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A Comprehensive Energy Audit of 210 MW Super Thermal Power Plant for Improving Efficiency

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***Abstract*—**Energy constitutes a strategic area for cost reduction. A well done energy audit will always help owners to understand more about the ways energy is used in their organizations, and help to identify areas where waste can occur and where scope for improvement exists. The energy audit would give a positive orientation to the energy cost reduction, preventive maintenance, and quality control programs which are vital for production and utility activities. Such an audit program will help to keep focus on variations that occur in the energy costs, availability, and reliability of supply of energy, help decide on the appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment, etc. In general, the energy audit is the translation of conservation ideas and hopes into reality, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

Keywords:—Generator, Turbine, Boiler, Condenser, Cooling Tower, Furnace, Coal, Oil, Water, Grinder, Chimney, Fans, Super heater, Air pre-heater, Economizer, Ash Handling Plant.

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 fulfill its energy demands. The energy imports are expected to exceed 53% of the India's total energy consumption. In 2009-10, 159.26 million tones 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%. The country has five nuclear reactors under construction. Now, India became third highest in the world who is generating the electricity by nuclear and plans to construct 18 additional nuclear reactors by 2025, then India will become second highest in the world.

Power Capacity in India

The energy generates by different resources in the given table. This table also shows the growth of installed power capacity in India.

Table 1: Growth of Installed Power Capacity in India

Time period	Thermal		Hydro		Nuclear		Renewable Power	
	(%)	(MW)	(%)	(>25MW)	(%)	(MW)	(%)	(MW)
1.4.2002	70.85%	74429	25%	26269	2.59%	2720	1.55%	1628
1.4.2007	64.06%	87015	25.51%	34654	2.87%	3900	7.55%	10258
31.9.2010	63.95%	106518	22.41%	37328	2.70%	4560	10.90%	18,155
31.03.2012	65.84%	131603	19.50%	38990	2.39%	4780	12.25%	24503
30-06-2014	69.05%	172286	16.32%	40730	1.91%	4780	12.70%	31692

(Source: Ministry of New and Renewable Energy, Government of India)

Total Installed Capacity (June2014)

The installed capacity in respect of various resources is as on 30.06.2014 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 2: Installed capacity in respect of various resources

Source	Total Capacity (MW)	Percentage
Coal	148,478	59.51
Hydroelectricity	40,730	16.32
Renewable energy source	31,692	12.7
Gas	22,608	9.06
Nuclear	4,780	1.91
Oil	1,200	0.48
Total	249,488	99.98

(Source: Ministry of Renewable Energy, Government of India)

Table 3: Sector wise Generation Total Capacity

Sector	Total Capacity (MW)	Percentage
State Sector	90,836.70	38.83%
Central Sector	66,997.94	28.64%
Private Sector	76,095.30	32.53%
Total	**233,929.94**	**100.00%**

(Source: Ministry of Renewable Energy Government of India)

Conventional Energy Sources

India is not endowed with large primary energy reserves in keeping with large geographical growing population which increase final energy indeed.

Table 4: Region Wise Energy generation in India

Region	Total in MW	% of National Installed Capacity
Northern	62670.12	26.79%
Western	81117.99	34.68%
Southern	57679.96	24.66%
Eastern	32381.5	13.84%
Total	**233849.57**	**99.97%**

Source: Central Electricity Authority (CEA)

Energy audit throughout the India indicates that coal is the main energy resource of the country. The coal is contributing 70% of the total energy production. The region wise energy generation is indicated in table. The generation is compared with initiative target in the given table.

Renewable Power

The Government has been promoting private investment for the setting up of projects for power generation from renewable energy sources and to the special tariffs being provided at the State level.

