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Carbon Emission Reduction Through an Electrical Energy Audit in Thermal Power Plant-Indian Scenario

[1]Anil B. Onkar, [2]G.A. Dhomane, [3]R.M. Moharil and [4]Prashant P. Mawle
[1]MSPGCL-KTC Koradi, 444111 Nagpur, India
[2]Department of Electrical Engineering, Govt. College of Engineering, 431001 Chandrapur, India
[3]Department of Electrical Engineering, Yashwantrao Chavan College of Engineering (YCCE), Hingna, 440034 Nagpur, India
[4]National Power Training Institute (NPTI), Gopal Nagar, 440022 Nagpur, India

Abstract: In this study, electrical energy conservation measures in thermal power plant is discussed. Research study is related with CO_2 reduction techniques through energy audit of thermal power plant. The implementation of energy conservation measures drawn from energy audit study will reduce the energy consumption about 15-20% and saved energy can be made available to feed in the grid which increases net electrical energy generation. In house auxiliary consumption reduction can provide attractive method to increase the net generation capacity which reduces CO_2 emission factor. In this study, CO_2 reduction/annum is calculated as 13980.24 tons of CO_2. It also shows that energy environment implication can be reduced by means of electrical energy audit in thermal power plant.

Key words: TPP (Thermal Power Plant), PWM (Pulse Width Modulation), CHP (Coal Handling Plant), AHP (Ash Handling Plant), WTP (Water Treatment Plant), CWP (Cooling Water Pump), MDBFP (Mechanical Driven Boiler Feed Pump), ID (Induced Draft fan), FD (Forced Draft fan), PA (Primary Air fan), VFD (Variable Frequency Drive), EEA (Electrical Energy Audit), CO_2 (Carbon di-oxide) emission

INTRODUCTION

Energy is the central element in the process of development. Energy is a fuel for economic growth energy enters into our life one form of another. The world today acknowledges that the guiding concept for the future is sustainable. Development where industrial growth is linked to husbanding of the earth's resources. Negotiation on the Kyoto protocol to the United Nation Framework Convention on Climate Change (UNFCCC) were competed Dec. 11, 1997. Committing the industrialized nation to specify legally binding reduction in emission of six greenhouse gases, i.e., CO_2, N_2O, HFCS, PFCS and SF6. The present study has been undertaken in search of reduction in specific coal consumption. Kyoto protocol was introduced on 16th February, 2005 after Russia joined. Kyoto protocol planes a gradual reduction of the elements that contribute to global warning; intervention by countries throughout the world is needed to reduce the emission of CO_2 and other Green House Gases (GHG). According to the treaty, some countries have pledged a 5.2% reduction in GHG compare to that produced in 1990 for the period 2008-2012. So, the energy efficiency of industrial plants and equipment must be increased. Thus, the use of primary energy derived from fossil fuels will be reduced and the energy management in industrial activities will be improved. Cogeneration is an efficient way of generating electric energy and heat simultaneously from a given amount of fuel. Energy savings can reach 15-40% of primary energy. Cogeneration helps to reduce CO_2 emission and GHG, giving lower capital expenditure in electric energy transmission grid capacity and avoiding transmission loss while assuming high quality power supply. The Kyoto protocol provisions allow for the use of Clean Development Mechanism (CDM), under which GHG emission form projects are to be minimized. The air pollutants relevant to the activities of TPS were identified as CO_2, SPM, RPM, SO_2, NOX and CO. The 98% values of SPM during winter season varied between 151-245 $\mu g/m^3$. Higher levels of SPM were contributed due to unpaved roads and heavy transportation activities. The repairable particulate matter (98%) varied from 61-123 $\mu g/m^3$. A 500 MW plant using coal with 2.5% sulphur (S), 16% ash and 30,000 (kJ/kg) heat content will emit each day 200 m tons of sulphur dioxide (SO_2) 70 tons of nitrogen dioxide (N_2O) and 500 tons of fly ash if no controls are present. In addition the plant will generate about 00 tons of

Corresponding Author: Anil B. Onkar, MSPGCL-KTC Koradi, 444111 Nagpur, India

Table 1: Types of generation and installed capacity (MW)

