastra.

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Abstract

The world over, energy resources are getting scarcer and increasingly exorbitant with time. In India bridging the ever-widening gap between energy demand and supply by increasing supply is an expensive option. The share of energy costs in total production costs can, therefore improve profit levels in all the industries. This reduction can be achieved by improving the efficiency of industrial operations and equipments. Energy audit plays an important role in identifying energy conservation opportunities in the industrial sector, while they do not provide the final answer to the problem, they do help to identify potential for energy conservation and induces the companies to concentrate their efforts in this area in a focused manner.

Hence, there is a growing interest in understanding the energy audit study Therefore, in this project, the present study of Energy Audit mainly focused at identifying practical, sustainable and economically viable energy cost saving opportunities in boiler of Unit-III of the Parli Thermal Power Station. The study shows that there is significant energy cost saving opportunities, and recommendations have been made to realize this potential.

1.Introduction [1][2][3].

Energy may be defined as the capacity for vigorous activity. Energy is present in nature in various forms. Mankind uses the various forms energy for different purposes consist of lighting, heating, cooking, running machinery, transportation and for other applications. It is the crucial resource for all nation building activities, which keep the country's wheels of progress moving at an accelerated pace. Without energy the activities of mankind will come to a standstill and the life on the earth become impossible.

Energy conservation is a wise and efficient use of energy in order to ensure that for a given amount of energy maximum activities, productive work and profitability is achieved.

The availability of commercial sources of energy such as oil, coal and gas within our country are rapidly dwindling and the supply of them has to be supplemented by import. Based on the present consumption, the commercial resource will last for oil – 17 years; gas – 59 years; and coal – 300 years (30 years for high grade coal).

Keeping above considerations in view, it is high time to focus our attention towards energy conservation. Conserving energy is a national need wherein every individual at whatever level can participate and help. By energy conservation, we can save 10 to 30% of energy and cost through simple action.

In the case of industries, such as power plants the energy conservation is must. In this study our attention is focused on Energy auditing. Energy audit serves to identify all the energy streams into a facility quantify energy use according to discrete function.

Energy audit is a vital link in the entire energy management chain. The energy manager in proposing course of action and evaluating their consequences required a detailed information base from which to work. The information base is produced by energy audit a vital element in the overall energy management program.

The overall program includes other managerial and operational activities and responsibilities. However, the audit process is the most important part of the program and is essential to the program's implementation.

The term audit signifies an analysis of the input and output parameters to evaluate discrepancies if any. Energy audit also aims at identifying, evaluating and analyzing various forms of energy input and output. But the scope of energy audit does not end here. With the help of this information, potential areas of energy conservation are identified so as to review the specific energy input both in terms of cost as well as absolute quantity. Energy audit also throws pointers where further action may be required for improving the performance of the equipment / process. It is therefore lays the foundation for development of better process. In an energy audit study of system interaction effect opens the potential for improvement in other areas such as quality, working conditions, environmental effects etc. Thus, energy audit is not merely an audit but is more of a total system improvement technique.

In this project, the study is mainly targeted at identifying, sustainable and economically viable energy cost saving opportunities in boiler section of Unit-III of Parli Thermal Power Station, Parli-Vaijanath. The study shows that, there is a significant cost saving opportunities and recommendations have been made to realize this potential.

2. Relevance of Energy Audit [4][5][6] [7] [8][9][10][11].

The energy audit serves to identify all of the energy streams into a facility and to quantify energy use according to discrete function.

Energy audit can be considered as the first step towards understanding how energy is being used in a given facility. It indicates the ways in which different forms of energy are being used and quantifies energy use according to discrete functions. Energy audit does not provide the final answer to the problem. They identify where the potential for improvement lies and, therefore where energy management efforts must be concentrated.

2.1 Methodology

It is true that there is no clear-cut methodology, which can be tailor-made for conducting energy audit. Historically energy audit are broadly classified in to two types:

Preliminary Energy Audit A preliminary energy audit study typically involves two or three days. In preliminary energy audit, the entire audit exercise can be divided into three steps:

Step-1: Identifies the quantity and cost of various energy forms used in the plant.

Step-2: Identifies energy consumption at the department/process level.

Step-3: relates energy input to production, thereby highlighting energy wastage in major equipment/ processes.

The typical output from preliminary audit assignments is:

Set of recommendations for immediate low-cost action, and Identification of major areas/ projects, which require a more time in depth analysis.

Detailed Energy Audit The detailed audit goes beyond quantitative estimates of costs and savings. It includes engineering recommendations and well-defined projects, and lists priorities. Approximately 95% of all energy is accounted during the detailed audit.