Table 5: Share of Different Renewable Sources in India

Resource	Power In (MW)	Up to 9th Plan	Up to 10th Plan	Up to 11th Plan	Target Up to 30.09.10	Cumulative Achievement	12th Plan Projection (2017)
Wind Power	48,500	1667	5,427	9,000	4,714	12,809	27,300
Small Hydro Power	15,000	1,438	538	1,400	759	2,823	5,000
Bio Power	23,700	390	795	1,780	1,079	2,505	5,100
Solar power	20-30 MW/sq km	2	1	50	8	18	4,000
Total	4,000	13,497	6,761	12,230	6,560	18,155	41,400

Resource	Potential (MW)	Up to 9th Plan	Up to 10th Plan	Up to 11th Plan	Target Up to 30.09.10	Cumulative Achievement	12th Plan Projection (2017)
Wind Power	48500	1667	5427	9000	4714	12809	27300
Small Hydro Power	15000	1438	538	1400	759	2823	5000
Bio Power*	23700	390	795	1780	1079	2505	5100
Solar Power	20-30 MW/sq km	2	1	50	8	18	4000
Total	4000	13,497	6761	12230	6560	18155	41400

(Source: Ministry of New and Renewable Energy, Government of India)
* Includes biomass, urban and industrial waste to energy

These include capital subsidies, accelerated depreciation and customs duties. The capital subsidy being provided depends on region and the renewable resources. The capital subsidies vary from 10% to 90% of project cost. The higher level of capital subsidies are given for projects in the North-Eastern Region or Special category States. Generation Based incentives have been introduced recently for Wind Power to attract private investment by Independent Power Producers. There are not availing Accelerated Depreciation benefit and feed in tariffs for solar power.

Off-Grid Renewable Power Programs

Most importantly, it provides energy access to large rural populations in which including those in unreachable areas. Those meet the un-obtained demand in many other areas.

Achievement in Off Grid Power System

Technology	Install Capacity in (MW)
Bagasse Cogeneration	517.34
SPV Systems (>1 kW)	159.77
Biomass Gasifiers - Industrial	146.4
Waste to Power	119.63
Biomass Gasifiers - Rural	17.63
Water Mills/Micro Hydel	10.18
Aerogenerator/Hybrid Systems	2.18
Total	973.13

(Source: Ministry of New and Renewable Energy, Government of India)

Perhaps the outmost areas can get electricity only through renewable sources. Secondly, very important, unrecognized consequence attributed to off-grid applications. In this way or the other, they replace fossil fuels. These can make a significant contribution to reduction in their consumption which is most important from the point of view of energy security. For instance, solar PV replaces diesel or furnace oil in various areas, rural lighting replaces kerosene, a biogas plant or solar cooking system replace cooking gas. Renewable energy can also meet the requirement of process heat in small enterprises and replace small diesel generator sets which consume diesel oil. It has a giant strength in its ability to supply power in a decentralized and distributed mode which has the advantage of consumption at the production point and so reduces land and environmental concerns.

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

Energy audit is a powerful tool for exposure operational and equipment improvements that will reduce energy costs, lead to higher performance and save energy. Sometimes, the energy audit is also called an “energy assessment” or “energy study”. Energy audits can be done as a stand-alone effort but may be conducted as part of a larger analysis across an owner’s entire group. The purpose of an energy audit is to find out how, when, where and why energy is used. The energy audit is also used to identify opportunities to improve efficiency. Energy auditing services are offered by engineering firms, energy services companies and energy consultants.

The energy auditors do the audit process. The first thing energy auditor needs to be aware of end user expectations and then audit starts with an analysis of historical and current utility data. This sets the stage for an onsite inspection. The most important outcome of an energy audit is a list of recommended energy efficiency measures (EEMs). Energy audit serves the purpose of identifying energy usage within a facility, process or equipment, and then identifies opportunities for conservation, called energy conservation measures (ECMs). Audit provides the most accurate picture of energy savings opportunities. Energy audits can be targeted to specific systems i.e. boiler, turbine, generator and any motor etc.

All audits should include the following:

a) Data acquisition
b) Data analysis
c) Recommendations

The complication and documentation required will usually read out the type of audit performed along with the available budget. Most audits will generally fall the following three

Categories:

i. Data Collection:

(a) Meeting with Key Facility Personnel: Set up a meeting with all key operating personnel and to go over audit objectives and roles and responsibilities of project team members, facility rules and regulations, scope of work and a description of scheduled project activities.

(b) Site and Facility Walk-through: Conduct a walk-through of the facility to study the various operations and focusing on the main energy consuming systems.

(c) Existing Available Document Review: Review existing facility documentation with facility engineering representatives. This documentation should include all existing architectural and engineering plans; facility operation and maintenance procedures and utility bills for the previous three years.

(d) Facility Inspection: After a thorough analysis of the construction and operating documentation, the main energy consuming equipment and processes in the facility should be further investigated.

