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Energy Management Approach To Improve Performance Of Thermal Power Plant

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Abstract:- Various thermal power plants have implemented the techniques/ approaches available for energy management to improve energy efficiency of equipments in the thermal power plant. There are critical energy management factors which are suitable to improve the performance indicators are considered in this research paper. This paper focuses on energy management practices followed in thermal power plant to identify the areas for improvement of energy efficiency of the plant. With implementation of periodic energy audits, energy conservation measures, process optimization and diagnostic studies, energy consumption can be reduced substantially in the plant for cost competitiveness and increase in profitability.

Keywords:- Energy management factors, Performance indicators and Energy audit

I. INTRODUCTION

At present the installed power generation capacity is 175000 MW in India. Based on the availability of fuel in India 70% of the power generation is based on pulverized coal firing. The thermal power plant also requires oil and electricity for its running continuously to generate power. As a thumb rule the thermal power plant consumes 10% of the electricity produced as auxiliary power to run various equipments. Today India is facing acute shortage of fuel supply. Therefore it is essential to run the plant efficiently to reduce energy consumption. Energy management is the solution to improve the plant performance parameters to save energy [1]. In order to monitor the energy consumption in the plant it is essential to carry out regular energy audit of the plant. This paper will be beneficial to the thermal power plant managers and engineers to verify implementation of energy management factors and its effect on performance indicators for the financial benefit of the organizations.

To meet the growing demand for energy in power industries, one of the aims is to identify the technical support in improving their energy performance through comprehensive energy audits, implementation assistance, technology audits, and capacity building. Energy audits help in identifying energy conservation opportunities in all the energy consuming areas. While these do not provide the final answer to the problem, but do help to identify the existing potential for energy efficiency, and induces the organizations/individuals to concentrate their efforts in this area in a focused manner.

II. DATA COLLECTION FOR ENERGY MANAGEMENT IN THERMAL POWER PLANT

A typical thermal power plant is having installed capacity of 4 x 210 MW and 1x 500 MW. The present total installed capacity of the thermal power plant is 1340 MW. The primary sources of energy for power generation are coal, furnace oil (FO) & light diesel oil (LDO). The basic fuel is coal (99.545%) for generating power. The data was collected to carry out the detailed energy consumption in thermal power plant to implement energy management aspects to improve the performance of the plant.

III. PROCESS DESCRIPTION OF THERMAL POWER PLANT

A typical thermal power plant is having a pulverized coal fired boiler with BHEL make turbo generator. In a thermal power plant the raw coal is crushed and pulverized in the mills to the size of 200 mesh. The primary air supply dries and transports the coal into the boiler furnace. The coal burns in the furnace to generate superheated steam which drives a turbine connected to an alternator to generate electricity. After steam passes through the turbine, the steam is condensed in a condenser and again resends back to the boiler with the help of pumps for steam production. The process of power generation is shown in figure1.

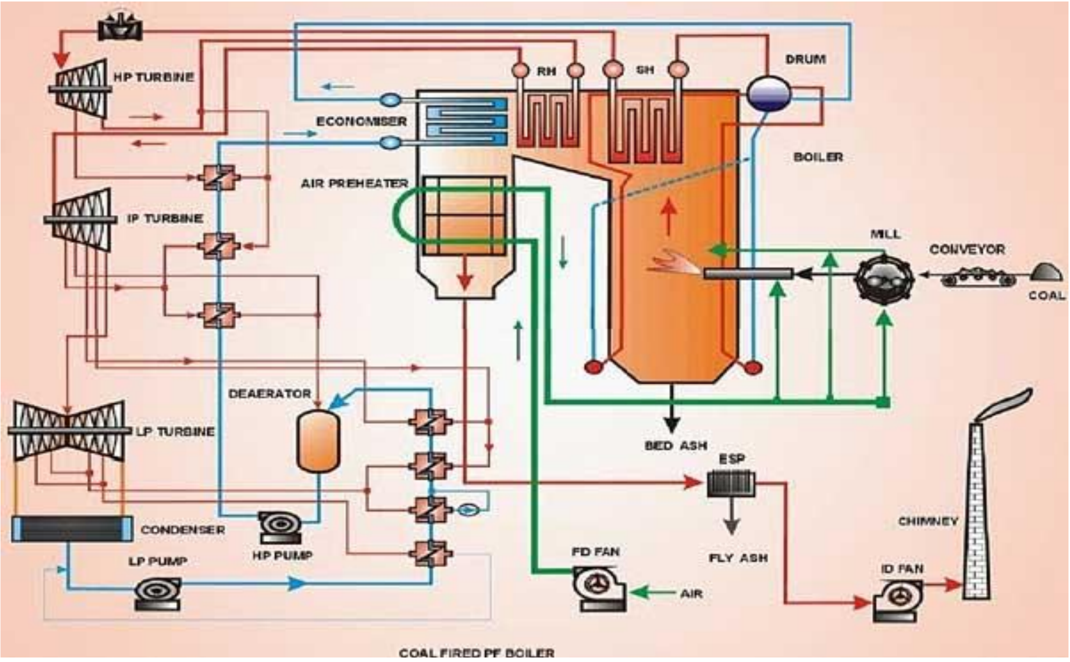

Figure1: Flow diagram of thermal power plant

IV. FLOW CHART FOR ENERGY MANAGEMENT SYSTEM

The flow chart for carrying energy management improvement plan is shown in the figure 2.

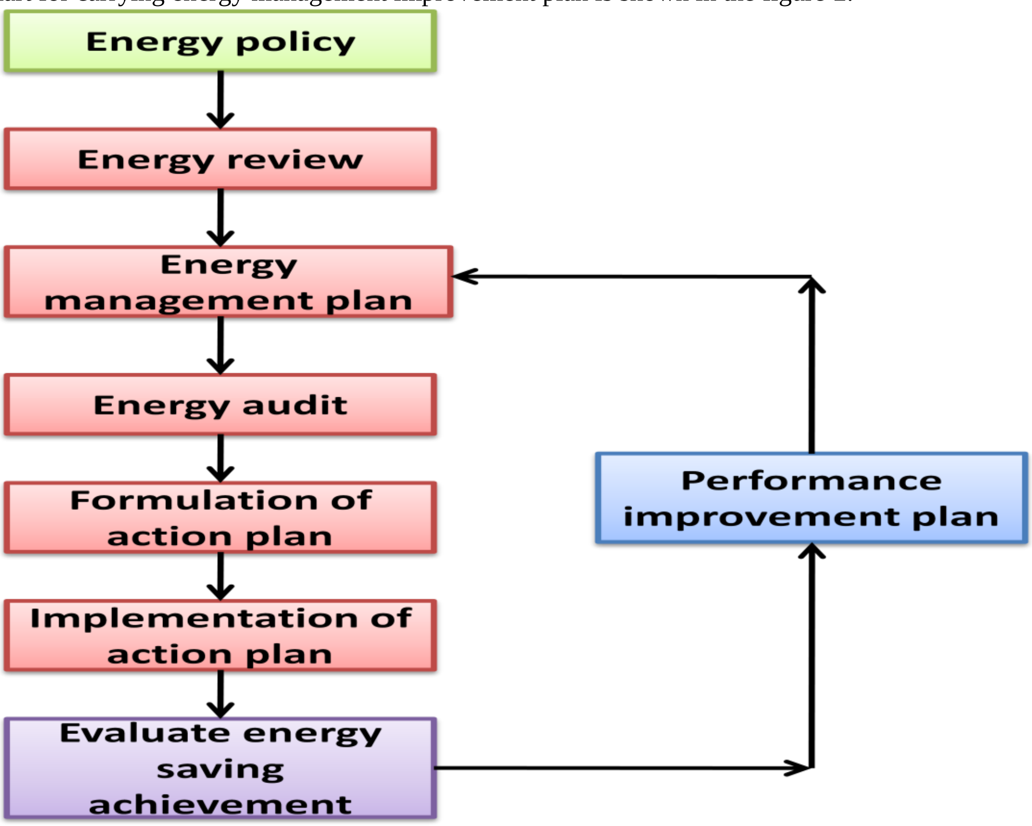

Figure2: Flow chart for energy management system

V. GAP ANALYSIS STUDY AND ENERGY REVIEW

The performance parameters of the plant based on design and operating values have been studied. It was observed that there is a gap between the design values and operating values of performance indicators. The following are the observations shown in table 1.

