Energy Audit of Boiler Feed Pump System and Air Compressors in a Thermal Power Plant

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Abstract: The results from the energy audit from KOTHAGUDEM Thermal Power Station, Andhra Pradesh have been presented in this paper. Study of heat transfer, effectiveness, proportioning of heat and pressure drop in the heat exchangers of water steam circuit, study of auxiliary power consumption; overall performance evaluation such as gross and the net overall Efficiencies, Boiler Efficiency, Boiler Pump Efficiency, Air Compressor Efficiency, Evaporation Losses and Blow Down Losses of Cooling Tower etc. Results from such a study at 500MW Power Plant are presented in this report.

The Variable Speed Drive system of Boiler feed pump system replaces Hydraulic Coupling method which is energy efficient and the energy conservation technique of using Air compressors improve the efficiency of thermal Power Plant.

keywords: Energy audit, thermal Power Station, efficiency, losses, Combustion.

INTRODUCTION

Energy auditing of a Thermal Power Plant involves the study Of Boiler System, Electrical System, Pumping System, Air Compressor System. This project analysis the performance Assesment of Boiler feed pump and techniques of improving the energy conservation of air compressors of a 500MW. KOTHAGUDEM

I. PROFILE OF KOTHAGUDEM THERMAL POWER PLANT

KOTHAGUDEM thermal power station is a coal, fired thermal power generating station with a total installed capacity of 1180 MW out of which KTPS-A station has two stages. Stage – I consists of two units 1 & 2 and stage-II consists of two units 3 & 4 each of 60MW capacity. The KTPS-B, station stage-III consists of two units 5 & 6 of each 110MW capacity and KTPS-C, station stage-IV consists of two units 7 & 8 each of 110MW. Recently during 1996, one more stage KTPS-V stage was constructed which consists of two units 9 & 10 each of 250MW.

The KTPS-V stage is highly technical and has more advantages.

Units 9 & 10 of KTPS-V stage were successfully Completed and commissioned in a record time of 31 & 28 Months respectively after commencement of work.

Thus the total installed capacity of the plant is:

KTPS-A Station:4 * 60 = 240 MW (commissioned in the year 1996)

KTPS-B Station: 2 * 110 = 220 MW (commissioned in the Year 1973)

KTPS-C Station: 2 * 110 = 220 MW (commissioned in the Year 1976)

KTPS-V Station: 2 * 250 = 500 MW (commissioned in the year 1996)

Total : 1180 MW

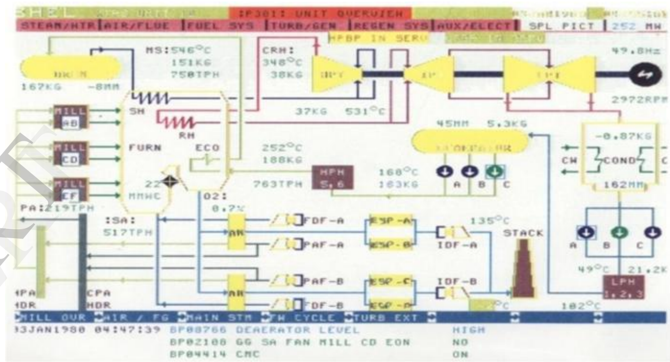

Figure 1 plant overall energy generation and consumption

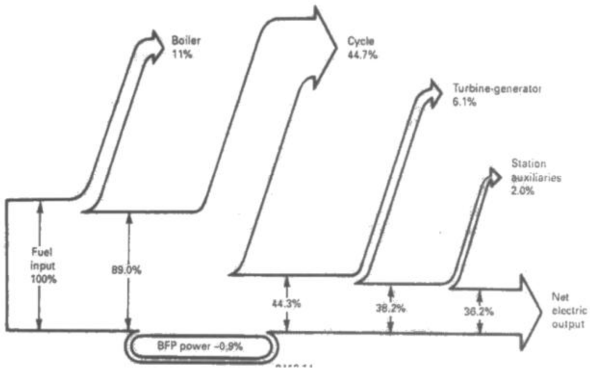

Figure2 various losses of thermal power plant

ENERGY AUDIT

The objective of energy auditing is to find out the different ways to reduce the energy consumption in different fields by elucidating the losses at various stages.

An Energy Audit can be classified into the following two types.

i) Preliminary Audit

ii) Detailed Audit

Preliminary Audit finds out all information about plant and identify the major energy consumption areas in the plant by using energy meters. In Detailed Audit different energy auditing techniques are used and methods to reduce energy consumption are suggested.