(ii) Analysis Steps

a) Utility Analysis: The utility analysis is a detailed analysis of energy bills from the previous 12 to 36 months. This should include all purchased energy agreements and including liquefied petroleum gas, electricity, fuel oil, natural gas, and purchased steam.

b) Calculate Feasible ECMs: Energy audits should expose both minor operation modifications and major facility modifications requiring detailed economic analysis offering simple or quick paybacks. Develop a list of most important ECMs for each of the major energy-consuming systems i.e. envelope, lighting, HVAC, process and power.

c) Economic Analysis: Within the calculation, include the implementation cost, energy savings and simple payback for each of the ECMs. A lot of the detail and complexity is unnecessary or unjustified for many applications.

(iii) Report Preparation

(a) Prepare Audit Report: Go over the results of findings and recommendations in a final report. The report should include a description of the facilities and their operation. It should also include a debate of all major energy-consuming systems and an explanation of all recommended ECMs with their specific energy impact implementation costs and benefits.

(b) Present and Review Report with Facility Management: Clarify the process and all activities performed to confirm the report's conclusions. Provide economic results as a formal presentation of the final recommendations. Explain the data on the benefits and costs which make a decision or set priorities on implementation of ECMs. After the audit: Read the report and understand the contents and give the prioritize improvements according to choice i.e. Energy reduction, Cost, Need (equipment failure) etc.

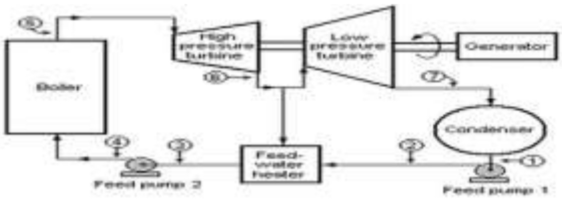
Methodology Used

Energy audit of thermal power plant is carried out on 80% and 100% MCR load. The measured values and calculated values are compared. To compare loads options, a simple approach is to increase the efficiency of plant by check and repair periodically of the equipments of plant and replacement of less efficient or damage equipments with more efficient or new equipments.

To undertake the detailed energy audit of **(GHTP) situated at Panjab**.

The basic objective of the detailed energy audit was to:

1. Study the load consumption/ distribution pattern in the plant.
2. Study the operations of energy concentrated systems/equipments to identify potential area wherein energy savings are practically feasible.



2.1 Single Line Diagram of Thermal Power plant.

Calculations

GHTP, Unit-(I) 210MW at 100% MCR

Air Heater Performance Test

1. Test Fuel Analysis %	
Carbon	41.34
Hydrogen	2.08
Oxygen	10.78
Sulphur	0.30
Moisture	14.28
Ash	31.44
Nitrogen	1.81
2. Condition at Air Heater	
Air Inlet Temperature °C	42.67
Air Outlet Temperature °C	330.00
Gas Inlet Temperature °C	353.00
Gas Inlet Temperature °C	140.00
3. At Inlet %	
O_2	3.88
CO_2	15.48
N_2	80.78
4. At Outlet %	
O_2	5.10
CO_2	14.20
N_2	80.78
5. Combustible in ash kg/kg fuel	0.015
6. Theoretical Air required kg/kg fuel	5.70
7. Carbon burnt kg/kg fuel	0.39

GHTP, Unit-(I) 210MW at 100% MCR

Simplified Turbine Heat Rate – Reheat Unit-1

Power Generated P	210.3
Turbine Stop Valve Steam Pressure P_1	[illegible]
Temperature T_1	[illegible]
Enthalpy H_1	3401.88
Steam Flow W_1	654.0
Economizer Feed Inlet Temperature T_2	238.0
Enthalpy H_2	1028.37
1. Heat Flow From Turbine Stop Valve	
HF_1	$= W_1 (H_1 - H_2)$
	= [illegible]
Reheat Steam Flow W_3	= [illegible]
W_3	[illegible]
Turbine I.P. Inlet Steam Pressure P_4	[illegible]
Temperature T_4	[illegible]
Enthalpy H_4	[illegible]
Turbine H.P. Exhaust Steam pressure P_5	[illegible]
Temperature T_5	347.00
Enthalpy H_5	[illegible]
2. Heat Flow From Re-heater To Turbine	
H.P. Exhaust Steam	$= W_3 (H_4 - H_5)$
HF_2	[illegible]
3. To Calculate Reheat Spray water Heat Rate	
Spray Water Flow Actual W_3	0.00
Turbine I.P. Inlet Steam Enthalpy H_6	[illegible]
Reheat Spray water Enthalpy H_7	1018.57
Heat Flow from Re-heater to spray water	$= W_3 (H_6 - H_7)$
HF_3	= 0.00
Total Heat Flow to Turbine	
$HF = (HF_1 + HF_2 + HF_3)$	= 1753922.7
Total Heat Rate	= HF/(Px4.187)
	= 2001.42