Table 1: Gap between design and operating performance parameters

Sr. No.	Performance indicator	Design performance indicators	Operating performance indicators
1	Boiler efficiency % (output factor plant auxiliaries' efficiency)	87.0	84.3
2	Plant Heat Rate Kcal/KWh (output factor fuel energy consumption)	2277.3	2589.9
3	Turbine Heat rate Kcal/ KWh (output factor fuel energy consumption)	1989.8	2167.8
4	Specific coal consumption Kg/ KWh (output factor fuel energy consumption)	0.581	0.67
5	Auxiliary power consumption % (output factor plant auxiliaries' efficiency)	9.1	9.8

As per the table 1 the input factors planning and operating procedures, energy policy and objectives and the third is maintenance management which are most influencing on the performance indicators under study. These energy management factors have positive impact on improvement of plant performance, fuel energy consumption and plant auxiliaries' efficiency. The energy consumption sources namely coal, light diesel oil (LDO) and furnace oil (FO) for the power plant for energy management study has been found from the previous data available for the years from 2010-11 with energy management cell and it is shown in the table 2.

Table 2: Yearly Source wise consumption history of thermal power plant

Description	Units	2010-11	2011-12	2012-13	2013-14	2014-15 (up to Jan)
Coal	MT	4966780	4765420	4740820	4188601	3636497
LDO	kL	856	660	937	2159	539
FO	kL	8367	15268	31271	32818	4509
Coal Calorific Value	kCal/kg	3045	3195	2896	2794	2967
LDO Calorific Value	kCal/kg	10612	10668	10619	10537	10409
FO Calorific Value	kCal/kg	10122	10166	10206	10076	10056
Energy Input by Coal	TOE (Tonnes of oil Equivalent)	1512385	1522552	1372941	1170295	1078949
Energy Input by FO	TOE (Tonnes of oil Equivalent)	781	605	855	1956	482
Energy Input by LDO	TOE (Tonnes of oil Equivalent)	7791	14279	29361	30422	4171
Total Energy Input	TOE (Tonnes of oil Equivalent)	1520957	1537437	1403159	1202674	1083603
Net Energy Generated	MUS	5715.839	5903.237	5381.168	4576.608	4169.991
Average Energy Input by Coal (TOE)						**1331424**
Average Energy Input by FO (TOE)						**936**
Average Energy Input by LDO (TOE)						**17205**

Five years energy consumption data is used for calculating the average energy consumption of various sources. The details of the analysis is seen from the figure 3 coal is the main source of energy which contributes to around 98.67%, while LDO contributes around 1.2% and the rest is FO consumption. The monthly coal consumption and yearly LDO and FO consumption is in the figures 3, 4 and 5 respectively.