Parameters	Values
Coal based	185172.88
Gas	24508.63
Diesel	993.53
Nuclear	5780.00
Hydro	42783.42
RES (MNRE)	42849.38
Grand total	302087.84

Table 2: Types of generation and installed capacity (MW)

Parameters	Values
Coal based	26478.26
Gas	3475.93
Diesel	0.00
Nuclear	690.14
Hydro	3331.84
RES (MNRE)	6613.29
Grand total	40589.46

Table 3: Power generation efficiency auxiliaries and reduction measures

Parameters	Values (%)
Product efficiency	5
Energy and feed stock substitution	20
CO_2 capture and storage	22
Process innovation	4
Energy efficiency	49

solid waste and about 17 Giga Watt Hour (GWH) of thermal discharge. Other significant air pollutants are respirable and suspended particulates, contributed mainly due to power plants and stone crushers. The wide spread disposal of fly ash and stone rejects, too contribute in making the ash/dust air born and inflicting air with poor visibility. Energy efficiency is the least expensive way for power and process industries to meet a growing demand for cleaner energy. The IEA (International Energy Agency) 2006 energy technology perspectives model is a bottom up, least cost, optimization program. The model was developed to describe the global potential for energy efficiency and CO_2 emission reduction in the period to 2050 particularly in Industrial Sector. As per this model CO_2 emissions are stabilized globally in 2050-2005 level and world narrowly avoids a costly climate crisis (Annoymous, 2016).

Table 1 represents all India installed capacity in MW of power station (As on 31.03.2016) (Fig. 1). Table 2 represents installed capacity in MW for Maharashtra state as on 31.03.2016.

The International Energy Agency's "Accrelated Technology Scenario" suggests that Power Generation Efficiency can contribute significantly to the overall global effect to stabilize CO_2 emission by 2050 at or near to 2005 level model shows that "power generation efficiency" alone which includes improved auxiliaries and other reduction measures has a larger climate impact than even nuclear power (IEEE, 2007) (Fig. 2 and Table 3).

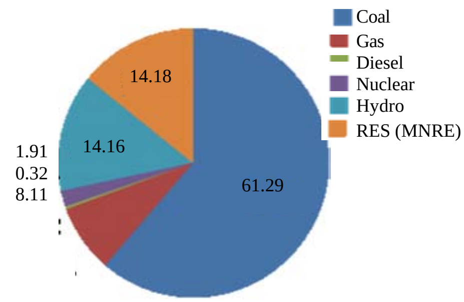

Fig. 1: Mode wise contribution in percentage (All India) as on 31.03.2016

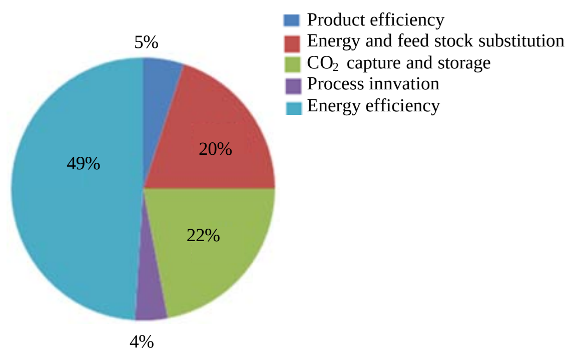

Fig. 2: Mode wise contribution in percentage (Maharashtra) as on 31.03.2016

Power plant processes: In coal based thermal power plant auxiliaries serve to keep the steam water cycle safely circulating and to return it to its thermodynamic auxiliary system accounts for about 8-10% of gross generation capacity. Example of auxiliary process in thermal power plant are shown in Fig. 3:

- Conveying and preparing the fuel
- Moving necessary air to the furnace
- Moving flue gas from the furnace
- Returning the condensed water back to the steam generator
- Maintaining the necessary cooling effect in the condenser
- Operating various emission cleaning process
- Pneumatic control

A majority of this process are run by centrifugal pumps, fans and compressor driven by large electrical motors. This study describes how auxiliary consumption reduction can provide attractive method to increase the net generation capacity by reducing fuel consumption which ultimately reduces green house emission.

