THERMAL POWER PLANT PERFORMANCE COMPARISON AT VARIOUS OUTPUT LOADS USING ADVANCED ENERGY AUDITING

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ABSTRACT

Cost effective designs and low maintenance operation schemes are key requirements for survival in today's industrial establishments. Buildings and industrial factories are characterized by high level of electrical energy consumption. Significant amounts of wasted energy may occur annually because of many reasons, typically in the form of heat loss, loss of cool air via inefficient thermal insulation, and electric power losses due to high impedance connections and low power factor operating equipment. On the other hand, recent world-wide available technologies offer effective ways of efficient energy conservation strategies in industrial facilities, buildings and generating stations. An energy audit is an inspection, survey and analysis of energy flows for energy conservation in a process, building or system to reduce the amount of energy input into the system without negatively affecting the output(s). This paper describes the experiments carried out to validate results obtained by Energy Auditing at Guru Gobind Singh Super Thermal Power Plant, Ropar in unit no. 5 ,which has maximum power generating capacity of 210 MW. The Energy auditing of unit no. 5, is basically covers overall process of data collection and carrying out analysis for evolving specific energy management action. Energy Audit defines the performance of each and every equipment and compared it with the base case.

***Keywords: Energy Audit, Energy Management, Power Plant and Energy Conservation*.**

I INTRODUCTION

Guru Gobind Singh Super Thermal Power Plant is located at Ghanauli near Ropar in Punjab. The power plant is one of the coal based power plants of PSPCL.The plant has an installed capacity of 1260 MW. The first unit was commissioned in September, 1984. During March 1985, the second unit was commissioned and in later years four more units were added. The station received the Incentive award for reducing fuel oil consumption in 1999.The station also received the Shield and excellent performance by Prime Minister of India during 1986-87 for achieving 70.08% PLF against then 53.2%.The plant has its source of water supply from Nangal Hydel Channel. The coal used mainly comes from mines in Bihar, West Bengal and Madhya Pradesh from more than 50 sources called calories.It has 210 MW 3 cylinder mixed flow tandem coupled 3000 rpm BHEL make turbines. It has 247 MVA, 15.75 kV, 9050 A at 0.85 lag, 50 Hz, 3 phase, double star two pole generators. The overall performance for all the 6 units of Plant is shown in Table 1.

Table 1: Overall Year Wise Performance review of Thermal Plant

Year	Generation (MU)	Plant Load Factor (%)	Auxiliary Consumption (%)	Oil Consumption (%)	Coal Consumption (%)
2001-02	8856	80.23	22.72	18.32	0.59
2002-03	8246	74.71	22.05	14.22	0.55
2003-04	8304	76.5	9.91	7.32	0.55
2004-05	9087	82.32	8.57	6.98	0.60
2005-06	9329	84.52	11.67	6.32	0.61
2006-07	9770	88.52	11.14	3.04	0.64
2007-08	9806	88	11.25	3.49	0.68
2008-09	9610	87.07	10.20	3.21	0.96
2009-10	10056	91.11	10.14	2.70	0.62
2010-11	9717	88.04	10.74	0.68	0.37
2011-12	9564	86.41	9.91	2.37	0.46
2012-13	9166	83.05	8.57	1.37	0.47

1.1 Energy Audit

An energy audit is a technique for identifying energy losses, quantifying them, estimating conservation potential, evolving technological options for conservation and evaluating techno economics for the measure suggested[8].

- Assists industries in reducing their energy consumption.
- To promote energy- efficient technology through training programs and workshops.
- To promote transfer of energy- efficient and environment- sound technology to the industrial sectors in the context of climate change.

1.2 Energy Audit Technique

The energy audit evaluates the efficiency of all process equipments/systems that use energy. The energy auditor starts at the utility meters, locating all energy sources coming into a facility. The auditor then identifies energy streams for each fuel, quantifies those energy streams into discrete functions, evaluates the efficiency of each of those functions and identifies energy and cost saving opportunities. The types of Energy Audit are as follows:

a. Walk through Audit
b. Total system Audit
c. Fired Heaters
d. Boilers/Steam Generations Plant
e. Steam System Audit
f. Electrical System Audit
g. Insulation Audit
h. Specific Energy Consumption

i. Hot steam Analysis
j. Cooling systems audit
k. Energy Projects Evaluation

From the above mentioned systems, this research work containing the study of total system Audit and its implementation methodology [9].