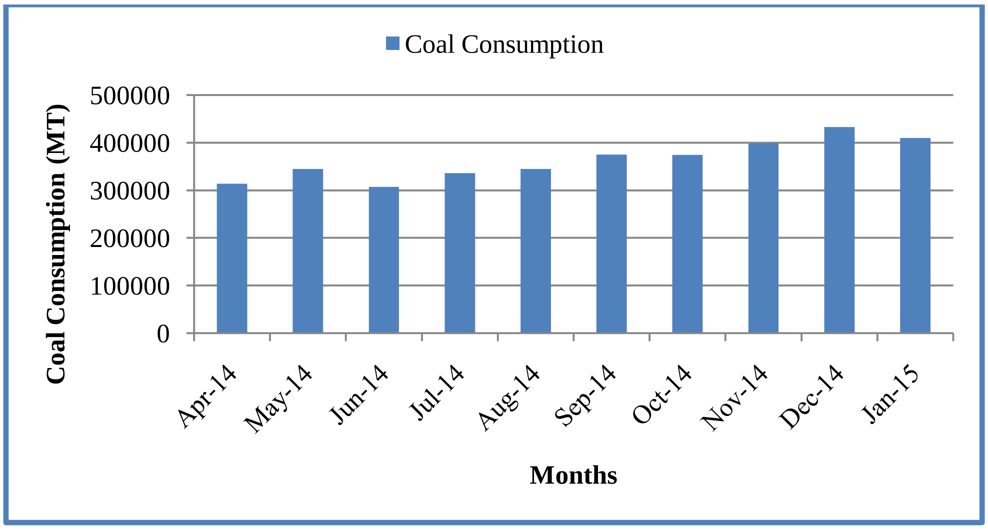

Fig 3: Monthly coal consumption of power plant for year 2014-15

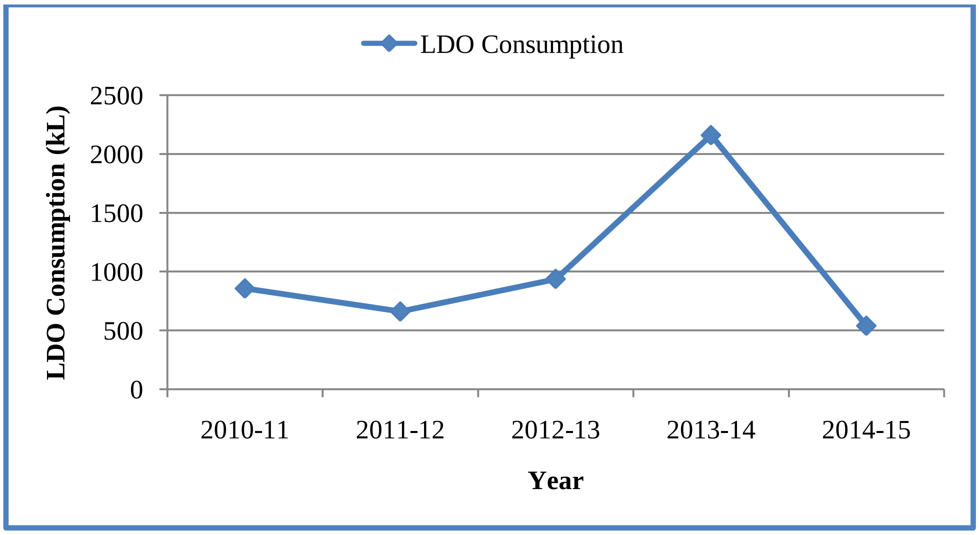

Figure 4: Yearly data for light diesel oil consumption

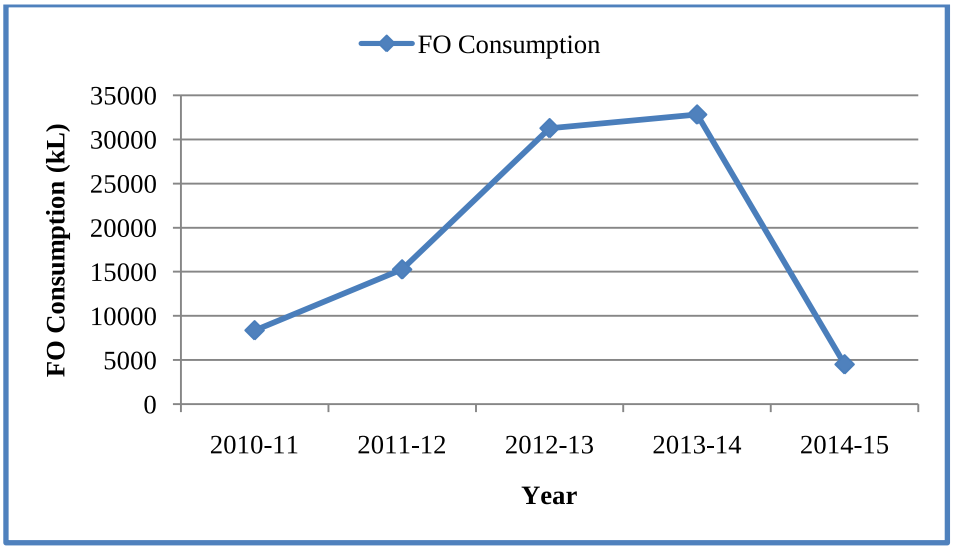

Figure 5: Yearly data for furnace oil consumption

VI. ENERGY POLICY

The following is the energy policy declared by the top management to achieve the targets and objectives as shown below.

The thermal power plant is committed to...

- Continually improve its annual generation within the installed capacity through cost effective measures.
- Continually reduce energy resource consumption (Fuels & Power) to generate one unit of electricity through cost effective measures.
- Establish a regular analytical process to identify major areas of generation loss and excessive power & fuel consumption.
- Cultivate a culture of studying and promoting use of latest & cost effective trends and technologies.
- Create greater and greater energy conservation awareness amongst employees by conducting regular training programs, workshops, visits to other power stations.
- Set measurable and time bound objectives & establish & implement their action plans based on energy policy.

Sd/-
Chief General Manger

VII. OBJECTIVES OF ENERGY MANAGEMENT

The thermal power plant has set the following objectives of energy management to be fulfilled.

- Plant performance (availability factor) $\geq 73\%$
- Plant performance (plant load factor) $\geq 73\%$
- Fuel energy consumption (specific oil consumption) ≤ 4 ml/KWH
- Electrical energy consumption (auxiliary power consumption) $\leq 10.3\%$
- Fuel energy consumption (gross plant heat rate) ≤ 2612 Kcal/ KWH

VIII. FORMATION OF ENERGY MANAGEMENT TEAM

The purpose of energy management team is to find out the potential areas of performance improvement, to operate the power plant at highest energy efficiency & optimum cost and to create awareness about energy efficiency amongst all the operation and maintenance staff. Energy management cell achieves objective of "highest energy efficiency and at optimum cost "through following steps [2].

- Regular internal energy audits
- Documentation for energy management activity
- Regular energy audits through accredited energy audit firms
- Regular filling of energy returns to state level designated agency
- Enhancement of employees' knowledge through internal training programmes
- Energy conservation projects – Identification, Evaluation & Implementation
- Application of energy efficiency techniques in the entire gamut of activities of including purchase, training, operation & maintenance, inspection & testing etc.
- Establishing the efficiency test procedures & schedules for all equipments & systems
- Appointment of certified energy auditors and managers

The energy auditors and managers are to be employed in energy management team who are certified by Bureau of Energy Efficiency (BEE) and passed the examination conducted by BEE. They should have experience in carrying out energy audit of thermal power plant.

The typical energy management team for the plant is shown in the figure 6.

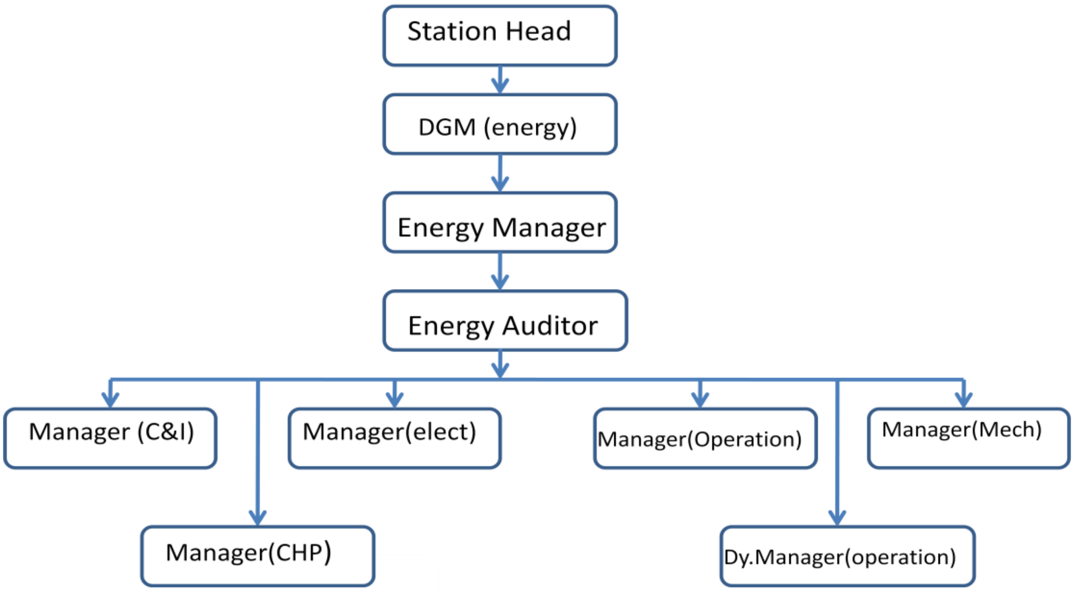

Figure 6: Energy management team

IX. ACTION PLAN FOR ENERGY MANAGEMENT

The performance testing exercise intends to measure the boiler efficiency & turbine output / plant heat rate along with measurements of other critical parameters of boiler & turbine, measurement of auxiliary power consumption of various critical auxiliaries of main plant and balance of plant to establish the current values and deviations with respect to design values. Areas contributing to the loss of efficiency are capacity short fall; heat rate deterioration and higher auxiliary power consumption have been identified from the performance data collected during test, calculations and analysis. The aim of the action plan is to verify the relationship between the energy management factors and performance factors extracted from the data analysis in this study paper. Keeping in view the gap identified between the design and operating parameters, the action plan is suggested in this study [2].

The factor planning and operating procedures involve proper scheduling of various operations to reduce start up time of the plant so as to bring the machine on bar quickly, running of various plant auxiliaries on full load for efficient performance, standard operating procedures and written work instructions are practiced and documented and regular monitoring of energy consuming auxiliaries is carried so as to find out energy consumption pattern.

The action plan for energy audit for the thermal power plant involves data collection of energy consumption of various auxiliaries, in-depth analysis of equipments for performance for energy saving, potential areas of energy improvement, team of energy auditors and managers is formed and external energy audit is also carried out at-least once in a year.

The action plan for energy policy and objectives involve develop a policy for more efficient use of energy, energy policy is prepared and communicated to all the employees, fix targets and objectives to meet the energy policy and review how well the energy policy works, and continually improve energy management.