The power stations especially base load ones are running at full load all the time it is easy to imagine that

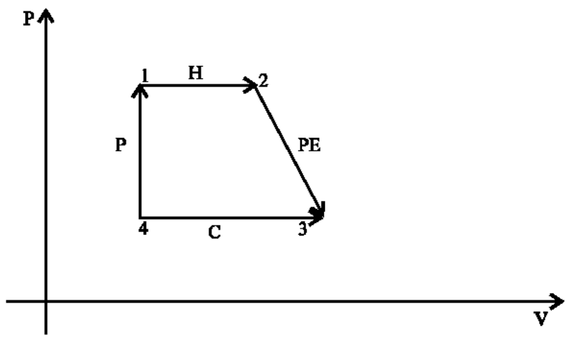

Fig. 3: Process in thermal power plant

not much change or control is needed for the auxiliary process in such cases. The fact is however, that very few power stations run at their maximum capacity throughout the year instead the capacity is being adjusted all the time to match demand and various operation condition and parameters auxiliary are design to operate reliably under all operating conditions which leads to part load operations.

This study also concludes that variable frequency drive increase the plant availability and flexibility through improved process control VFD reduces maintenance cost and improve heat rate by increasing the efficiency of auxiliary process which in turn reduces emissions (Rowan and Lipo, 1983).

Basics of fan: Devices used to produce a gas flow. Centrifugal fan behaviours are characterized by affinity law:

- Flow α N (If no counter pressure)
- Pressure head α N^2
- Pumping power (QH) α N^3

Electrical power demand also depends on efficiency of the fan and efficiency of the electrical motor.

Operation and design aspect of large fan in thermal power plant: Induced Draft (ID) fan is used to suck away the flue gases from the furnace and to push them further through stack in to the atmosphere. Gas flow needs to be controlled in order to maintain ideal burning condition inside the boiler. ID fan also needs to generate a high enough pressurefor the gas stream in order to overcome the counter pressure of air preheater, electrostatic precipitator, FGD (Flue Gas Desulphurization) Plant and the stacks. If VFD is used to control ID fan an ID fan can be selected to operate at or close to peak efficiency. Even base loaded unit will typically show significant power savings initial over dimensioning (Blaabjerg *et al*., 1997).

Efficiency is essentially independent of speed. Now a day's energy is a critical input to production and consumption activities in an economy. In spite of the increase in prices of electricity, consumption has also gone up. Substantial saving of electrical energy can be achieved by following methods such as Improving the power factor, slip energy recovery, captive power generation and variable speed dive.

In recent years, there has been a considerable increase in the use of induction motor and AC drives to provide a low output voltage distortion, fast dynamic response, high reliability and continuous power supply especially for motors. Low Total Harmonic Distortion (THD) and high efficiency are commonly required in high power applications such as three-phase inverter systems. Distortions and non-sinusoidal currents can cause more voltage drops on the supply network impedance resulting in unbalanced conditions. They also cause Electromagnetic Interference (EMI) and resonances. The harmonics have negative influence on the control and automatic equipment protection systems and other electrical loads. Resulting in reduced reliability and availability. Several controllers including repetitive control hysteresis regulation predictive control and multi-loop feedback control have been proposed to obtain an output voltage with low distortion for three-phase inverter. From this case study we can conclude that reduction of throttling is economical. Pumping system often demand variable output. There are several options available to cater to these. But it needs to be stressed that choosing the most effective system for given application needs a thorough understanding of the system needs as well as proper knowledge of pump and their characteristics. It is imperative that the equipment as well as the measuring system has to be well maintained and the personnel appropriately trained to sense variation in performance. Variable frequency drives may offer a suitable option especially for retro fitting. The concept of life cycle cost can be effectively used for long term energy savings:

$$f = \frac{NP}{120}$$

Where:

f = Frequency (Hz)
P = No of poles
N = Speed in RPM

Therefore, if the frequency applied to the motor changed. The motor speed changes in direct proportion to the frequency change. The two most basic function of a VSD are to provide power conversion from one frequency to another and to enable control of the output frequency. There are two basic components. a rectifier and inverter to accomplish power conversion. The inverter can be controlled. To produce an output frequency of the power value for the desired motor shaft speed.

