Energy Audit as an Effective Tool for Energy Conservation in Thermal Power Plant

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Abstract— In the current situation, the greater part of the power produced all through the world is from steam power plants. In this manner, it is critical to guarantee that the plants are working with most extreme efficiency. In India connecting the ever widening hole between energy request and supply by expanding supply is a costly choice. The offers of energy expenses altogether creation expenses can, in this manner enhance benefit levels in every one of the commercial enterprises. This lessening can be accomplished by enhancing the productivity of modern industrial operations and equipment. Energy Audit assumes a critical part in distinguishing energy conservation opportunities in the mechanical area, while they don't give the last response to the issue. Here selected plant is one of the Indian coal based thermal power plant having capacity of 130MW (2×67.5MW) generation. By performing an energy audit found that great opportunity for the energy conservation in the thermal power plant. From the energy audit found that coal saving about 19779.3 MT annually from the boiler operating system, energy saving 678731 kWh annually from the FD fan and 391920 kWh annually in lighting area.

Key words: Cost Benefit Energy Conservation, Energy Audit, Energy Saving

I. Introduction

The electricity sector in India had an installed capacity of 278.734 GW as of 30 September 2015. Out of total installed capacity Renewable Power plants contributed 28% and Non-renewable Power Plants contributed the remaining 72%. In 2014-15 year the gross electricity generated by utilities is 1,106 TWh (1,106,000 GWh) and 166 TWh (166000 GWh) by captive power plants. The total electricity generation includes auxiliary power utilization of power generation plants. India contributed 4.8% global share in electricity generation surpassing Japan and Russia in the year 2013 which is the third largest producer of electricity in all over word India generating per capita electricity was 1,010 kWh with total electricity consumption (utilities and non-utilities) of 938.823 billion or 746 kWh per capita electricity consumption during the year 2014-15. Among all countries Electric energy consumption in agriculture was recorded highest (18.45%) in 2014-15. The per capita electricity consumption is lower in India compared to many countries despite cheaper electricity tariff in India.

A. *Energy Conservation and Energy Audit:*

Energy conservation defines reduction in energy consumption but without making any sacrifice of quality and quantity of production. It is therefore prescriptive that electricity, which is in shortage, be use efficiently and corrective measures are found for adoption. This could be done by “Energy Audit” preserving the continuum of the Specifications. Energy Audit is a systematic way for verdict-making in the field of energy management. It efforts to balance the gross energy inputs with its utilize, and serves to find all the energy streams in a convenience. It quantifies energy utilization comfortable to its several functions. Industrial energy audit is an impressive tool in finding and pursuing broad energy management programme. In 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".

B. *Requirement of Energy Conservation and Energy Audit*

In the resent scenario of quickly ontogenesis demand of energy in domestic and industrial sectors, transportation, agriculture, the preservation of energy has become crucial for overcoming the climbing problems of the world wide environmental erosion and crisis. There are two elements contributing to the enhance in the energy consumption (i) worldwide betterment standard of living and (ii) greater than 20% enhance in world’s population. The industrial sector exhaust about 50% of our energy and so increasing energy efficiency is the focus of the thesis work. It has been guess that 25% betterment in the energy efficiency of the industrial sectors is possible

Energy audit of a power plant should not be treated as a compulsory activity that has to be performed as per the Energy Conservation Act, 2001 of the Government of India, under which thermal power plants have been declared as Designated Consumers of energy by the Bureau of Energy Efficiency (BEE). Rather it should be treated as an exercise to continuously improve energy efficiency of the plant. As per the BEE notification under the Act, power plants are required to (1)appoint or designate qualified energy managers, (2)regularly conduct energy audits by accredited auditors, and (3)implement techno-economically viable recommendations. While implementing these directions, it is important to understand the benefits of such audits with regard to improving operation and maintenance (O&M) practices, saving fuel cost, and contributing to the environment in terms of emission reduction.

C. *Methodology of Energy Audit in Power Plant:*

The Energy Audit is a process firstly gathering information about equipment operation and its past record of utility bills. This data is then evaluated to get idea of how the equipment uses and possibly wastes energy, as well as to help the auditor learn that areas to audited to reduce energy cost. Fixed changes called Energy Conversion Opportunities are found and analyzed to determine their benefits and their cost analysis. These ECOs are increased in terms of their benefits and costs and economic comparison is made to rank different ECOs. Lastly an action plan was created whether certain

ECOs are selected for execution and the actual system of energy conservation & saving money begins.