GHTP, Unit-(I) 210MW at 100% MCR

Heat Balance for No.6 H.P. Feed Heater to Determine Bled Steam Flow

H.P. Heater – 6 Bled Steam Pressure P_3	[illegible]
Temperature T_3	347.00
Enthalpy H_3	3101.11
Feed Water Inlet Temperature T_2	198.00
Enthalpy H_2	843.36
Feed Water Outlet Temperature T_8	236.00
Enthalpy H_8	1016.57
Feed heater drain temperature T^1	190.00
Enthalpy H^1	[illegible]
Feed Flow Through Heater W^1	652.00
Bled Steam Flow W_b	$= W^1 (H_8 - H_2)/(H_3 - H^1)$
	= [illegible]

Results & Conclusions

Results and Conclusions of Boiler

S. No.	Results	Conclusions
1	Wet stack loss (6.10%) and dry stack loss (5.13%) are occurred due to moisture in coal.	The moisture of coal should be reduced before use. The moisture can be removed by primary air. The dry coal increases the boiler efficiency.
2	6% of radiation losses are increased in the furnace.	The radiation loss occurs due to poor insulation. So, insulation should be good in quality e.g. Rock wool insulation.
3	Un-burnt carbon in bottom ash and respectively.	There should be proper crushing of coal. The classifiers in mills should be cleaned and checked periodically.

Results and Conclusions of Air Pre Heater

S. No.	Result	Conclusions
1	Tramp air leakage was of order of 2.09 kg/kg at Air Pre-Heater which comes around 35% of theoretical air. It is indicated corrosion in heater elements.	Air leakage should be controlled or minimized. Because it makes the major effect on boiler efficiency.
2	The flue temperature was 123.0 C at outlet against designed value of 140 0C.	This loss of temperature can be reduced by replacement of metallic joints with fabric joints. The leakage was found large through metallic joints and this increased the loading on ID Fans
3	O2 contents were high being 5.10% in flue gasses. It indicates that air is not as per requirement and makes difficultly to complete combustion in furnace.	This loss of O2 can be reduced by replacement of metallic joints with non metallic (fabric) joints. Easy to handle, quickly installed, high flexible, no transfer of vibration are advantages of non metallic joints over metallic joints.

Results and Conclusions of Furnace

S. No.	Result	Conclusion
1	In the furnace, the radiation loss was observed more than 6% during the test.	This loss can be reduced by improving the insulation of furnace. Rock wool insulation should be applied in place of glass wool insulation.

Results and Conclusions of Turbine

S. No.	Result	Conclusion
1	The efficiency of turbine is reduced by leakage air and flue gasses.	Replacement of glass wool insulation by rock wool insulation to increase efficiency of turbine.
2	Its efficiency also depends upon steam generated by boiler.	Reduced or minimized the steam leakage
3	No such changes can be done in case of blade and tip loss.	These can be minimized in the overhauling after every 5 years and replacement of damaged one.
4	O2 contents come to the turbine due to makeup water used in regenerative cycle.	O2 should be minimized by use of dearator. O2contents reduce the life of blade.

Results and Conclusions of Condenser

S. No.	Result	Conclusion
1	Due to dirty tubes and air leakage, the drop in condenser vacuum was of order of 0.025 kg/cm2 and substantial losses were occured.	The condenser should be checked periodically.
2	Drop in condenser vacuum due to incorrect quantity of cooling of water.	Condenser tubes and priming pumps should be checked and repaired periodically.
3	Actual hot well was 330C but designed is 44C. It indicates under cooling of 11.0C.	Excessive water quantity of cooling water being supplied.
4	Due to air leakage, the value of air suction depression was increased from optimum. The optimum value is 30C but the actual value was 170C.	Checking and repairing the tubes periodically.

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