What is VFD: Induction motors are wound to match supply voltage and frequency which prevails in the country. When it is desired to operate an induction motor at variable speed it is necessary to consider the effect of voltage and frequency on flux and torque. Operation of induction motor depends on rotating field created by the balance three phase current in the stator winding. The magnitude of the field is controlled not by the strength of the current but by the voltage induces in the field winding by the supply. This induced voltage can be expressed as:

$$E = K\Phi nf$$

Where:

E = Induced emf
Φ = Flux per pole
n = No. of turns/pole
f = Supply frequency
K = Constant

For economy of material the magnetic circuit of standard motor is designed to operate every close to saturation at rated voltage and frequency. This is the optimum production of torque. At rated frequency any further increase in voltage leads to increase in current and subsequently increases in losses. From the equation:

$$\Phi = E/Knf$$

This shows that since, 'n' is fixed and 'K' is constant a linear relationship must be maintained between emf and frequency. If the flux is to be remained constant at different speed. This linear relationship is known as constant V/f this is the principle of operation of Variable Frequency Drive (VFD):

$$F = NP/120$$

Frequency for economical speed decides the frequency of operation. I am utilizing VFD characteristics as an input for energy conservation potential for case study.

When comparing the different methods of mechanical flow control it is clear to see only a VFD gets close to the maximum efficiency of the theoretical fan curve (Anonymous, 2005).

Periodic declaration: When a load is stopped quickly and the inertia of the load wants to keep turning such as a large drum (in this case the cycle time or how many times the load is stopped over time as well as the magnitude of the stopping power required determines how much energy can be recovered).

Continuous declaration: When a load such as a decline conveyor operating under the influence of gravity will overhaul the motors speed and the drive is used to regulate the speed in a slower controlled fashion than what the natural physics of the application would produce. This would also be a general description of a hoist and crane application in thermal power plant.

Power factor: AC power has two basic components: voltage and current. When these two components are in sync (called power factor displacement: Fig. 3), AC power is wasted through inefficiency. Moreover when the AC power has high level of harmonic content called power factor distortion, the displacement and distortion are multiplied by each other which further decrease efficiency:

$$\text{Total PF} = \text{Distortion PF} \times \text{Displacement PF}$$

Review of previous research: Many papers have been so far published in the field of control and topologies. Deadbeat control on both output voltage and inductor or capacitor current for three-phase PWM has been proposed, either in multi-loop configurations or in a conventional linear filter for single-phase voltage source UPS inverter has been investigated in and compared with an C output filter. In unified control scheme as well as a novel connection arrangement is developed to simplify the inverter circuit for design and speed control of motors. a digital inverter circuit for design and speed control of motors. A digital control scheme of three-phase inverter based on multi-loop control strategy consisting of a filter capacitors current and output voltage is proposed in. The technique also includes a load predictive feed-forward loop in a voltage controller and an output voltage feed forward loop in a current controller. Linear and nonlinear adaptive control strategies for three-phase inverters have been presented (IEEE, 1992).

A three phase PWM inverter: If switching frequency is high enough, the PWM inverter is considered as a Voltage Source Inverter (VSI) and dynamic response of the inverter is mainly determined by the elements of the filter (Faiz and Shagholian, 2006).

Semiconductor switching devicesof the inverter are controlled by PWM signals to abstain three-phase near sinusoidal ac voltage of the desired magnitude and frequency at the inverter output.

Case study of ID fan: The function of induced draft fan is to suck the gases out of furnace and throw them into the stack. Boiler is provided with two nos. of induced draft fans. Each ID fan is provided with regulating damper control and scoop control for controlling the loading on fans:

$$\text{Slip} = \frac{\left(\frac{I}{P}\text{Speed} - \frac{O}{P}\text{Speed}\right)}{\frac{I}{P}\text{Speed}} \times 100\%$$

Principle of hydraulic coupling: ID fans are controlled with VFC control. The variable fluid coupling works on the principle of hydrodynamics. It consists of an impeller and rotor (runner) enclosed in a casing the impeller is connected to the prime mover while the rotor is connected to the driven machine. The coupling is filled with fluid, usually mineral oil. The speed of the driven equipment is varied by varying the quantity of fluid supplied between the impeller and runner (IEEE, 2003).