II. OBSERVATION AND ANALYSIS

A. Boiler:

Boiler efficiency has been calculated in heat loss method and details are given below. The following data has been measured and recorded.

- Fuel Samples
- Flue Gas Analysis
- Flue Gas Temperature
- Ash Samples
- Air Heater Leakage
- Sensible Heat in Bottom Ash

Various losses in the boiler are calculated by indirect method. So different required parameters are measured and collected from the field. The details are discussed in table 1

Description	Unit	Boiler 1	Boiler 2
Ultimate Analysis Report of Coal			
Carbon	%	41.23	42.46
Hydrogen	%	2.58	2.66
Nitrogen	%	1.79	1.73
Sulphur	%	0.42	0.46
Oxygen	%	8.58	8.27
Moisture	%	3.87	7.57
Ash	%	41.53	36.85
Total	%	100	100
Coal Heat Value	kCal/Kg	3935	4047
Flue Gas Analysis at APH outlet			
Flue gas temperature	˚C	135.5	148
Corrected Temperature	˚C	143.28	154.27
Ambient temperature	˚C	31	31
DBT	˚C	31	31
WBT	˚C	28	28
Oxygen	%	1.5	1.5
CO_2	%	15.4	15.4
CO	ppm	56	125
Fly Ash and Bottom Ash Analysis			
Fly Ash Analysis Un-burnt	%	3.89	3.16
Bottom Ash Analysis Un-burnt	%	13.13	5.72
Boiler Efficiency Assessment			
Theoretical air required	kg of Air / kg of coal	5.32	5.51
% of excess air	%	7.69	7.69
Actual mass of air supplied	kg of Air / kg of coal	5.73	5.93
Mass of dry flue gas	kg / kg of coal	6.11	6.24
Loss Calculation			
Dry flue gas losses	%	3.95	4.37
Heat loss due to H_2 in fuel	%	3.74	3.78
Loss due to moisture in fuel	%	0.62	1.2
Loss due to moisture in air	%	0.17	0.19
Loss due to CO present in flue gas	%	0.02	0.05
Radiation & unaccounted loss	%	1.5	1.5
Sensible heat loss from bottom ash	%	2.65	1.86
Sensible heat loss from fly ash	%	2.24	0.84
Loss due to un-burnt in fly Ash	%	0.19	0.18
Loss due to un-burnt in bottom Ash	%	0.32	0.28
Total Losses	%	15.4	14.25
Boiler Efficiency Assessment by Indirect Method	%	84.6	85.75

Table 1: Boiler Energy Assessment By Indirect Method

Observation: losses due to un-burnt are higher side.

B. Air Pre-Heater Performance:

During the Boiler test study at air preheater (APH), the operating parameters like pressure, temperature and oxygen percentage along the flue gas path has been carried out and also fig 1 shows take reading parameter at outlet APH through flue gas analyser.

Fig. 1: Flue Gas Analyser Takes Reading At Aph Outlet

The test was targeted to analyse the performance of air heater and air ingress in the air pre heater. The details are in table 2.

Description	Unit	Unit 1		Unit 2	
		APH A	APH B	APH A	APH B
O_2 at APH inlet	%	1.5	1.5	1.5	1.5
O_2 at APH outlet	%	2.6	3.25	2.7	2.4
Air leakage	%	5.38	8.87	5.9	4.35
C_p of air	kCal/Kg/°C	0.24	0.24	0.24	0.24
Gas leaving temp.	°C	135	136	149	147
Air entering temp	°C	31	31	31	31

C_p of flue gas	kCal/Kg/°C	0.23	0.23	0.23	0.23
Corrected temperature of flue gas	°C	140.84	145.72	156.2	152.2
Temperature of the combustion air at inlet to APH	°C	31	31	31	31
Temperature of the combustion air at Outlet of APH	°C	312	310	296	295
Temperature of the Flue gas at Inlet of APH	°C	330	332	325	323
Effectiveness (Gas side efficiency)	%	0.6326	0.6189	0.573	0.584

Table 2: Performance Of Air Pre-Heater

Observation: there is an increase in oxygen percentage, indicating air leakage in the section of APH.