The action plan to achieve the performance improvement for the input factor; technological innovations involve uses of the computer based performance package to monitor performance of the power plant, use of energy efficient equipments is made in the plant, Heat recovery technology is adopted wherever necessary/required, Use of energy efficient lighting in the plant to save electricity, Number of suggestions come from the staff to improve the performance related to energy management are then implemented and regular reviews and improvements are made to acquire changes in the technology or to adopt modern technology in the plant for energy saving [3].

The action plan for input factor of team work and proactive role of management include involvement of the management of the organization towards the strategy adopted for performance improvement, a team approach such as cross functional teams, group discussions in problem solving and continuous improvements adopted for energy management, all department heads of the plant accept their responsibility for performance improvement through energy management, management have a practice of initiating corrective/preventive actions every month for energy saving, system for awarding employees for adopting good energy management practices and energy management manual is prepared and circulated to all the employees [4].

The action plan to fulfill the requirement of maintenance management are based on equipment performance analysis, the maintenance programs developed for energy saving based on equipment performance, mostly reputed suppliers which have been certified to supply standard material for energy saving are identified, equipment supplier is informed regarding poor performance of equipments and maintenance planning of various equipments. The action plan for maintenance management is essential to keep the plant equipments energy efficient so as to maximize the performance.

X. DATA COLLECTION AND ANALYSIS

The past and present data for fuel (thermal) energy consumption namely coal and oil was analyzed. Monthly data was collected for coal and oil consumption, the data was collected for 36 months from the year 2010-11 to 2014-15 up to January 2015. The data was also collected for gross heat rate, boiler efficiency, turbine efficiency and auxiliary power consumption. The data was collected in the format as shown in table 3, 4, 5, 6, 7 and 8 below.

Table 3: Design and actual plant parameters

Sl No.	Description	Unit	Design (A)	Operating (As Fired Coal) (B)	Deviation (A-B)/A in %
1	Load	MW	210	206.4	-3.048
2	Gross Heat Rate	kcal/kwh	2277.3	2589.9	-12.345
3	Turbine Heat Rate	kcal/kwh	1989.8	2167.8	-8.946
4	Boiler Efficiency	%	87.3	83.7	3.013
5	GCV	kcal/kg	4000	3886	2.850
6	Specific Coal Consumption	kg/kWh	0.581	0.67	-15.318
7	Secondary Fuel Oil Consumption	milliliter/kWh	0	0	Nil
	Main Steam Parameters				
8	Flow	t/h	634	664	30
9	Temp.	°C	535	543.2	-1.533
10	Pressure	kg/cm^2	150	141.3	5.800
11	Condenser	Ksc	0.12	0.162	-35.000
12	Feed water flow	t/h	627	627	Nil
	Turbine Cylinder Efficiency				
13	HPT	%	89.24	86.21	3.395
14	IPT	%	91.48	92.31	-0.907
15	LPT	%	88.6	78.65	11.230
	Flue gas / Air temperature				
16	Flue gas temperature at I/L	°C	339	326	3.835
17	Flue gas temperature at O/L	°C	152	139.4	8.289
18	Air temperature at I/L	°C	29	35	-20.690
	Other important features				
19	Super Heater spray	t/h	0	0	Nil
20	Reheater spray	t/h	0	1.4	-1.4
21	Make up water	%	3	3	0.000
21	Furnace Draft	mmwc	-5	-2	-3
23	ID Fan margin	%	30	13.3	55.667
24	Type of Mill		Bowl	Bowl	
25	No of mill in operation	No	2	2	0.000
26	No of auto loop in operation	--	---	*Without CMC	---
27	Cost of fuel	Rs/t	---	4200	---
28	PLF (Avg. of last 12 months)	%	100	100	0.000
29	CW inlet temperature	°C	36	31	13.889
30	CW outlet temperature	°C	44.2	40.5	8.371
31	Auxiliary consumption	%	9.1	9.8	0.7
32	Type of Cooling Tower	--		Induced draft	

Table 4: Overall performance of the unit

	Load	TG Heat Rate	Unit Heat Rate	Unit Efficiency (Gross)	Boiler Efficiency	Coal Flow	Oil Flow
Units	**MW**	**Kcal/kwh**	**Kcal/kwh**	**%**	**%**	**t/h**	**Lit**
Design, 100%	210	1989.8	2277.3	36.69	87.3	122.1	-
80%	168	2050.2	2340.1	36.63	87.6	97.8	-
60%	126	2097.4	2388.2	35.89	87.8	74.6	-

Table 5: Overall performance of the unit on 206.4 MW load

	Load	TG Heat Rate	Unit Heat Rate	Unit Efficiency (Gross)	Boiler Efficiency	Coal Flow	Oil Flow
Units	**MW**	**Kcal/kwh**	**Kcal/kwh**	**%**	**%**	**t/h**	**Lit**
Actual	206.4	2168.7	2591.0	32.71	83.7	137.8	-

Table 6: Overall performance deviation of the unit

	Load	TG Heat Rate	Unit Heat Rate	Unit Efficiency (Gross)	Boiler Efficiency	Coal Flow	Oil Flow
Units	**MW**	**Kcal/kwh**	**Kcal/kwh**	**%**	**%**	**t/h**	**Lit**
Design (A)	210	1989.8	2277.3	36.69	86.3	122.1	-
Actual (B)	206.4	2168.7	2591.0	32.71	83.7	137.8	-
Deviation (A-B)/A in %	1.714	-8.991	-12.393	10.848	3.013	-12.858	-

Table 7: Proximate coal analysis

Parameters	Unit	Design	Actual
Fixed carbon	%	38.96	35.06
Volatile Matter	%	14.8	19.88
Moisture	%	10	8.49
Ash	%	45	36.57
GCV	Kcal/kg	4000	3886

Table 8: Heat Rate deviation, controllable parameters

Parameters	Unit	Reference	Actual	Deviation	HR Deviation
Main Steam Temp	^oC	535	543.2	-8.2	-5.25
Main Steam Press	Kg/cm^2	150	141.3	8.7	0.74
Condenser Press	Kg/cm^2	0.12	0.162	-0.042	62.12
RH Temp	^oC	535	540.7	-5.7	-3.36
SH Spray	t/h	0	0	0	0.00
RH Spray	t/h	0	1.4	-1.4	0.34
Makeup	%	3	3	0	0.00
Excess Air	%	28.619	9.995	18.624	-138.00
Exit Gas Temp	^oC	143	139.4	3.6	-4.32
UBC	%	9.5	14.88	-5.38	15.92
Coal Moisture	%	10	8.49	1.51	-3.02
HPT Efficiency	%	89.28	86.21	3.07	14.55
IPT Efficiency	%	90.56	92.31	-1.75	-6.41

-ve sign indicated gain in Kcal and +ve sign is loss in Kcal

XI. ENERGY AUDIT ANALYSIS

Based on the site walk down survey, analysis of information / data collected during various tests and computation of results from these data and from the review of documents made available, major observations are recorded here as under:-

- The audit on unit along with their auxiliaries and common equipment in balance of plant was conducted.
- Boiler and Turbine performance test at maximum continuous rating (MCR) was carried out.
- Boiler test was carried out with 5 mills against the design of four as station didn't agree for four mill operation due to operational constraints and coal quality.
- The overall plant housekeeping was poor.
- Boiler efficiency has been evaluated at maximum continuous rating.