Slipis thedifference between input and output speed is essential in a fluid coupling in order to enable it to transmit torque. Difference between input and output speed is normally expressed as percentage of the input speed and referred to as slip.

Hydraulic coupling losses: There are two types of power in VFC.

Hydraulic losses: Since, the regulation is based on slip regulation, evidently there is slip; loss occurred which heat up the working oil and must therefore br removed by heat exchanger. The amount of loss depend upon the run of char and slip required to attain the desire O/P speed.

Mechanical losses: Mechanical losses occurred due to friction in the bearings, ventilation losses and losses in the oil circulating system which usually do not exceed 1% and are therefore of little significance. Loss in a typical VFC can be shown graphically:

Hydraulic losses calculation

Heat loss method: The heat gained by the cooling water supplied to the VFC is an indication of the power loss. The energy loss in VFC estimated by measuring the cooling water flow and the temperature difference between the inlet and outlet cooling water. Cooling water flow rate is measured by ultrasonic flow meter and ECW temperature gain is obtained from infrared thermometer.

The calculation related to VFC loss is given in Table 1. The above calculation of hydraulic loss by heat loss method is validating by slip loss calculation. It is given as:

$$\text{Total heat} = \frac{\left(\text{ECW } \left(m^3/h\right) \times \text{ECW°C} \times 1000\right)}{860 \text{ Kcal/h; ECW temp. Gain (°C)}}$$

$$\text{ECW W flow } \left(m^3/h\right)$$

Slip loss method: Some technologist regarded fluid coupling as the hydraulic analog of the AC squirrel cage induction motor as the motor torque is developed by interaction between the magnetic field at synchronous speed created by the attar current and the field created by the current it generates in the rotor cage which in turn is slightly lower speed equivalent to the slip. Speed measurement is done by stroboscope. Current and Voltage values are from PMS:

$$\text{I/P Power} = \frac{\text{O/p}}{(1\text{-Slip})}$$

Hydraulic loss by slip loss method is shown in Table 2.

Efficiency aspect: Efficiency of variable fluid coupling = 1-slip. Fan driving system efficiency can be improved by regulating fan speed by digital Variable Frequency Drive (VFD) instead of VFC (Table 4-6):

$$\text{Fan driving system efficiency } \eta\text{driving} = \eta\text{motor} \times \eta \text{ VFC} = \eta\text{motor} \times (1 - \text{slip})$$

Present efficiency calculation average slip of VFC = 21.86%.

Recommendation: Installing a variable frequency drive for this variation in flow requirements will result in substantial energy saving. The speed of the fan can be varied to attain the desired flow. There are two options:

- To install variable frequency drives for the ID fan with VFC in place
- In this case, fan speed is varied by keeping VFC scoop 100% open
- Design VFC slip at scoop 100 and 3.4%
- To install variable frequency drives for the ID fans and remove VFC. In this case VFC slip loss is nilsince slip = 0

HT VFD of this capacity is running in several plants
Cost-Benefits:

$$\text{Energy saving}(\%) = \frac{\text{New efficency - Old efficiency}}{\text{New efficiency}}$$

Table 4: Parameters with performence

Parameters	Unit-1 ID fan 1A	Unit-1 ID fan 1B	Unit-2 ID fan 2A	Unit-2 ID fan 2B	Avg.
A. Motor I/P power (kW)	1224	1243	1257	1289	1253
B. ID fan motor efficiency (%)	96	96	96	96	96
C. Scoop position (%)	55	54	53	54	54
D. Motor speed (rpm)	733	734	731	733	733

Table 5: New efficiency

Parameters	η new (%)
A (η motor)	96
B (η driving)	96

Table 6: New efficiency

E. fan speed rpm	F. Slip (%)	G. VFC, I/L power (kW)	H. fan shaft I/L power	I. VFC loss
574	576	568	573	572
21	21	22	21	21
1175	1193	1206	1237	1203
920	936	936	966	940
254	256	269	270	263

F = 100* (F-G)/F, G = A*B (100), H = G* (1-F/100), I = G-H

Table 7: Present efficiency (HOLD)

Parameters	η old (%)
A (η motor)	96.00
B (Slip)	21.86
C = (1-B)100/100 (η VFC)	78.14
D = A*C/100 (η driving)	75.01