The detailed energy audit which must always be conducted after a preliminary energy audit, is an instrumental survey followed by detailed plant energy analysis. Sophisticated instrumentation, including flow meters, pyrometers, flue gas analyzer and infrared scanners are used to enable the energy auditor to compute energy efficiencies and balances during typical equipment operation. The actual tests performed and the instruments required depend on the type of facility under study and objectives, scope and level of funding of the energy management program. Thus, an energy audit can take as little as one-man week or as much as several man years in a sophisticated plant.

3. Factors affecting the operating efficiency of boiler [12] [13].

3.1 Quality of coal

In the situation we are, there is practically no or very little control of quality of fuel in general and coal is particular for our power station management. They get coal of wider variations in specification, from the designed ones. The effects due to variations are highlighted below.

Inherent moisture With each percentage increase in moisture the loss may increase by 25 to 30 KJ/kg of fuel.

ISSN: 2278-0181
Vol. 2 Issue 6, June - 2013

Hydrogen The increase in wet stack losses is directly proportional to increase in hydrogen content.
Ash The increase in ash content will lead to higher auxiliary power consumption, increase in unburnt carbon content and loss of sensible heat, increase in soot blowing frequency etc.

Hardness More milling power and increase in unburnt carbon.

Volatile Low volatile coals are slower burning, if the values fall below certain limits it may create problem. The fineness has also to increase; adjustments in primary air are also required.
The Indian coals for power generation are of poor quality. High ash content and low volatile matter characterize these.
Air for combustion optimization:

The importance of correct air supplies can hardly be over emphasized. It is convenient to consider these aspects under the following heads.

3.2 Total air quality

With the reduction in total air indicated by percentage increase in carbon dioxide, the stack losses would reduce and air temperature will fall at air heater outlet. The fan power (ID and FD) will decrease, but the unburnt material will increase and also after a certain point unburnt gas may appear leading to increase in loss. The variation in coal characteristics has not much effect on optimum percentage of carbon dioxide, but the variation in load do have effect, primarily because the mixing of the fuel and air is not good. The optimum values of carbon dioxide would be lower at lower loads.

Primary Air The primary air acts as carrier of pulverized fuel from the mills and helps to burn the volatile matter. Both the quantity and temperature of PA have significance in mill operation. The temperature required depends upon the wetness of the coal and the hot air may have to be tempered with cold air to control the temperature. The velocity of primary air passing through the mills, which is of course directly related to its volume, will affect not only the materials rejected fuel. At high velocity large size particles would be lifted and may appear a unburnt carbon in ash, while at low velocity PA may fall back to mill or if carried may separate out in PA pipes, leading to fire hazards. The frequency of soot blowing is also affected by PA variations.

Secondary Air Variations affect the C and A loss and if reduced to very low values will also lead to unburnt gas loss, as CO will be formed. The optimum wind box pressure is formed by carrying out a series of tests to determine the combustible loss at various wind box pressure.

The control over temperature of SA is also important, as it has a bearing on heat loss. For example, if the temperature at SA outlet is 5° C lower than the air heater outlet temperature, then the loss of heat is the equivalent of about 0.2%. Thus SA piping should have good lagging.

Excess air This is the quantity of air required over the theoretical to ensure complete combustion. Due to the stratification of gases or other physical constraints, it is not possible to have all the oxygen molecules to come into the contact with fuel particles at right time to take part in combustion process. It is therefore operational necessity. It is imperative to regulate air supply in such a way that an optimum value is achieved, as too low a value would mean formation of CO and consequently increase in unburnt losses and higher values would tend to increase stack losses. The better mixing of PA reduces amount of excess air, which in modern boiler is in the range of 20% to 25%. The inference about the excess air can be had from oxygen or carbon dioxide indicators. The excess air can be calculated with the following formula.

Leakage air The increase of air into the gas

$$ExcessAir = \frac{O_2\% \times 100}{21 - O_2\%}$$

circuits dilutes the components of flue gases. It increases the burden on ID fans and electrostatic precipitators, as this air has not taken part in the combustion process. The errors are more significant with respect to oxygen, a 5% dilution causes an error of 19.5%. This aspect has to be taken into account when oxygen indicators are installed at the air heater outlet of gases, as there wrong inferences are likely to be drawn. The leakage of air can be calculated by using the following equation.

$$\%\ \text{Leakage} = \frac{8.2\,(O_2 \text{ after APH})\ \ 4.25\,(O_2 \text{ before APH})}{21.0\ \ 8.2\,(O_2 \text{ after APH})}$$

4. Typical losses in boiler [9].

4.1 Dry flue gas loss

This loss is arising due to heat discharged to atmosphere through the flue gases. The burning of carbon and sulphur are the main components giving rise to dry flue gases. There is not much the operator can do, expecting to control the temperature after air heater, keeping in view the formation of dew point temperature. Seigert formula, based upon % of carbon dioxide in flue gives the losses

% Loss = K (T – t) / (% CO2)

Where K is 0.68 for anthracite and 0.63 for bituminous coal.