The action plan for energy audit is as follows [5] [6]

- Defining scope of energy audit, e.g. walk through audit is suitable for organization with limited resource and detailed audit is suitable for organization with more resources.
- Forming an energy audit team.
- The team shall include management representatives, maintenance staff and energy auditors and managers.
- Estimate time frame & budget, e.g. auditor-hours and the cost of measuring instruments etc.
- Conducting site inspection & measurement to identify means for improvement.
- Analyzing data collected.
- Recommending the improvement actions and measures.

The results of energy audit are detailed as below

XI. 1. Boiler efficiency

The boiler efficiency calculations are as per table 9.

Table 9: Boiler efficiency calculations

Sr. no.	Parameter	Design efficiency%	PG test efficiency%	Efficiency as tested in energy audit	Deviation w r t PG test value %
1	Boiler efficiency	87.28	87.88	86.02	1.86

There has been a deviation of about 1.86% in boiler efficiency with respect to performance guarantee Test (as tested & without correction) efficiency [7]. The unit was commissioned in year 2001. Considering the age of the unit, the deviation observed in boiler efficiency is on higher side. The deviation in boiler efficiency however can be partially recovered by implementing short term measures and implementation of better operation and maintenance (O&M) practices.

XI.2 Turbine heat rate calculations

The turbine cycle heat rate evaluated from test data at 100%, maximum continuous rating condition. The results are shown in table 10 and 11.

Table 10: Turbine performance (heat rate)

Sr. no.	Parameter	Tested heat rate Kcal/KWh	Corrected Heat rate Kcal/KWh	PG test Heat Rate Kcal/KWh	Shortfall Kcal/KWh
1	Heat Rate	2088.03	2023.29	1976.37	46.9

Table 11: Turbine performance (efficiency)

	Load	Efficiency			Shaft Power		
		HPT	**IPT**	**LPT**	**HPT**	**IPT**	**LPT**
Units	**MW**	**%**	**%**	**%**	**MW**	**MW**	**MW**
Design (A)	210	89.28	90.56	89.05	59.91	66.8	86.48
Actual (B)	206.4	86.21	92.31	76.88	61.29	71.92	76.32
Deviation % (A-B)/A*100	1.714	3.439	-1.932	13.666	-2.303	-7.665	11.748

There is a shortfall of 46.9 Kcal /kWh in heat rate at 100 % MCR load with respect to design values. The shortfall can be partially recovered by implementing short term & long term measures and implementation of better O&M practices [8]. The steam consumption of unit is on higher side due to poor vacuum.

XI.3 Auxiliary power consumption

The power consumed by various plant auxiliaries is shown in the pie chart below. It is observed that the power consumption by boiler feed pump, CW pumps, ID fans and PA fans consume major power [9]. It is essential to reduce this power consumption by implementing energy management practices like planning and operating procedures, technological innovations and maintenance management. The breakup of auxiliary power consumed by the plant auxiliaries is shown in figure 7.

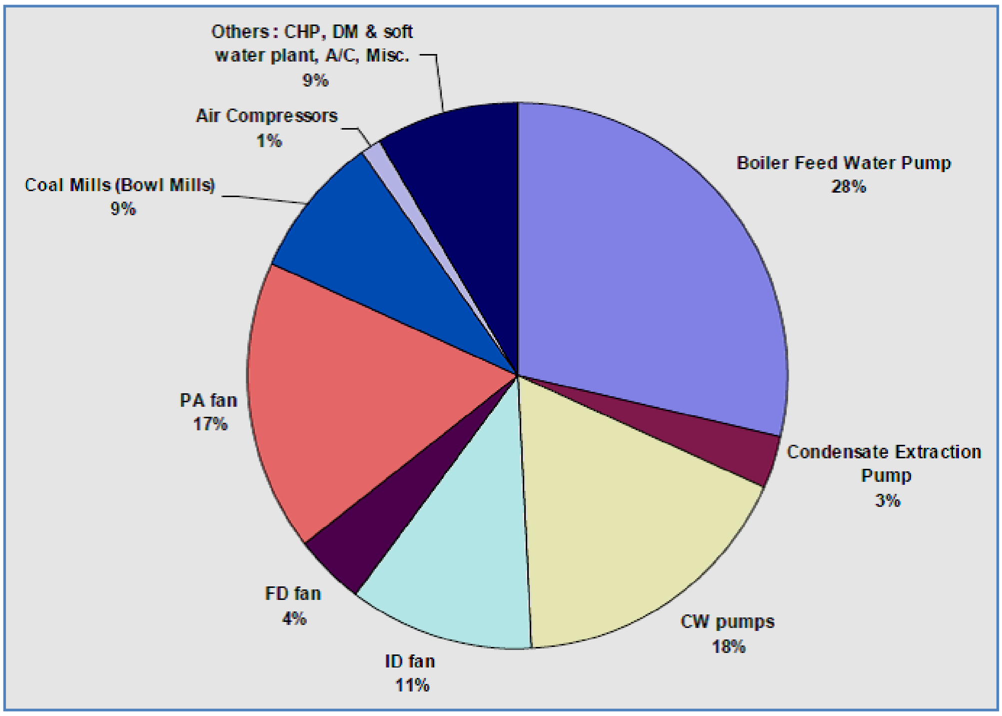

Figure 7: Pie chart representation of auxiliary power consumption for unit

XI.4 Major factors effecting deterioration in heat rate

The major findings of the study are as follows

Loss of heat rate due to condenser vacuum is 60.4 Kcal /KWh. The major factor contributing to condenser vacuum deterioration is air ingress.

- Loss due to low main steam pressure at turbine inlet is 5.22 Kcal/KWh. It can be minimized by operating Turbine at rated MS pressure.
- HRH temperature during test was around 525 Deg C. It is causing a loss of 5.72 Kcal/kWh. The loss can be minimized by maintaining hot re heat (HRH) steam temperature as close to design value as possible.
- Minor quantity (6.8 T/hr) of HRH attemperation flow was there during the test. Heat rate loss due to HRH spray is 2.6 Kcal/KWh. The HRH attemperation has two effects. It will cause heat rate loss and may also leads to deposition on initial stages of intermediate pressure turbine (IPT) blades. HRH attemperation can be minimized which will improve hot reheat temperature and also heat rate further.
- The final feed water temperature at HPH 6 outlet is 236.6 OC against the design value of 241 OC. The effect of low final feed water temperature on heat rate is 3.13 Kcal/kWh. Both HP heater 6 and 5 are under performing. TTD, DCA being higher than design and FW temperature rise less than design value.
- The evaluated HP cylinder efficiency during test was 82.5 %. There is a drop in HP cylinder efficiency compared to design efficiency of 85.8% and previous audit value of 83.55%. This drop may be due to increased blade depositions and blade roughnesses, increased clearances in inter stage gland seals and blade tip seals.
- IP cylinder efficiency evaluated based on test data is 91.96% compared to design figure of 90.26%. There could be minor error in IP inlet or outlet temperature DCS data. The cylinder efficiency

evaluation is very much sensitive to measured temperatures. Based on the data captured, there is no much deterioration in IP cylinder internals observed.