Table 8: New efficiency (HNEW)

Parameters	η new (%)
A (η motor)	96.0
B (Slip)	3.4
C = (1B/100)100 (η VFC)	96.6
D = A*C/100 (η driving)	92.7

Table 9: Measurise VFD value

Parameters	Values: VFD With VFC-Scoop100 (%)	Values: VFD without VFC
A. Energy saving/fan (kW)	239.48	274.01
B. No. of fan (No.)	4.0	-
C = A*B. Total energy saving (kW)	957.92	1096.04
D. Cost unit (Rs.)	4.5	4.5
E. Total investment (Rs. CR.)	5.6	5.6
F. Annual operating hours (h.)	8200.0	8200.0
G = C*D*F. Annual saving (Rs. CR.)	3.53	4.04

Table 10: Efficiency of units with and without VFC

Parameters	VFD with VFC at FULL speed (scoop = 100%)	VFD with out VFC
A. Average motor I/P power (A)	1253.25	
B. Л old (%)	75.01	
C. Л new (%)	92.73	96.00
D. Energy saving (%)	19.10	21.86
E. kW Saving (kW)	239.48	274.02

D = 100* (C-B)C, E = A*C/100

In TPS, there are 4 no. ID fans. Above energy saving calculation is for one fan. If cost of unit is 4.50 Rs./kWh and annual operating hours = 8200 h, benefit and simple payback period is shown in Table 7-10.

ID fan has higher efficiency when inlet vane or inlet damper are totally eliminated, reliability, controllability, operability, lower noise, soft starting capability, reduced maintenance (Schachter, 2000; Kusagur *et al*., 2009).

MATERIALS AND METHODS

Energy audit methodology: Energy audit is a engineering techniques used to established the pattern of energy use, level of operating efficiency, identify how and where losses are occurring, identify generic design deficiencies, identify process bottle necks, identify performance deterioration, addressing technological obsolesces, addressing chronic operation and maintenance problem, suggest appropriate techniques to conserve energy along with economic implications and evaluation of performance efficiency helps for renovation and modernization, up gradation (Bhatt, 2001). Energy audit methodology consists of three phases:

- Preliminary energy audit
- Detailed energy audit
- Report preparation

Steps of energy audit:

- Meeting and discussion with plant officials
- Study of process/activity of the organization
- Collection of technical details along with drawings
- Collection of monthly post data (2 and 3 years) on electrical and fuel energy consumption
- Action plan for detailed audit
- Performance evaluation of each utility and end use equipment by observation, conducting tests and measurements
- Data analysis, processing, computation, observation of result and comparison with design values
- Identifying energy conservation measures and techno economic analysis
- Recommendation for energy conservation and preparation of draft report
- Submission of draft report to client
- Receiving comments from client
- Submission of mutually agreed final report contains recommendation for improvingenergy efficiency with cost benefit analysis and action plan

Typical plant losses: Equipment covered under station auxiliary in thermal power plant are shown in Fig. 5 and 6.

Transformers: Assessment of the health and transformer load loss of generator. Transformer, unit auxiliary transformer. Identification of possible energy conservation in this area.