1.3 Total System Audit

This approach analysis is the total system by detailed analysis as the total energy data is entered in a master data base file. This contains design data and also the observed data. This approach gives the energy performance of the total system and identifies areas of improvements on energy cost of energy quantity basis. This method requires rigorous data entry and analysis.

II POWER GENERATION AT THERMAL POWER PLANT

Thermal Power Plants basically operates on the Rankine Cycle. Coal is burnt in a boiler, which converts water into steam. The steam is expanded in a turbine, which produce mechanical power driving the alternator coupled to the turbine. The steam after expansion in prime mover (Turbine) is usually condensed in a condenser to be fed into the boiler again. In a practice, however a large number of modifications and improvements have been made so as to effect economy and improve thermal efficiency of the plant [4].

The entire arrangement for the sake of simplicity is divided into four main circuits namely:

1. Fuel and Ash circuit.
2. Air and Fuel gas Circuit.
3. Feed water and steam circuit.
4. Cooling water circuit.

2.1 Problem Formulation

In GGSSTPP, Unit 5th having an maximum output capacity of 210 MW is considered for Energy Audit Process. Energy Audit has been done for evaluation the performance of main unit and sub units like Boiler, Turbine & Generator, Condenser& Heaters and compared it with the performance of units at different output loads[1]. The main problems highlighted in Unit 5th of GGSTPP, Ropar are:

Energy efficiency has to be improved to survive in global market.

- To extend the life of units by 15 to 20 years.
- To restore original rated capacity of units.
- To improve Plant Availability/Load Fator.
- TO enhance operational efficiency and safety.
- To remove ash pollution and meet environmental standards.

2.2 History of Unit under consideration: The unit was commissioned on 29:03:1992, One of the main achievements are listed below:

Unit 5th generated 6063.95MU (PLF of 70.36) during 2014 Which is highest in this year. Specific Coal consumption of Unit 5th remained 0.618 Kg/Kwh during this FY, which is the lowest since its commissioning. Also percentage Aux consumption of unit 5th remained 8.97% during this FY. Earlier Aux Consumption was 9.98 % last year and Monthly Generation is 687 MU with monthly PLF of 75.07%.

2.3 Data Collection

This study includes the energy auditing by collecting data of various units with the help of experimental work performed at various loads i.e 210MW, 190MW & 170 MW. Summarized data for the various parameters at various loads are given below in tables numbered 1,2 &3.Here LP,HP& IP stands for Low, High & Immediate Pressure and same LPT,HPT & IPT are Low, High & Immediate Pressure Turbines.

Table 2: Data for Thermal Power Plant at Output Load of 210MW

Sr No.	Description	Condition	Pressure (Bar)	Temp (°C)	Flow (T/Hr)	Enthalpy (KJ/KG)	Energy (MW)
1	Steam inlet HPT	superheat steam	136	538	783	3432.1	746.447429
2	Steam outlet HPT & inlet re-heater	superheat steam	34.7	345	703	3091.01	603.5815227
3	Steam outlet reheater and inlet IPT	superheat steam	33	533	703	3527.29	688.7739183
4	Steam outlet IPT and inlet LPT	superheat steam	7	330	659	3120.06	571.126983
5	6th extraction HPT and inlet HPH6	superheat steam	32	313	62	3043.48	52.4087256
6	5th extraction IPT and inlet HPH5	superheat steam	17	430	45	3316.99	41.462375
7	3rd extraction IPT and inlet LPH3	superheat steam	0.6	288	25	3051.47	21.18940768
8	2nd extraction LPT and inlet LPH2	superheat steam	-0.25	107	16	2693.07	11.96800308
9	First Extraction LPT inlet LP1	superheat steam	-0.6	96	22	1551.32	9.48011652
10	Exhaust steam outlet LPT	superheat steam	-0.923	44	610	1925.31	326.234153
11	Condensed steam inlet to LPH1	water	10	52	685	1745.2	332.059204
12	LPH1 and inlet LPH2	water	10	70	685	1814.1	345.168807
13	Condensate outlet LPH2 and inlet LPH3	water	9.5	75	685	1845.3	351.105231
14	Condensate outlet LPH3 and inlet dearater	water	8	115	685	1875.3	356.813331
15	Condensate inlet HPH5	water	165	161	740	1784.5	366.803975