C. Turbine:

Steam turbine is a mechanical prime mover which extracts thermal energy from steam, and converts it to useful mechanical work. During turbine parameter measurement measure parameters like pressure, temperature and flow rate along the steam-water path has been carried out and also fig 2 shows take reading parameter.

Fig. 2: Takes Reading From Ultrasonic Flow Meter

For steam turbine heat rate is very important. Heat rate is an important index for estimating the conversion efficiency of fuel to produce power. It should be endeavour of any power station to improve the operating Heat Rate as much as possible. Heat rate improvement led to fewer throughputs, and less carbon emission which helps to reduce the production cost of electricity. Hate rate calculation of this plant given in table 3.

Description	Unit	Unit 1	Unit 2
Duration	Hr	2	2
Avg. Unit load	MW	75	75
% of NCR	%	107	107
Main stream flow			
Flow	Tph	307	309
Temperature	°C	513	519
Pressure	Bar	89.27	89.27
Enthalpy	kJ/kg	3421	3436
Feed water			
Temperature	°C	228	223
Flow	Tph	307	309
Enthalpy	kJ/kg	980.81	957.49
Turbine heat rate	kCal/kWh	2385.7	2438.9
Heat Rate Deviation	%	6.03	8.39
Turbine cycle efficiency	%	36.04	35.26

Table 3: Turbine Cycle Efficiencys

Observation: Heat Rate Deviation was remarkable according to BEE regulation now a day it must be up to 5%.

D. Heater Performance:

In this thermal power plant two low pressure (LP) heaters, one De-aerator and two high pressure (HP) heaters. These heaters performances directly depend on extraction of steam turbine. Therefore, they have must operating in the range of grate performance parameters. So, heater performance is given in this table 4

Description	Units	Unit 1		Unit 2	
LP Heater Performance		LPH - 2	LPH – 1	LPH – 2	LPH – 1
FW/ Condensate inlet temperature	°C	71.0	56.0	82.0	59.0
FW/ Condensate outlet temperature	°C	110.0	71.0	113.0	82.0
Δ T of FW/ condensate	°C	39.0	15.0	31.0	23.0
Steam pressure	kg/cm^2 (a)	2.1	1.0	2.1	1.0
	bar (a)	2.1	1.0	2.1	1.0
Saturation temperature	°C	121.6	99.9	121.6	99.9
Drip temperature	°C	97.0	80.0	101.0	84.0
Terminal Temperature Difference	°C	11.6	28.9	8.6	17.9
Drain Cooler Approach	°C	26.0	24.0	19.0	25.0
Effectiveness		0.8	0.3	0.8	0.6
Deaerator Performance		Deaerator-3		Deaerator-3	
FW/ Condensate inlet temperature	°C	110.0		113.0	
FW/ Condensate outlet temperature	°C	162.0		163.0	
Δ T of FW/ condensate	°C	52.0		50.0	
Steam pressure	kg/	8.4		8.2	

	cm^2 (a)				
	bar (a)	8.3		8.1	
Saturation temperature	ºC	172.3		170.8	
Terminal Temperature Difference	ºC	10.3		7.8	
Effectiveness		0.8		0.9	
HP Heater Performance		HP H-5	HP H-4	HP H-5	HP H-4
FW/ Condensate inlet temperature	ºC	186.0	162.0	183.0	163.0
FW/ Condensate outlet temperature	ºC	228.0	186.0	223.0	183.0
Δ T of FW/ condensate	ºC	42.0	24.0	40.0	20.0
Steam pressure	kg/ cm^2 (a)	36.2	15.2	35.2	14.2
	bar (a)	35.5	14.9	34.6	14.0
Saturation temperature	ºC	243.7	199.6	241.8	194.9
Drip temperature	ºC	203.0	195.0	197.0	194.0
Terminal Temperature Difference	ºC	15.8	13.6	18.8	11.9
Drain Cooler Approach	ºC	17.0	33.0	14.0	31.0
Effectiveness		0.7	0.6	0.7	0.6

Table 4: Performances Of Heaters

Observation: Drain Cooler Approach and Terminal Temperature Difference of some of heaters are slighty more. By maintaining these parameters from operating system improve the heat rate of plant.