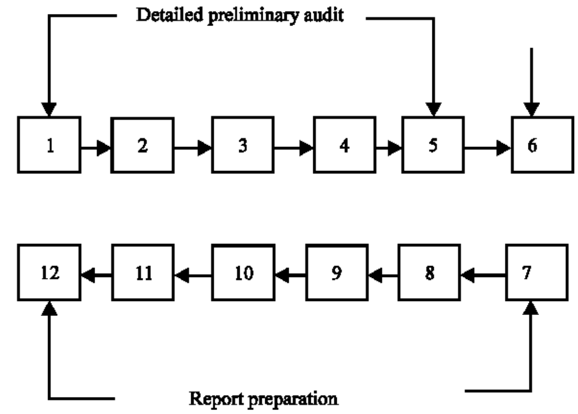

Fig. 5: Energy audit

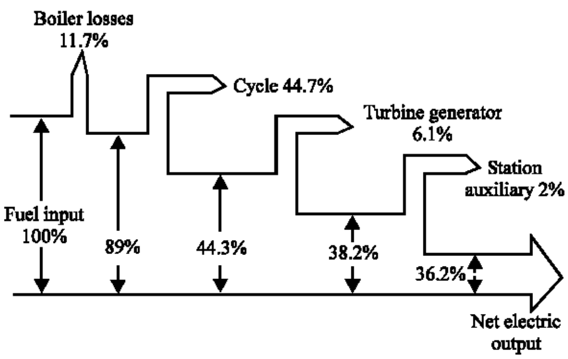

Fig. 6: Plant losses

Motors: Assessment of loading condition of HT (High Tension) and LT (Low Tension), motor of boiler area, turbine area and balance of plant area. Assessment of operating parameters. Like load variation, power factor of HT and LT motors consuming power more than 50 kW. Identification of possible energy conservation options in this area (with latest techniques like VFD).

Capacitors: Assessment of health of capacitors.

Plant lighting system: Lighting load survey and assessment of ILER (Installed Load Efficiency Ratio) at various areas of plant assessment of present lighting controls identification of energy conservation operation opportunities.

Fans performance: Fan loading and combined efficiency of fans motor. Specific energy consumption (ID, FD, PA fans) input power measurement.

Pump performance: BFPs, CEPs, Auxiliary CWP and CWP and pump consuming power more than 50 kW.

Check the performance of the pump by comparing the corrected measured flow at operating speed todesign speed with that of the expected flow derived from the characteristics curve against the correctedtotal dynamic head at design speed:

- Determine pump efficiency as the ratio of power input to thepump shaft to hydraulic power
- Obtain specific power consumption

Balance of plant

Compressed air system:

- Check volumetric efficiency of compressor
- Free air delivery of compressor
- Assessment of compressor air leakage quantity
- Assessment of specific power consumption
- Study of compressed air network and suggest suitable energy saving options

Air conditioning system: Performance evaluation with respect to net cooling, refrigeration capacity, along withheat load of air handling unit and energy requirement at operating conditions.

Ash plant: Performance of Ash slurry pumps through power measurement and flow measurement. Ash/water ratio assessment and recommendations for optimizations inwaterand power consumption.

Cooling tower performance: Establishment of liquid/gas ratio. Fan efficiency as the ratio of shaft power developed and theworks done by the fan. Coolingtower effectiveness, approach and range. Cooling capacity.

RESULTS AND DISCUSSION

Coal handling plant: Input power measurement of all the key equipment of the CHParea like paddle, feeders, conveyors, stackers and recamier, wagon tippler crushers. establishment of specific energy performance indicatorsinstrument used was dulycalibrated from NABL accredited lab as per ASME specified to get the most reliable data.

Parameters required for energy audit: Auxiliary power consumption for pump, fans and compressors (As per BEE recommendations), i.e., designed and measured (Table 11).

Pump efficiency:

$$\frac{\text{Discharge (m}^3\text{/sec)} \times \text{Total Head (HD - HS)(m)} \times \text{density(kg/m}^2\text{)/1000}}{\text{Power input (kW)}}$$

Table 11: Energy audit parameters

Item	Units
Unit load	MW
Grid frequency	Hz
CEP flow	TPH
Condenser pressure	kg/cm^2
Hotwell level	m
Suction pressure	kg/cm^2
Discharge pressure	kg/cm^2
Total head	kg/cm^2
Suction temperature	0_c
CEP motor power input	kW
Liquid kW	kW
Efficiency comb.	
(Pump+motor)	(%)
Load on motor	(%)
Load on flow	(%)
Load on head	(%)
SEC (specific energy consumption)	kWh/tone

Table 12: Air compressor's parameters

Parameter	Unit
Trial time	
Initial Pressure (P_1)	kg/cm^2
Final Pressure (P_2)	kg/cm^2
Atmospheric Pr (Po absolute)	kg/cm^2
Ambient temp (t)	°C
(Receiver+Pipeline Volume) V	m^3
Time (T)	Min
Capacity at ambient temp	Nm^3/min
FAD (at NTP)	Nm^3/min
Design (FAD) at NTP	Nm^3/min
Actual power consumption	kW
Design power consumption	kW
Actual SEC	$kW/Nm^3/min$
Design SEC	$kW/Nm^3/min$

Fan efficiency (Mechanical):

$$\frac{\text{Volume (m}^3\text{/sec)}\times\text{AP(Total Pressure) mmwc}}{102\times\text{Power input to the shaft (kW)}}$$

Performance demonstration of various air compressors (Table 12):

$$Q = \frac{P_2 - P_1 V}{P_0}\times\frac{Nm^3/min}{T}$$

Observation during audit: (Performance text is conducted at load factor more than 80%). Implementation of energy conservation measures will reduce the auxiliary power from 9.61-7.82% after recommendation of corrective measures (Table 13 and 14).