16	Condensate outlet HPH5 and inlet HPH6	water	165	210	740	2092.4	430.09282
17	Condensate outlet HPH6 and inlet economizer	water	160	242	740	2579.12	530.138116
18	Coal supply to Boiler	coal			120	0	0
19	Cold water inlet to condenser	water	5	30	35000	1261.97	12269.15376
20	Hot water outlet from condenser	water	4	36	35000	1511.77	14697.76506

Table 3: Data for Thermal Power at Output Load of 190 MW

Sr No.	Description	Condition	Pressure (Bar)	Temp (°C)	Flow (T/Hr)	Enthalpy (KJ/KG)	Energy (MW)
1	Steam inlet HPT	superheat steam	131	533	753	3425.37	716.4709414
2	Steam outlet HPT & inlet re-heater	superheat steam	34	343	665	3090.18	570.8180496
3	Steam outlet reheater and inlet IPT	superheat steam	32	529	665	3520.25	650.26058
4	Steam outlet IPT and inlet LPT	superheat steam	6	325	625	3114.05	509.4897205
5	6th extraction HPT and inlet HPH6	superheat steam	29	303	45	3004.99	37.562375
6	5th extraction IPT and inlet HPH5	superheat steam	15	415	30	3288.82	27.3958706
7	3rd extraction IPT and inlet LPH3	superheat steam	0.5	279	21	3033.76	17.595808
8	2nd extraction LPT and inlet LPH2	superheat steam	-0.24	105	15	2053.1	8.5532146
9	First Extraction LPT inlet LP1	superheat steam	-0.56	89	19	1532.12	8.08499724
10	Exhaust steam outlet LPT	superheat steam	-0.81	42	575	1752.4	279.8968328
11	Condensed steam inlet to LPH1	water	9.5	48	635	1726.1	304.4633268
12	LPH1 and inlet LPH2	water	9.5	65	635	1744.9	307.7794212
13	Condensate outlet LPH2 and inlet LPH3	water	9	74	635	1826.42	325.811411
14	Condensate outlet LPH3 and inlet dearater	water	7.8	110	635	1845.23	329.1668892
15	Condensate inlet HPH5	water	161	141	675	1811.6	339.675
16	Condensate outlet HPH5 and inlet HPH6	water	165	190	675	1952.6	366.1125
17	Condensate outlet HPH6 and inlet economizer	water	160	226	675	2754.3	516.43125
18	Coal supply to Boiler	coal			110	0	0
19	Cold water inlet to	water	4	30	30000	1261.06	10508.84174

	condenser						
20	Hot water outlet from condenser	water	3	35	30000	1469.09	12242.42646