T = Temperature at air heater gas outlet in °C &

t= Temperature of air at FD fan inlet in °C.

4.2 Wet flue gas loss

These arise due to moisture and hydrogen in fuel. The nature and extent of losses are as follows.

4.2.1 Moisture in fuel loss.

The moisture that enters the combustion chamber as part of the fuel causes the heat loss because it must be heated from its initial temperature to boiling temperature then evaporated and finally superheated to leave the boiler at the same temperature as the final gases.

Heat loss due to moisture can be calculated by the following equation.

% Loss = M/100[1.88(T-25) + 2442 + 4.2(25 – t)] KJ / Kg fuel

Where M = % moisture / Kg of fuel.

Combustion of hydrogen Hydrogen combines with oxygen in the boiler furnace producing water, it is thus necessary to evaporate water that results in loss of the boiler efficiency.

% Loss = 9H / 100 [1.88(T-25) +2442 + 4.2(25 – t)] KJ / Kg fuel

4.2.2 Moisture in combustion air loss.

The moisture in air exists in vapor form and thus takes heat on account of rise of temperature from ambient to that at outlet of air heater. The loss is about 0.2% and is generally ignored.

Gross wet flue gas loss = a + b + c

Loss due to unburnt carbon in ash This is due to the unburnt carbon left in the fly ash or grit. The unburnt carbon depends on the quality of grinding and the distribution of different components of total air. Coarser the grinding and air supply below optimum, higher the loss. It may also be noted that over grinding increases power consumption in milling system and additional excess air, results in stack losses.

% Loss = CA X 33820 / 100 KJ / Kg fuel

Where C = % of carbon in ash.

A = Kg ash / Kg fuel.

Sensible heat carried away by ash The loss which is due to sensible heat in ashes, grit and dust is due to the their leaving the boiler at a relatively high temperature. It is entirely separate loss from that which is due to the refuse containing combustible matter.

The amount of heat carried away by grit / dust is about 125 KJ /Kg with 10% ash in coal. Indian coals may have dust / grit as high as 40%. Thus heat loss on this account is about 500 KJ / kg.

Radiation and unaccounted losses The radiation loss depends upon the boiler casing insulation. In modern PF fired boiler, high insulation coupled with water-cooled furnaces, the radiation losses are kept low. The losses can be reduced by taking air at FD fan inlet, as circulated through boiler columns. The % radiation loss varies with the size of unit for comparable qualities of lagging, as proportional surface area per MW decreases with increase in unit size. The unaccounted losses include heat in ash / grit, evaporation from water filled hoppers exposed to direct radiant heat from the furnace.

Boiler loss = 100 – total losses.

Excess air

Excess air supplied can be calculated by the below equation

Air heater leakage Air heater leakage can be

$$\%\ \text{Excess air supplied} = \frac{O_2\%\ X100}{(21 - O_2\%)}$$

determined by following formula based on gas inlet and outlet analysis.

$$\%\ \text{Leakage} = \frac{(\text{Downstream}\ O_2\% - \text{Upstream}\ O_2\%)\ X100}{(21.0\ \ \text{Downstream}\ O_2\%)}$$

5. Efficiency evaluation of FD, PA and ID fans.

The following observations have been made to calculate efficiency of FD, PA and ID fans.

Total static pressure in terms of mm WC.

Airflow rate in m3 /s.

Actual power consumption in KW.

By using above parameters, the theoretical efficiency of fans can be calculated from the below formula.

$$P_{The} = \frac{WQh_g}{1000} KW$$

Where, P The = Theoretical power in KW.
W = Weight density of air in N / m3
hg = Total static pressure in meter of air column.

The efficiency of fan can be calculated by the following formula.

$$\eta_{fan} = \frac{\text{Theoretical Power}}{\text{Actual Power X Efficiency of motor}}$$

Efficiency of motor is taken as 0.9.

6. Observation and Calculation.

The various readings are considered in the table 1,2,3,4,5 and 7. Calculated results are in the table 6,8 and 9.