Types of measures suggested measures for saving:

Total saving in MWh/month = 29124.5 MWh/year

Total saving in MWh/years = 349506 MWh/year

Total saving in milion units/years = 349.506 Mus/year

Table 13: Performance report of various sections

Particulars	Actual power, (kW)	Actual gross gen. (%)	Possiblegross gen. (%)
BFP (u. 1-4)	20455	2.97	2.28
CEP	6604	0.34	0.27
ID fans	22436	1.17	0.86
FD fans	7646	0.40	0.33
PA fans	19140	1.00	0.86
Mills	14926	0.78	0.67
BCP (u. 5-7)	1725	0.14	0.09
In house auxiliary	92936	4.85	3.91
CHP	4334	0.23	0.15
AHP	5899	0.31	0.20
WTP	1295	0.07	0.07
Air com pressor	2160	0.11	0.10
CWP and CT	33639	1.76	1.50
GSP/ACW	4530	0.24	0.22
Outlaying auxiliary	51861	2.71	2.24
Lt and other losses	23243	1.21	1.01
Discom power	292	0.02	0.02
Generator excitation power	1918	0.28	0.22
GT and ST losses	4259	0.22	0.22
Total	1745	9.11	7.47
MD BFP operation	6584	0.54	0.33
Abnormal cyclic opn.	2993	0.16	0.14
Total station aux. power	184089	9.61	7.82

Table 14: Power saving measures

Type of measures	Power saving MWh/month
Immediate	
ESP transformer management, optimizing water to ash ratio reducing air leakage in compressor, reducing pressure of service air compressor to 4 kg/cm^2 cleaning of equipment and coolers, increasing FD fan discharge pressure, online computation of flue gas flow, optimizing voltage level at motor terminal avoiding overloading of motor, other all possible technical deficiencies	500.67
Medium term	
Use of digital AVR, Replacement of APH seals, Ammonia Dozing in ESP, overhauling of all pump, fan, reducing air ingress in F.G. duct, optimizing discharge PA fan pressure, VFD for seal air fan, reducing pressure drop across APH, Mill maintenance, motor controller for conveyor	20152.28
Long term	
Installation of VFD for ID, FD, PA and fixed capacitor bank at VAT and ST secondary	8472.55

Calculation of CO_2 emission factor: CO_2 emission factor before energy conservation measures for auxiliary power for the year 2015-16 (Thermal power plant under case study CSTPS chandrapur).

$$\text{Specific } CO_2 \text{ emission} = \frac{\text{Absolute } CO_2 \text{ emission}}{\text{Net generation}} = \frac{12994153.8}{11158.697}$$

$$\text{In mus} = 1.16 \text{ tons of } CO_2/MWh$$

CO_2 emission factor after energy conservation measures for auxiliary power (thermal power plant under case study):

$$\text{Net generation will increas} = \frac{12994153.8}{(11158.697+349.50)} =$$

$$\frac{12994153.8}{11508.1} = 1.12 \text{ tons } CO_2/\text{MWh}$$

$$\text{Total saving} = (1.16 - 1.12) = 0.04 \text{ tons/MWh}$$

$$CO_2 \text{ reduction/year} = (1.16 - 1.12) = 13980.24 \text{ tons } CO_2/\text{year}$$

CONCLUSION

By applying various energy conservation measures for auxiliary (or in house power) in thermal power plant. CO_2 emission factor will reduce from 1.16 tons of CO_2/MWh to 1.12 tons of CO_2/MWh and total CO_2 emission reduction will be 13980.24 tons of CO_2/annum. Thus we can say that energy environment implication can be reduced by reducing CO_2 emission by the application of electrical energy audit in thermal power plant.

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