Table 4: Data for Thermal Power at Output Load of 170 MW

Sr No.	Description	Condition	Pressure (Bar)	Temp (ºC)	Flow (T/Hr)	Enthalpy (KJ/KG)	Energy (MW)
1	Steam inlet HPT	superheat steam	129	513	721	3373.94	675.6989638
2	Steam outlet HPT & inlet re-heater	superheat steam	32	340	640	3087.66	548.8933182
3	Steam outlet reheater and inlet IPT	superheat steam	30	525	640	3513.26	624.5522302
4	Steam outlet IPT and inlet LPT	superheat steam	5	323	615	3112.13	531.6451679
5	6th extraction HPT and inlet HPH6	superheat steam	26	300	44	3006.62	36.7408964
6	5th extraction IPT and inlet HPH5	superheat steam	13	411	28	3288.82	25.5541314
7	3rd extraction IPT and inlet LPH3	superheat steam	0.4	275	20	2836.73	15.7438515
8	2nd extraction LPT and inlet LPH2	superheat steam	-0.22	104	14	1955.94	7.5890472
9	First Extraction LPT inlet LP1	superheat steam	-0.55	85	17	1512.33	7.1381976
10	Exhaust steam outlet LPT	superheat steam	-0.79	38	572	1710.24	271.7229312
11	Condensed steam inlet to LPH1	water	9	45	631	1699.52	297.8748704
12	LPH1 and inlet LPH2	water	9	62	631	1722.87	301.9674249
13	Condensate outlet LPH2 and inlet LPH3	water	8	67	631	1756.3	307.826701
14	Condensate outlet LPH3 and inlet dearater	water	7.6	105	631	1824.3	319.745061
15	Condensate inlet HPH5	water	159	139	665	1817.6	335.747072
16	Condensate outlet HPH5 and inlet HPH6	water	163	186	665	1856.3	342.895736
17	Condensate outlet HPH6 and inlet economizer	water	158	223	665	2715.3	501.570216
18	Coal supply to Boiler	coal			90	0	0
19	Cold water inlet to condenser	water	3	28	30000	1176.55	980.4591177
20	Hot water outlet from condenser	water	3	32	30000	1343.73	1119.775896

Note: Energy is calculated using tables 2, 3 & 4 by formula, **Energy= Flow (Kg/Sec)*Enthalpy (KJ/Kg)/1000**.

III DATA ANALYSIS

In this step, the data collected by experimental work at various units is analyzed for calculation of efficiency, effectiveness etc, calculations for the load of 210 MW are as below [3]:

Step1: Boiler Section

Inlet toBoiler

Coal Inlet =120T/hr =120 x 1000/3600 =33.33Kg/Sec...... ....(I)

Calorific Value of Coal= 4000Kg/Sec

Therefore, Energy=4000 x 33.33 x4.2/1000=559.944 MW

Reheated Steam Inlet Energy=603.581 MW... (II)

Inlet from Economizer Steam Energy=496.11 MW.. (III)

Total Inlet = I +II +III = 559.944 + 603.581+ 530.13=1693.655 MW

Outlet from Boiler

-Steam Inlet HPT Energy=746.447 MW.. (IV)

Steam Outlet From Reheated Energy=688.773 MW.. (V)

Flue gases = Generally not taken into consideration.. (VI)

Total Outlet = IV + V + VI= 746.447 + 688.773 =1435.22 MW

Loss in Boiler=1646.859- 1435.22 MW =211.639 MW

Efficiency of Boiler=1435.22x100/1693.655=84.74%

Step 2: Turbine & Generator Section

HPT Inlet= 746.44 MW... (VII)

HPT Outlet +Extraction HPT = 603.581 + 52.408 = 655.98 MW................................... (VIII)

Net Energy at HPT= VII – VIII= 746.44-655.989=90.451 MW

IPT Inlet =688.77 MW ....(IX)

IPT Outlet +Extraction IPT = 571.126+41.462=612.58 MW... (X)

Net Energy at IPT= IX-X=688.77-612.588=716.18MW

LPT Inlet=571.12 MW... (XI)

LPT Outlet + Extraction LPT + Inlet LPH= 19.78+11.96+15.57=47.31 MW.................. (XII)

LPT Inlet =571.12 MW ....(XIII)

LPT Outlet + Extraction LPT + Inlet LPH =19.78+11.96+15.57=47.31MW.................. (XIV)

Net Energy at LPT= XI-XII=571.126-47.31=523.816MW

Net Input at Turbine (HPT, IPT& LPT) =90.451+76.182+523.816=690.449MW

Efficiency of Turbo Generator=210x100/690.449=30.41%

Step 3: Condenser Efficiency

Condenser Efficiency = Actual Cooling water Temp rise/Max. Possible Temp rise

=Water Outlet Temp-Water Temp at Inlet to Condenser/ Exhaust Steam Temp- Water Temp at Inlet to Condenser x 100=(36-30)/(44-30)=6/14=42.85%

Step 4: Heaters Section(LP & HP)