- The unaccounted loss evaluated is found to be 30.6 Kcal/KWh .It can be partly recovered by attending to passing in high energy drains located in boiler and turbine side areas. Both HPBP valves downstream temperature was 450 deg C which may reduce the creep life of CRH pipe lines. Passing in HPBP may be attended on priority.
- The extraction II stage pressure is much higher than design. Previous data (if available) may be checked for ruling out the possibility of measurement error if any. If the measurement is alright then it indicates a restriction in stage which may be due to heavy deposits in moving & guide blades /damage. This may be leading to blocking of steam flow & reduction in steam passing capacity of stage.
- Calculated CW flow (27066m3/hr) across condenser is less than design flow (28500m2/hr). Condenser tubes cleaning may be carried out for removal of possible blockage by dead leaves, loose debris etc. There may be slight under performance by one of the pumps also. Pump performance may be monitored regularly and if any major drop in CW flow is observed pump overhauling may be taken up.
- Unit auxiliary power consumption (APC) as determined during audit is 9.79%. This is on higher side as compared with Central Electricity Regulatory Commission recommendation of 8.5 % with natural cooling tower.
- Performance of Boiler feed pumps, Condensate extraction pumps, CW pumps and ID / FD Fans have been evaluated at present operating parameters. The performance of BFP, CEP, PA fans, CW Pumps has shown slight deterioration. FD fan internal inspection / overhauling is required to reduce power consumption.
- ID fans internal inspection/ overhauling and rectification of external air ingress shall facilitate in stopping of one ID fan and shall lead to substantial reduction in unit aux. power consumption.
- Unit aux. power consumption could be reduced by stopping one condenser vacuum pump and using two ash disposal pumps in series instead of thee during de-ashing.
- Thermal insulation of boiler needs attention and replacement / rectification at major locations as observed during the survey.
- Measurement of Auxiliary power consumption (unit / stage / plant) should be done on monthly / annual basis and should be trended. Present practice is to install Online Energy Management System measures, displays and stores power consumption data of all HT motors / Transformers, and provide reports on customized formats.

The estimated saving after implementation of recommendations has been computed. The aux. power consumption saving is in the tune of 13.186 MUs equivalent to 8.3% reduction in aux. power consumption with respect to previous year consumption.

The estimated cost saving by implementation of suggestions will result in an approx. saving of Rs. 1596 lakhs per annum. The summary is shown in the in table 12 below.

Table 12: Cost saving due to implementation of energy management factors

Sr. No.	Recommendations	Energy saving in MUs	Saving in Rs. Lakhs	Investment in Rs. Lakhs
A	**Boiler and Turbine performance**			
1	**Boiler efficiency**			
a	Reduction in un burnt by combustion optimization, Mill fine tuning and repair	Coal saving of 10545.7 MT/year	232.5	---
b	Reduction in flue gas outlet temp. to design value by Furnace /SH/RH cleaning & APH repair / element replacement	Coal saving of 934.4 MT/year	20.6	---
	Total	**11480.7 MT/year**	**253.1**	---
2	**Turbine Heat Rate**	Turbine heat Rate improvement (kcal/kWh)		
a	Improving Main steam pressure	5.22	100.64	---
b	Reduction in RH spray by improving heat pick up in water	2.61	50.28	---

	wall / SH			
c	Improving condenser vacuum by arresting air ingress/ cleaning of tubes	35.0	684.38	---
d	Improving HP heater Feed outlet temp by restoration of LPH-3 & rectification of HP heaters problem	3.0	57.84	---
e	Improving HRH temp. by operational practice & RH spray valve passing	6.0	110.38	---
		51.83 KCL/KWH	**Rs.1003.52 L**	---
3	**Thermal Insulation**			
a	Reapplication / rectification of insulations as per recommendation	**Coal saving of 864.3 MT/year**	**19.03**	**2.28**
4	**Auxiliary Power Consumption study**			
1	**Main Plant Auxiliaries**			
a	**Boiler Feed Pump**			
(i)	Reduction in DP across feed regulating station	0.3	8.2	---
b	**Induced Draft Fan**			
(i)	Arresting Air ingress in flue gas ducts from APH outlet to ID fan inlet facilitating stoppage of additional ID fan	8.4	217	---
c	**Forced Draft fan**			
(i)	Optimizing air flow and inspection/maintenance of Forced draft fan A & B	0.4	10.3	---
d	**Coal Mills**			
(i)	Overhauling of Mills & ball feeding frequency	2.4	61.0	---
e	**Circulating water pump**			
	Providing polymer coating on CW pump internals	0.70	18.6	20.0
f	**Provision of Online energy monitoring system**	0.796	20.4	15.0
5	**Off site auxiliaries**			
a	**AHP,BCW, HP Water and other pumps**			
(i)	Polymer/ceramic coating on pumps	0.19	5.03	---
	Total	**13.186 MUs**	**1595.72**	**35.00**
Remark: (i) Saving has been calculated taking power sale rate of Rs.2.58 /unit.				

XII. Energy management and performance monitoring

Electricity, being the primary input for any industry has been always of prime importance for industrial growth of a country. The gap between supply and demand has been increasing as the capacity addition is not able to cope up as the rate of increase in demand is more. It is expected that by 2017, world energy requirement will go up by five times of its present consumption. This needs the massive capacity addition in power generation. The capacity addition for power generation is a capital intensive and is having higher lead time; the other possible option is to bridge the gap partly to operate the existing plant at its maximum output / efficiency. The Energy management is one of such tools to optimize/ improve the plant performance / efficiency [10].

Operation of power plant with optimum thermal performance & minimum aux. power consumption is an important aspect of power generation. The savings due to optimization in performance parameters and auxiliary power consumption is indirectly equivalent to capacity addition. Performance monitoring is the tool used for evaluation of performance & efficiency of equipments, aux. power consumption, lighting loads, DM water consumption, specific oil consumption etc. of power plant and also for identifying the gaps & losses. The performance assessment of power plant is a continuous process. The trending of energy performance parameters i.e. Heat Rate, Efficiency, Aux. power consumption etc. will not only help to diagnose the deterioration but also helps to plan timely corrective and preventive actions. It also helps in reduction of O&M cost and inventory cost in addition to spare part planning for maintenance and overhaul.

Therefore by applying the energy management [11] aspects like planning and operating procedures, energy policy and objectives, team work and proactive role of management, Technological innovations and Maintenance management can improve the performance parameters such as Plant auxiliaries efficiency, Plant performance, Electrical energy consumption and fuel energy consumption of the thermal power plant. The energy management approaches for performance improvement are focused as follows.

XII.1 Planning and operating procedures

Availability / reliability of power station become most vital parameter. However there are instances when a power unit becomes unavailable for supplying the power to consumers. Such instances cannot be forecasted. These events lead to sudden tripping of power plant or a forced withdrawal of generating unit. These are unplanned kind of outages. These events increase the non availability for power plant in unplanned manner. Hence this requires even stricter control. If such an outage happens during high demand period, it may even affect the stability of regional power system also. Hence the aim of planning and operating the power plant on design parameters plays major role in energy savings. Starting and shutdown of the plant consumes much time due to which the availability of the plant and energy consumption by the auxiliaries get affected.

Shutdown Process time: Depending on the emergency we have to take the forced or planned shutdown of the unit for attending the faults. The cycle time required for this process of load reduction from full load to resynchronization of the unit from grid called as shutdown process time. The average time of shutdown process is 1 - 2 hours.

Startup Process time: After attending the faults depending on the condition of the unit whether hot, warm or cold we have to start the unit & synchronize it with the grid. The cycle time required for startup process is the time required for carrying out activities after receiving clearance from maintenance up to achieving full load. The average time of startup process is 4 – 10 hours.