E. Air Compressors:

Air compressors in thermal power plant generally include plant for service air system and instrument air system. This plant has installed three instrument air compressor, four primary air compressors and four ash convening compressor. On normal operation two IA, one PA and two MAC compressors are being operated. These running compressors analysed by power analyser as shown in fig 3

Fig. 3: Takes Reading from Power Analyser

By the detail study of five compressors data, it was observe that two compressor have more variation in parameter which graphical representation given below.

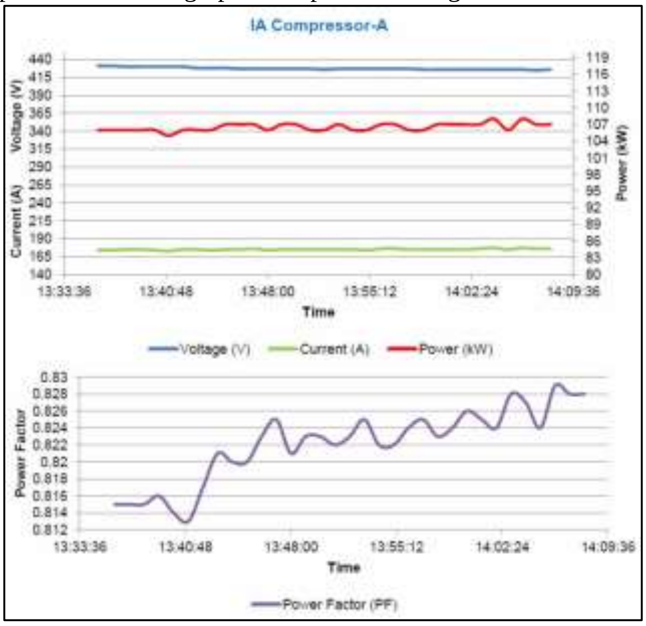

Fig. 4: Ia Compressor A Voltage, Current, Power And Power Factor Profile

From fig 4 observed that Voltage varies from 425 V to 431 V, Current varies from 173 A to 177 A, Power consumption varies from 105 kW to 108 kW and Power factor varies from 0.813 to 0.829.

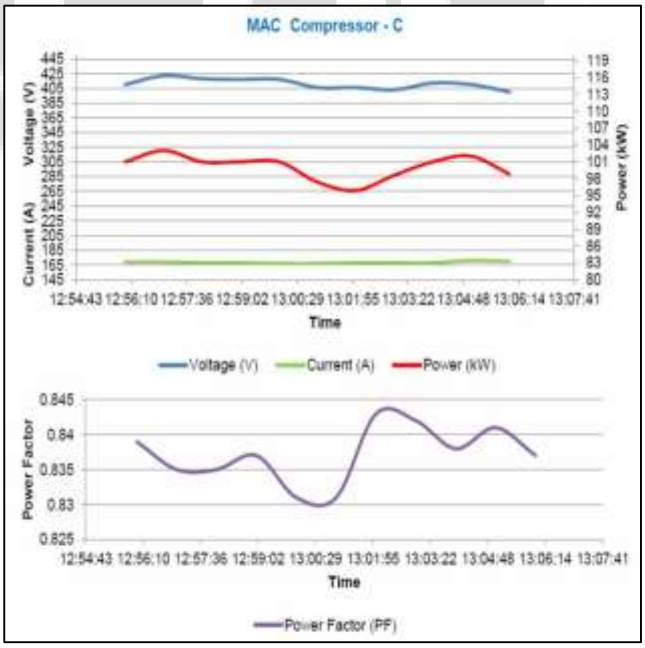

Fig. 5: Mac Compressor C Voltage, Current, Power And Power Factor Profile

From fig 5 observed that Voltage varies from 400 V to 422 V, Current varies from 167 A to 171 A, Power consumption varies from 95.9 kW to 103 kW and Power factor varies from 0.831 to 0.843.