LPH1 Effectiveness = $\frac{T[12]-T[11]}{T[09]-T[11]}$ =70-52/96-52 =18/44=0.409

LPH2 Effectiveness = $\frac{T[13]-T[12]}{T[08]-T[12]}$ = 75-70/107-70=5/37=0.135

LPH3 Effectiveness = $\frac{T[14]-T[13]}{T[07]-T[13]}$ = 115-75/288-75 = 40/213 =0.187

HPH5 Effectiveness = $\frac{T[16]-T[15]}{T[6]-T[15]}$ = 210-161/430-161 =49/269 =0.182

HPH6 Effectiveness = $\frac{T[17]-T[16]}{T[05]-T[16]}$ = 242-210/313-210=0.3106

Overall Unit Efficiency = Output of Station x 100 = Energy sent out (KW)

Fuel burnt (kg) x Calorific Value of fuel (K Cal/ Kg) =210x100/559.94=37.504%

Similary, for the Plant at running loads of 190MW & 170 MW data is analyzed as above and values are shown below in Table 5 :

Table 5: Analyzed data for plant at output loads of 190 MW and 170 MW

	Description	**At 190MW**	**At 170 MW**
Boiler Section	Inlet in Boiler	1619.229	1511.293
	Outlet from Boiler	1366.7309	1300.242
	Loss in Boiler	252.49	211.051
	Efficiency of Boiler	84.40%	83.279%
Section Turbine & Generator Section	Net Energy at HPT	108.0906	90.0651
	Net Energy at IPT	113.375	67.3532
	Net Energy at LPT	483.76877	501.175
	Net input at Turbine	705.2336	658.59
Section Condenser	Condenser Efficiency	41.66%	40%
Section Heaters (LP&HP)	LPH1 Effectiveness	0.4146	0.42
	LPH2 Effectiveness	0.125	0.11
	LPH3 Effectiveness	0.175	0.162
	HPH5 Effectiveness	0.1788	0.1727
	HPH6 Effectiveness	0.3185	0.324
Overall Station Efficiency		35.715%	33.177%

The table no. 6 shows the summarized data for different parameters at different loads calculated step by step.

Table 6: Summarized form of data collected

S No.	**Description**	**210MW**	**190 MW**	**170MW**
1	Boiler Efficiency	84.74%	84.40%	83.28%
2	Turbine & Generator Efficiency	30.41	26.94	25.812
3	Condenser Efficiency	42.85	41.66	40

4	Heater LPH1 Effectiveness	0.409	0.4146	0.425
5	Heater LPH2 Effectiveness	0.13	0.125	0.11
6	Heater LPH3 Effectiveness	0.187	0.175	0.1625
7	Heater HPH5 Effectiveness	0.182	0.1788	0.1727
8	Heater HPH6 Effectiveness	0.3106	0.3185	0.324
9	Overall Plant Efficiency	37.504	35.715	33.177
10	Coal Consumption	120	110	90

Now from this summarized table it becomes very easier to make the comparison between various Parameters. Various curves showing the comparison are as below:

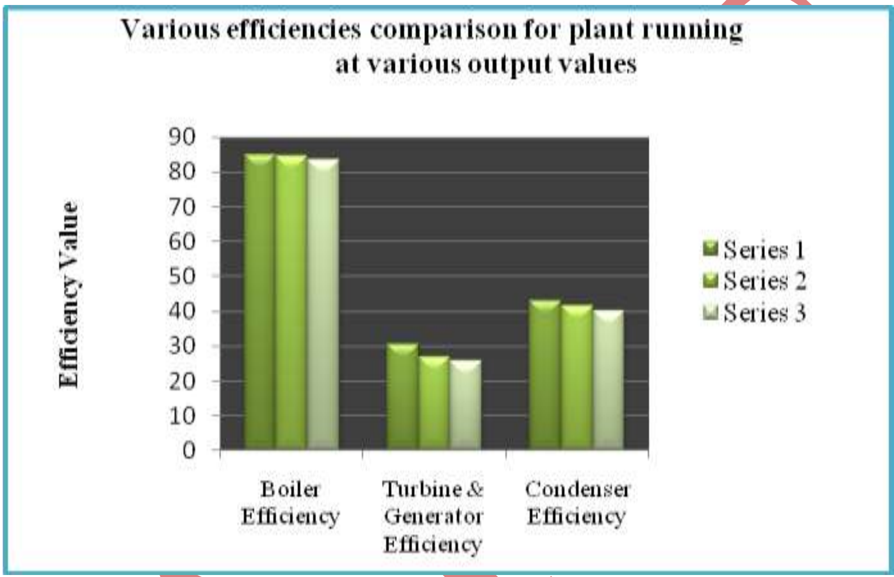

Figure1.Parato analysis for various efficiencies for plant running at various output values