So any delay in activities between the shutdown & start up process will increase cycle time. High cycle time leads to unpredictability in availability of the unit, High generation cost. Both these factors directly affect the customer. Also it increases generation cost due to High DM water consumption, Auxiliary power consumption, Generation loss & excess oil consumption. As the cycle time required for startup process is high & there is wide variation in the cycle time, so this project of reduction in startup process time is selected.

Start-up of Units are divided in three category

1) Cold Start-up (Turbine HP shaft temperature < 150°C)

2) Warm Start-up (Turbine HP shaft temperature 150 – 350 °C)

3) Hot Start-up (Turbine HP shaft temperature >350°C)

Secondary energy consumption like oil and auxiliary steam is high during start–ups. The availability of the units decreases and part load operation increases as the time required in achieving full load from the boiler light-up increases.

The average time required for

1) Cold startup 7 – 12 hours
2) Warm startup 5 – 7 hours
3) Hot restart up 2 – 3 hours

Cold start-up is planned activity & done once or twice a year only after the major overhaul of units. Warm and hot start-up being an unplanned activity where the bulk loss of oil and auxiliary steam is high. Numbers of warm start-ups are 5-6 a year.

The figure 7 shows below the time required for cold startup process.

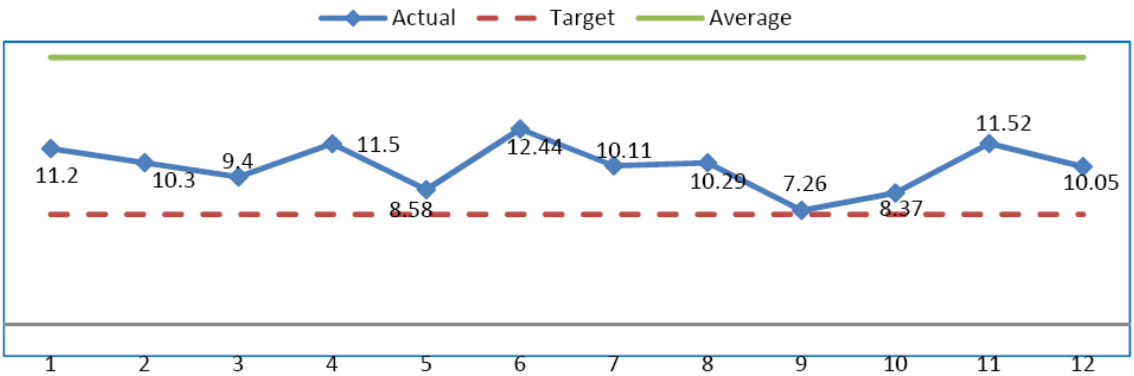

Figure 7: Cold start-up time for the unit

From the previous data & above graph it is clear that cycle time for start varies from 7 to 13 hours. This variation in startup process cycle time leads to unpredictability in availability of units. Also the high cycle time leads to:

- Higher generation costs
- Dissatisfaction to customer in competitive environment
- Generation loss (0.25 Million Units / Hour)
- Excess oil Consumption (8 KL/Hr)
- High auxiliary power consumption (1000 kWh/Hr)
- High deminaralized water consumption (32 Tons/Hr)

XII.2 Technological innovation

As per the result of the collected data, technological innovation [3] plays significant role in the energy management practices of thermal power plant to improve the performance of the plant. Some of the examples implemented in the plant have been explained below to save the energy.

a) **Installation of variable frequency drive (VFD) for seal air fan**

Background

The Seal air fan is used for providing sealing of mills, classifier gates and feeders. There are six mills and each mill have two seal air fan out of which one fan remains in service and other remains as hot standby. One running seal air fan motor draws approximately 120 KW power.

Observation

The existing control used for the matching of fan requirement with the system requirement is by damper control. Generally the header pressure requirement is 800- 1000 mm WC and the fans generate 1350 mm WC of pressure. The loss taking place across the damper is major source of energy wastage.

Technical and Financial analysis

It was concluded that the loss taking place across the damper is the major source of energy wastage. Hence decision was taken to install the variable frequency drive for the fan.

Impact of implementation

- Energy saving of Secondary Air Flow with 100% Damper open position when VFD in service.
- Without VFD application fan consumption: **122 KW**
- With VFD application fan consumption: **58 KW**
- Net energy saving due to VFD application: **64 KW**
- Energy savings per year: **6144 units X 350 days = 2150400 units**
- Estimated energy savings per year: **2150400 Units X Rs.2 per unit** = **Rs 43.00 lakhs**
- Cost of VFD: **Rs.30.5 Lakhs /- per unit**
- Payback period **=10 months**

b) **Use of variable frequency drive (VFD) for HFO pump**

Background

A coal based boiler requires to fire oil to support coal combustion. So as to keep the availability of the support fuel, an HFO firing pump is provided. The HFO firing pump is provided with a minimum recirculation valve so as to ensure minimum oil flow from the pump.

Observation

During the normal operation of both the units, the HFO consumption is zero. The HFO gets re-circulated through short and long re-circulation line of both boilers to maintain the HFO temperature. Flow through short & long re-circulation is very less & maximum quantity of HFO is re-circulated through Pressure

Control Valve (PCV), located near the HFO firing pumps, to HFO tank. PCV maintains the HFO discharge header pressure at 21-23 Kg/cm2 & remains approx. 50% open during normal operation of both units.

Technical & Financial analysis

Hence it was decided to install VFD for HFO firing pump motor rated 415V, 37 KW, to control and maintain the required flow and pressure of HFO by varying the speed of motor.

Impact of implementation

Energy consumption by pump will reduce considerably after installation of VFD. The proposed payback period is less than one year. Energy consumption by pump will reduce considerably after installation of VFD. The proposed payback period is less than one year. Installation and commissioning of suitable VFD for the 37 KW, 415 V HFO pump to have optimum performance with considerable energy saving.

During normal re-circulation mode average power measurement is

•Without VFD @ 18.10KW

•With VFD @ 8.36KW

•Difference @ 9.74

Saving in KWH = KW *HR *DAYS

= 9.74*24*365 KWH

= 85322 KWH

Saving in rupees @ Rs. 3.50 = 298628 per year

Cost of VFD = Rs.1, 63,223

Simple Payback period is 200 days or 6.65 months

c) CW pumps modification

There are three CW Pumps in unit 4, two as main & one as standby. Pump designed flow is 16500 M^3/Hr and motor capacity is 1265 kW.

Pump efficiency and can be improved by applying polymer coating on pump internals. There are manufacturers, who claim that pump efficiency can be improved by 5-6 % by coating. Energy consumption by such coating can be reduced by 4-5 %.

Total Power Drawn by two pumps = 2261 kW

Expected Power after improvement in efficiency = (1-.04)*2261

(Assuming 4 % improvement in power consumption) = 2170 kW

Expected Running Hours (assumed) = 8000 Hrs

Power saving = (2260-2170) =90 KW

Energy saving (Units) = 90* 8000 = 7, 20,000 kWh = 0.7 MUs

Cost of annual energy saving (Rs) = 7, 20,000 *2.58 = 18, 57,600 = Rs.18.6 Lakhs

Approximate cost of polymer coating on both pump internals = (Rs) 20 Lakhs

Pay Back Period = One Year

d) Replace the existing feed pumps Automatic Recirculation Control (ARC) valves with multi stage pressure reduction drag valves

During the study the feed water pumps were studied in details for possible energy savings. Auto re-circulation valves of the boiler feed water pumps were examined using the infrared temperature indicator. ARC valves are normally provided to protect the pump during no flow and low flow periods. During normal operation these valve should be fully closed and they should be automatically opened if the feed discharge pressure goes beyond certain pressure.