"Table 1. Operating Parameters of boiler-III"

Description	Units	Values at 185 MW	Values at 180 MW
Steam Flow	T/h	560	545
Steam pressure	Kg/cm^2	136	136
Steam temp.	^0C	535	535
Feed water temp. at ECO I/L	^0C	242	239
Feed water temp. at ECO O/L	^0C	299	295
PA temp. after AH A/B	^0C	255	255
SA temp. AH A/B	^0C	305	305
FG temp. AH I/L	^0C	-/330	-/330
FG temp. AH O/L	^0C	165/165	162/158
O_2 temp. AH I/L	%	4/3	3.2/3.0
O_2 temp. AH O/L	%	9.0	8.6
Furnace pressure	mmWC	-10	-10
Excess Air at AH I/L	%	20%	17.3%

"Table 2. Parameters of FD fan at 185 KW load"

Parameters	FD – A	FD – B
Inlet guide vane position	20%	15%
Air flow rate m^3/S	47.52	39.2
Air flow rate T/h	200	165
Total static pressure mmWC	35	27.4
Actual power KW	126	108

"Table 3. Parameters of PA fans at 185 KW load"

Parameters	PA – A	PA – B
Inlet guide vane position	90%	90%
Air flow rate m3/s	57.6	58.4
Air flow rate T/h	243	245
Total static pressure mm WC	910	860
Actual power KW	1080	1170

"Table 4. Parameters of ID fan at 185 KW load with parallel operating Condition"

Parameters	ID - A	ID – B	ID – C
Damper Position	100% open	100% open	100% open
Inlet guide vane position	100% open	100% open	80% open
Air flow rate m^3/s	208	108.7	86.96
Air flow rate T/h	615	321	257
Total static pressure mm WC	290	207	204
Actual power KW	1138	6636	806

"Table 5. Coal and ash analysis"

Parameter	Values at 185 MW	Values at 180 MW
Calorific value of fuel	16027.018 KJ/Kg	16027.018 KJ/Kg
Fixed carbon	32.63%	32.63%
Volatile matter	21.27%	21.27%
Ash in coal	38.57%	38.57%

Moisture	7.53%	7.53%
Carbon in slag ash	2.81%	2.81%
Carbon in fly ash	0.55%	0.55%
CO2 at AH O/L	11.5%	11.5%
Temp. of flue gas at FD fan intake (t)	40^0C	40^0C
Temp. of flue gas at AH O/L (T)	165^0C	160^0C

"Table 6. Evaluation of losses at different load condition"

Particulars	Values at 560 T/h	Values at 545 T/h
Dry flue gas loss	6.84	6.57
Wet flue gas loss	8.44	8.40
Loss due to unburnt carbon in ash	0.8154	0.8154
Sensible heat carried by gas	3.00	3.00
Radiation & unaccounted loss	1.22	1.22
Total loss	20.31	20.01
Boiler efficiency	76.69	79.96

"Table 7. Performance evaluation of Air Pre-heater"

Particulars	Units	Design	Operation
PA temp. after APH	°C	335	245
SA temp. after APH	°C	329	300
FG temp. before APH	°C	363	320/300
FG temp. after APH	°C	144	165/165
O2 in FG before APH	-	-	4.3/3.6

"Table 8. Efficiency evaluation of boiler – 3"

Parameter.	Actual power consumed. (Kw)	Theoretical power required. (Kw)	Efficiency. (%)
FD Fan-A	126	16.31	14.38
FD Fan-B	108	10.53	10.84
Total FD Fan	234	26.84	12.61
PA Fan-A	1080	514.19	52.90
PA Fan-B	1170	492.69	46.78
Total PA Fan	2250	1006.88	49.84
ID Fan-A	1138	591.72	57.77
ID Fan-B	636	220.72	38.56
ID Fan-C	806	174.00	23.98
Total ID Fan	2580	946.44	40.13

"Table 9. Summary of Energy saving potential"

Sr. No	Proposal	Annual coal savings	Annual energy savings in Lakh Units	Annual cost savings in Rs.Lakh
Boiler and auxiliaries				
1.	Efficiency of boiler improvement	10162	-	132.10
2.	Saving potential in PA fan by arresting air leakages in the rotary Pre-heater	-	28.43	41.22
3.	Stopping one of the ID fan by providing gates and rectifying inlet guide vane of fan C	-	27.25	39.52

7. Recommendations [14][15] [16].

- Decrease Oxygen % in the flue gas at AH inlet.
- Rectify the coal burner tilting to decrease the higher surface temperature to avoid the radiation loss.
- Rectifying seals and cleaning the heat transfer fins would result in reduction in flue gas temperatures and loading on ID fans.
- Arresting leakage of primary air in to flue gas path in AH would reduce the loading of PA fan.
- Wind box damper has to be rectified to meet the required balance air from FD fans.

8. Result & Conclusion.

- The efficiency boiler is 79.69% at 85% BMRC against the guaranteed value of 86.20% at 100% BMRC.
- 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.
- The efficiencies of PA, FD and ID fans are 49.84%, 12.6% and 40.11% respectively at 100% MRC.
- 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.
- The total cost saving of auxiliary power consumption of all the fans put together is Rs. 80.74 Lakhs.
- Increasing the boiler efficiency by 1%, we can save an annual cost of Rs. 132.10 Lakhs.

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