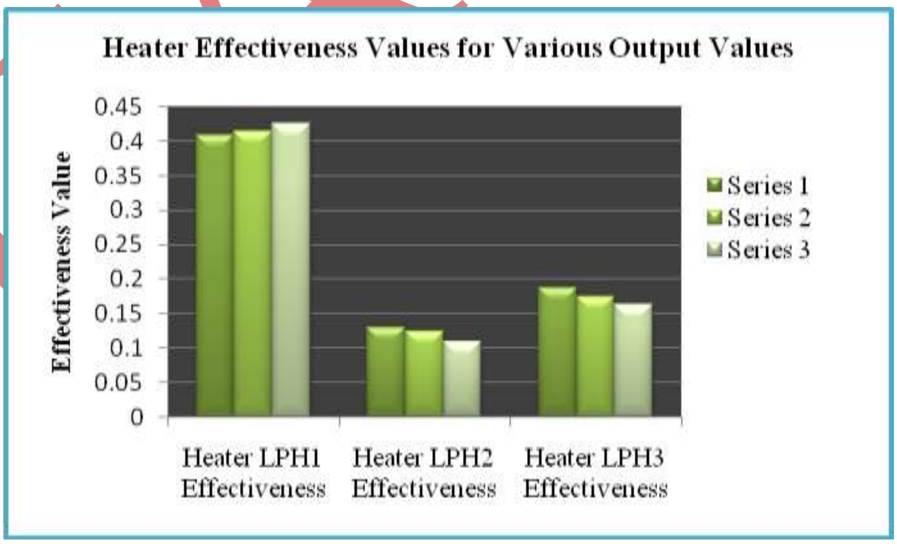

Figure 2. Parato Analysis for Heater Effectiveness values

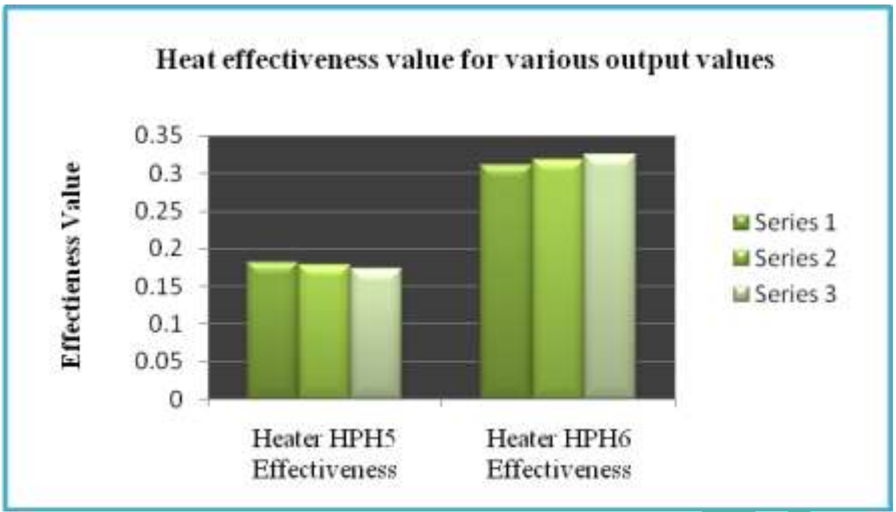

Figure3:Parato Analysis for Heaters Effectiveness values

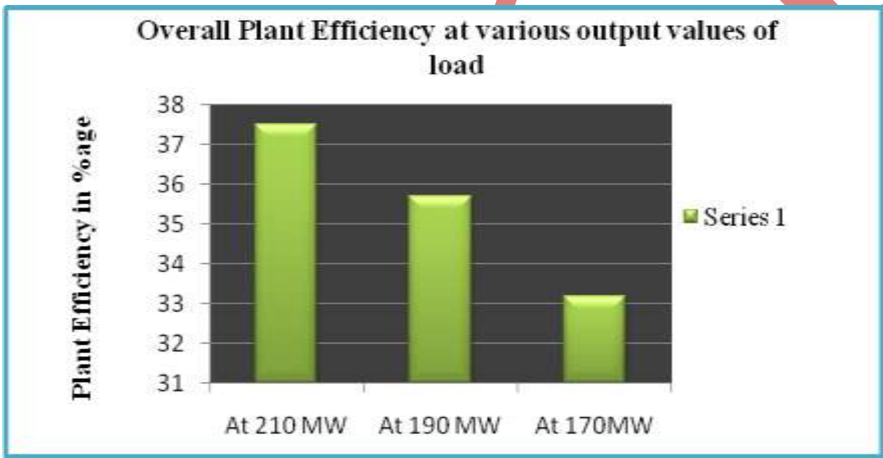

Figure4: Parato Analysis for overall plant efficiency of power plant at various output loads

IV RESULTS AND RECOMMENDATIONS

From the Analysis part of work, it is concluded that the overall plant efficiency varies with the variation or small change in the output loads. From the experimental work done in above steps shows that as the output load is lower then the efficiency of the total unit is low. Output load of the plant always depends upon the requirements for consumption of energy. As the energy consumption Decreases, Plant has to be staring to run at lower load and the overall performance is also lower, because energy cannot be stored . On the other hand if the plant or unit can run at full output load or 250 MW load the performance is higher. Some of the recommendations based on this research work are made for increasing the performance of the plant is shown in table 7.

Table 7 Recommendations for increasing Plant Efficiency

	Description	Recommendation
		• By increasing the oxygen content of the coal , result in reduced level of heating value.

Boiler Section	Boiler Efficiency can be increased to 90 to 95 %	• Boiler efficiency is attributed to dry flue gas , wet gas &sensible heat loss so that by reducing the flue gas exhaust temperature. • Periodic maintenance of Boiler like: Periodic cleaning of boiler Proper water treatment Steam Generation pressure and temperature Excess air control Percentage loading of boiler Boiler Insulation Quality of fuel
Turbine & Generator Section	There are recoverable energy losses that result from the mechanical design or physical condition of the steam turbine. For example, steam turbine manufacturers have improved the design of turbine blades and steam seals which can increase both efficiency and output	Combustion to improve fuel utilization and minimize environmental impact. Heat transfer and aerodynamics to improve turbine blade life and performance. Materials to permit longer life and higher operating temperatures for more efficient systems.
Condenser Section	Low condenser vaccum Due to : Air ingress in the condenser. Dirty Tubes. Inadequate flow of Condensate water in condenser.	Cooling water flow must be checked for correct quality. Condenser tubes must be cleaned regularly. Vaccum drop must be cleaned regularly. Air ingress must be arrested. Improvement in quality of cooling water and close cycle.
Overall Plant Efficiency	Overall Plant Efficiency can be increased	By using wash coal, which will save the energy from waste with ash.

V CONCLUSION

Energy Audit studies aim at determining the present level of performance of main power plant equipment and selected sub-systems and comparing them with design parameters. Reasons for deterioration are analysed. For the same, in this study different parameters at various loads shown in table no 2, 3 & 4 are studied and respective curves are being drawn to analyse the differences as shown in figure no 1, 2, 3 & 4 with the help of summarized form of data shown in table no.6.From this it is concluded that output load always depends upon the requirements for consumption of energy. As energy consumption decreases, plant has to run at lower load and overall performance is also lower because cannot be stored. In fact the objective is to reduce the consumption of various inputs (coal, oil, power, water) per unit of power generation and to increase the overall plant efficiency and how this can be attained is studied in this whole study which needs some consideration towards the points shown in table no 7.

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