In unit 4 (210 MW) there are 3 no's of feed water pumps are present, out of which 2 are in continuous operation. The pipe surface temperatures before & after the ARC valve indicates that the ARC valves of some of the operating feed pumps are passing. This means certain amount of boiler feed water is continuously re-circulating back to the de-aerator. Recirculation results in increasing the power consumption of the pump.

There is an opportunity to save energy by replacing the ARC valves with new valves. In ARC valve the entire pressure drop (discharge pressure to deaerator pressure) happens in two / three stages. This leads to significant erosion of the diaphragms. The latest trend is to install multi-pressure reduction drag valves. These valves reduce the pressure drop across the valve in even more stages which results in increasing the life of the valve.

Many plants have installed these multi stage pressure reduction drag valves and have saved good amount of energy. Due to the reduction of pressure in number of stage the life of these valves is considerably high compared to the normal ARC valves.

We recommend the following:

Replace the existing ARC valves will multi stage pressure reduction drag valve in unit 4

As a first step replace one of the valves

Later replace all the valves of other feed pumps in operation
On an average the power consumption of one BFP pump in unit 4 is 2400 kW.
On a conservative basis at least 4% reduction in power consumption is possible.
Reduction in power = 2400 kW x 0.04 = 96 kW
Annual Savings = 96 kW x 8000hrs x Rs. 2.4/kWh = Rs. 18, 43,200/- = **Say Rs. 18.00 Lakhs**
Investment for installing multi stage drag reduction valve for one pump in unit 4 = **Rs. 40.00 Lakhs**
Payback Period = Rs. 40.0 Lakhs x 12 months / Rs. 18.0 Lakhs
= **27 months**

e) Timely replacement of BFP cartridges

The BFP, or boiler feed pump is a very critical part of the boiler system. It regulates the amount of feed water going into the boiler drum and is part of a complex control system which involves controlling of the throttle valves and regulating the water supply based on the pre existent water and steam levels in the drum. Thus it is often observed that BFP takes a lot of power. However if BFP takes higher power, chances of interstage leakage in the recirculation process happen. Therefore, it should be observed as well as checked regularly and the BFP cartridge should be inspected thoroughly on a regular basis [1]. If the need arises, it should change for better efficiency and less power consumption.

Impact of Implementation

After replacing the cartridge the current drawn by BFP reduced by 60 Amp.
Power saved per day= 1.66*6.6*60*.84*24= 13,252 KWH
Power saved per year= 4837,117.82 KWH
Saving of cost= 4837, 117.82*3.4= Rs16829515

XII.3 Maintenance management

Maintenance management is vital energy management factor for the plant availability, plant load factor, cost of power generated and power sent out in the grid. The maintenance of main equipments viz boiler, turbine and generator and there auxiliaries is important for achieving high plant load factor and less auxiliary power consumption. Therefore maintenance planning and annual overall of the plant is essential to improve plant performance and reduce electrical energy and fuel energy consumption. The case study of boiler tube failure is quoted below.

Boiler maintenance for minimizing boiler tube failure

Boiler tube leakage is one of the major reasons for forced outage. The forced outage leads to reduction in power generation and hence reduction in plant load factor and increased oil consumption due to increased cold start up of boilers. Over stressing, Starvation, overheating of tubes, creep life exhaustion, stress corrosion, waterside corrosion, fireside erosion, hydrogen embrittlement, age embrittlement, thermal shocks, improper operating practices, poor maintenance, welding defects etc are the major causes for boiler tube failure. If a boiler has to continue to function at a given / desired level of availability, its constituent items need some expected level of maintenance either by replacement or by repair.

The analysis of causes for boiler tube failure in the thermal power plant shows that maximum failures were due to ash erosion with 43% shop floor / site weld defects 16%, blockage of reheater tubes 11%, steam erosion 10%, secondary air erosion 8%, attachment weld 6%, material defect 3% and creep failure 3%. The analysis of area wise tube failure indicates that about 40% of the failure occurred in super heater zone, 25% of the failure in water walls, 20% of the failures occurred in economizer and remaining 15% failure occurred in reheater zone.

Due to preventive maintenance it is found that the tube failure rate has reduced from 3.36 failures per year to 0.43 failures per year.

XIII. Summary of energy management implementation

The energy management approaches were implemented in the said thermal power plant with the following objectives [12]

1) Heat Rate improvement and optimization of operational parameters.
2) Identification of equipment efficiency degradation / improvement areas
3) Auxiliary power consumption reduction
4) Technological innovation for energy savings of auxiliaries

For this, the walk down survey of plant, interaction with plant and measurement of various plant parameters including auxiliary power consumption measurement of major equipments, lighting illumination survey, air conditioning load, Thermal insulation survey was carried out. Based on the data collected during this exercise, the computation of plant performance indices such as boiler efficiency, various losses in boiler, air heater efficiency / leakage, turbine heat rate, cylinder efficiency, heaters performance, condenser performance, auxiliary Power consumption etc have been done. The comparison with design data, where ever available, has been carried out to ascertain the deteriorations. Also gap analysis was carried out and measures have been suggested for improvements. With this approach, output / heat rate deviations have been identified and quantified.

This pro-active role of energy management approach is accomplished by identifying key "primary process indicators", which if monitored regularly, will help in taking corrective actions immediately if any deterioration is noticed.

A secondary purpose for monitoring such primary process indicators shall be to assist in instrument validation/instrument calibration. By closely monitoring critical instruments, drifts or irregularities in them can be quickly identified and the instruments calibrated or replaced.

This approach has several advantages such as:

- The requirement of fuel will be reduced. This lowers the cost of electricity generation.
- Improved heat rate reduces the amount of greenhouse gases .It amounts to the reduction of emissions to the environment.
- The identification of causes for higher auxiliary power consumption and its rectification results in increased net power output.
- The identification of causes for higher auxiliary power consumption and its rectification results in increased net power output.

The saving per year after implementing energy management approaches is summarized as follows.

1) Boiler efficiency- **Coal Saving- 11480.7 MT/year**
   Cost saving – Rs 253.1 Lakhs
2) Turbine Heat Rate Improvement - **51.83 KCL/KWH**
   Cost saving due to HR improvement – **Rs 1003.58 lakhs**
3) Thermal insulation replacement - **Coal saving - 864.3 MT/year**
   Cost saving – Rs 19.03 Lakhs
   Investment - Rs 2.28 Lakhs
4) Auxiliary power consumption reduction **– Saving – 13.186 MUs**
   Cost saving – Rs 1595.72 lakhs
   Investment – Rs 35 lakhs

The above results indicate that there are improvements in performance factors of electrical energy consumption, fuel energy consumption, plant performance and plant auxiliaries' efficiency due to energy management approaches and its implementation in thermal power plant.

IXV. CONCLUSION

After implementing the energy management approaches like 1) Planning and operating procedures 2) Energy Audit 3) Energy policy and objectives 4) Team work and proactive role of management 5) Technological innovations and 6) Maintenance management, there is an improvement in the performance parameters i.e. 1) Plant auxiliaries' efficiency 2) Electrical energy consumption 3) Plant performance and 4) Fuel energy consumption. The energy audit of thermal power plant plays major role in implementing the energy management practices for energy saving. It is also possible to develop a model between energy management approaches and performance indicators for the thermal power plant for energy efficiency, saving in energy and minimize the cost of power generation so as to maximize the profit.

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