F. Lighting Area:

This generating station, lighting system of the plant consists of T-8, T-5, and 70 watt SON, and 150 Watt HPSV, 250 Watt HPSV and 15 Watt CFL. There are eight MLDBs installed to supply lighting power for the whole plant premises. Each MLDB has one 100 kVA lighting transformer which power consumption Patten given in table 5.

Description	Time	Phase	Vol	Cur	Power
			V	A	kW
MLDB-1	Day	R	413	85	53.4
		Y	415	82	51.2
		B	415	112	71.6
MLDB-1	Night	R	414	105	66.2
		Y	415	95	59.3
		B	413	105	66.8
MLDB-2	Day	R	416	73	45.7
		Y	419	78	49.2
		B	417	61	37.9
MLDB-2	Night	R	407	85	50.9
		Y	411	83	51.3
		B	409	70	42.1
MLDB-3	Day	R	429	68	38.4
		Y	431	89	51.8
		B	430	69	39
MLDB-3	Night	R	420	77	43.6
		Y	423	90	52
		B	422	79	45
MLDB-4	Day	R	429	44	24.2
		Y	424	33	18.9
		B	424	40	22
MLDB-4	Night	R	420	54	29.5
		Y	423	40	23.1
		B	421	44	24.7
MLDB-5	Day	R	423	8	4.68
		Y	425	10	5.96
		B	423	10	5.93
MLDB-5	Night	R	422	30	18.2
		Y	425	20	12.1
		B	424	39	23.7
MLDB-6	Day	R	423	26	14.7
		Y	425	15	8.05
		B	423	25	14.3
MLDB-6	Night	R	427	38	22.5
		Y	430	31	18.9
		B	428	38	23.4
MLDB-7	Day	R	420	43	23.8
		Y	422	45	26
		B	421	49	28.6
MLDB-7	Night	R	418	44	25.5
		Y	421	56	33
		B	420	66	39.8
MLDB-8	Day	R	420	10	5.74
		Y	422	11	6.42
		B	421	15	8.85
MLDB-8	Night	R	417	32	18.2
		Y	421	35	18.9
		B	420	41	23.8
		Avg.	421		

Table 5: Lighting Transformers Power Consumption

Observation: The identified lighting DB's working voltage is high; it varies from 235.26Volt to 249.13Volt

III. ENERGY CONSERVATION OPPORTUNITY

A. Reduce Unburn Carbon In Fly Ash & Bottom Ash:

During boiler efficiency test fly ash and bottom ash sample is collected and the ash analysis is done. The ash analysis shows that the un-burnt in carbon in the bottom ash for Unit 1 & 2 (at 75 MW) is 13.13% and 5.72% respectively. Also the un-burnt carbon in the fly ash for Unit 1 & 2 (at 75 MW) is 3.89% and 3.16 % respectively so, if this parameter maintain than achieve great energy saving and cost benefit which given in table 6

Description	Unit	Unit 1	Unit 2
Unit Load	MW	75.0	75.0
Coal feed rate	TPH	50.4	51.3
Coal Heat Value (Average)	kCal/kg	3935.0	4049.0
Ash percentage in fuel (Average)	%	41.5	36.9
Total Quantity of Ash	Ton	20.9	18.9
Fly ash quantity	Ton	16.7	15.1
Un-burnt in fly ash	%	3.9	3.2
	TPH	0.7	0.5
Bottom ash quantity	Ton	4.2	3.8
Un-burnt in bottom ash	%	13.1	5.7
	TPH	0.6	0.2
Total un-burnt	TPH	1.2	0.7
Proposed system			
Expected of un-burnt in fly ash	%	1.5	1.5
	TPH	0.3	0.2
Expected of un-burnt in bottom ash	%	1.9	1.9
	TPH	0.1	0.1
Reduction in un-burnt	TPH	0.9	0.4

Boiler efficiency	%	0.8	0.9
Heat value of coal	kCal/kg	3935.0	4049.0
Reduction in coal consumption	TPH	1.7	0.8
Operating hrs	hr	7920.0	7920.0
	MT	19779.3	
Estimated annual monetary saving	Rs. Lakhs	596.0	
Estimated Investment	Rs. Lakhs	1000.0	
Payback	months	20.0	

Table 6: Cost Benefit Analyses Of Reducing Un-Burnt Carbon In Fly Ash & Bottom Ash

B. *Reduce Power Consumption Of Id Fans:*

The increase in average oxygen percentage from APH inlet to APH outlet is 1.5% to 2.6 / 3.25% and 2.6% / 3.25% to 6.7 / 7% from APH outlet to ID outlet for Unit 1. The increase in average oxygen percentage from APH inlet to APH outlet is 1.5 to 2.4% / 2.7% and 2.4% / 2.7% to 6% from APH outlet to ID outlet for Unit 2. If arrest the air leakage in APH and air ingress in flue gas duct than Power consumption of ID fans will reduce, ID will be able to handle more flue gas and obtain energy saving and cost benefit which is given in table 7

Description	Unit	Unit 1	Unit 2
Oxygen level at APH inlet (average)	%	1.5	1.5
Oxygen level at APH outlet (average)	%	2.925	2.55
Oxygen level at ID fan inlet	%	6.85	6
Coal feed rate	TPH	50.4	51.3
Calculated gas flow rate at ECO	TPH	311.	321.
Quantity of air leakage in APH	%	7.13	5.13
	TPH	22.22	16.5
Quantity of air ingress in flue gas duct from APH outlet to ID outlet	%	24.96	20.7
	TPH	77.81	66.6
Total air infiltration	TPH	100.03	83.1
Total flow of flue gas	TPH	411.8	404.83
Proposed system			
Reduce air ingress	%	50	50
Expected flue gas flow at ID	TPH	361.79	363.28
Percentage reduction in the flue gas volume	%	0.12	0.1
Reduction in fan power consumption	%	0.12	0.1
Average power consumption of the ID fan	kWh/hr	420	338
Reduction in fan power consumption	kWh/hr	51.008	34.689
Annual operating hours per year	hr/yr	7920	7920
Energy cost	Rs/kWh	2.16	2.16
Annual energy savings	kWh/annum	403987.1	274744.2
	kWh/annum	678731	
Annual monetary savings	Rs. Lakhs	14.66	
Expected Investment	Rs. Lakhs	20	
Payback	Months	16.37	

Table 7: Cost Benefit Analyses To Reduce The Id Fan Power Consumption

C. *Reduce Voltage Level Lighting System:*

The present operating voltage of the lighting circuit is varying from 235.26 – 249.13 Volts. The fluorescent and discharge lamps can be operated at 220 V with optimum efficacy. The reduction of voltage will slightly reduce the lumens output, which is negligible. So, install auto voltage regulator and maintain lighting voltage at 220V. This will reduce the lighting energy consumption. The cost benefit analysis is as follows in table 8

Description	Units	Value
Operating Voltage level	Volt	243
Average lighting Consumption	kWh/day	5954
Annual energy consumption	kWh/Annum	2173210
Proposed system		
Proposed voltage level	kV	220
Expected voltage reduction	%	0.095
Expected power reduction	%	0.1803
Expected energy saving per annum	kWh/Annum	391920.49
Energy cost	Rs./kWh	2.16
Estimated annual monetary saving	Rs. Lakhs	8.46
Total investment	Rs. Lakhs	13.6
Payback	Months	19

Table 8: Cost Benefit Analyses Of Lighting Voltage Reduction By Installation Of Auto Voltage Regulator

IV. CONCLUSION

From the energy audit it was found that this plant having great energy conservation opportunity and plant achieve energy saving in the form of electricity is 1071 MU or 1.18 % annually and in the form of coal is 19779 tonnes or 2.67 % annually. Therefore, above electricity saving helps to fulfil the gap between demand of electricity and supply of electricity and coal saving helps in to obtain energy security of the country.

Convincingly, the target which has been to appear, on a quantitative scale, the execution of the force plant has been accomplished. Also, it is expected to demonstrate that an energy conservation approach must be taken after given the kind of times that are coming ahead that brings genuine worries on energy and fuel assets. What's more, the assume that was cited before alluding to the measure of power moreover created can be given to far flung ranges which are still not profiting by power which incorporates ghettos and towns. This merges above and beyond on a lengthy, difficult experience to being a created country. The genuine motivation behind why this point is chosen is to highlight this potential force producing limit hole, which if brought down, could bring a radical change on the lives on the general population

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