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PUMPS AND PUMPING SYSTEM

1.PUMP TYPES

Pumps come in a variety of sizes for a wide range of applications. They can be classified according to their basic operating principle as dynamic or displacement pumps. Dynamic pumps can be sub-classified as centrifugal and special effect pumps. Displacement pumps can be sub-classified as rotary or reciprocating pumps. In principle, any liquid can be handled by any of the pump designs. Where different pump designs could be used, the centrifugal pump is generally the most economical followed by rotary and reciprocating pumps. Although, positive displacement pumps are generally more efficient than centrifugal pumps, the benefit of higher efficiency tends to be offset by increased maintenance costs.

1.1 CENTRIFUGAL PUMPS

A centrifugal pump is of a very simple design. The two main parts of the pump are the impeller and the diffuser. Impeller, which is the only moving part, is attached to a shaft and driven by a motor. Impellers are generally made of bronze, polycarbonate, cast iron, stainless steel as well as other materials. The diffuser (also called as volute) houses the impeller and captures and directs the water off the impeller.

Water enters the centre (eye) of the impeller and exits the impeller with the help of centrifugal force. As water leaves the eye of the impeller a low-pressure area is created, causing more water to flow into the eye. Atmospheric pressure and centrifugal force cause this to happen. Velocity is developed as the water flows through the impeller spinning at high speed. The water velocity is collected by the diffuser and converted to pressure by specially designed passageways that direct the flow to the discharge of the pump, or to the next impeller should the pump have a multi-stage configuration.The pressure (head) that a pump will develop is in direct relationship to the impeller diameter, the number of impellers, the size of impeller eye, and shaft speed. Capacity is determined by the exit width of the impeller. The head and capacity are the main factors, which affect the horsepower size of the motor to be used. The more the quantity of water to be pumped, the more energy is required. Figure3 shows the pump performance curve.

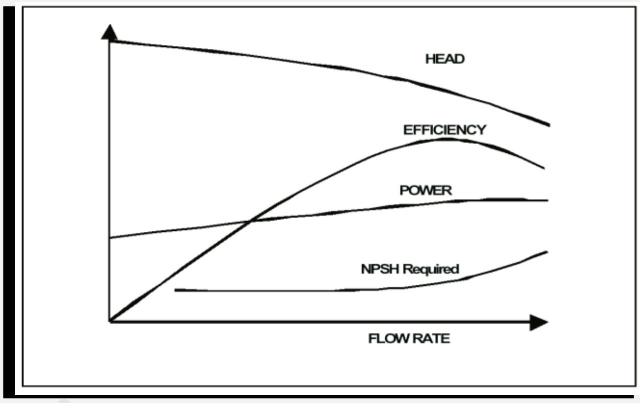

Figure3 Pump Performance Curve

2. ENERGY AUDIT OF BOILER FEED PUMPS

Function of the boiler feed pump is to pump the water from dereator to boiler drum with high pressure. There are six boiler feed pumps in the unit. Four are at running conditions, two at standby condition. Each pump capacity is 4.2MW. Rated efficiency of each pump is 80%. Energy audit techniques for speed control Boiler feed pump are as follows

2.1 HYDRAULIC COUPLING METHOD Drawback of this method is operating on full load rating irrespective of load i.e more power consumption. In this method driving shaft of motor and driven shaft are hydraulically coupled with oil casing. The scoop or coupling is varying according to load on the pump. For this 4.2MW induction motor is using.

2.2 EFFECT OF SPEED VARIATION

As stated above, a centrifugal pump is a dynamic device with the head generated from a rotating impeller. There is therefore a relationship between impeller peripheral velocity and generated head. Peripheral velocity is directly related to shaft rotational speed, for a fixed impeller diameter and so varying the rotational speed has a direct effect on the performance of the pump. All the parameters shown in below will change if the speed is varied and it is important to have an appreciation of how these parameters vary in order to safely control a pump at different speeds. The equations relating rotor dynamic pump performance parameters of flow, head and power absorbed to speed are

Flow: Flow is proportional to the speed

$Q1 / Q2 = N1 / N2$ (1)

Head: Head is proportional to the square of speed

$H1/H2 = (N1^2) / (N2^2)$ (2)

Power (kW): Power is proportional to the cube of speed

$kW1 / kW2 = (N1^3) /(N2^3)$ (3)

2.3 FORMULAE FOR CALCULATING PUMP EFFICIENCY

Pump Efficiency = Hydraulic power x 100 /power input to pump shaft --------------------------------- (1)

Hydraulic power P (kW)= Q x (h_d – h_s) x ρ x g / 1000 ------(2)

Shaft power = motor input x motor efficiency ------------- (3)

There are five boiler feed pumps are running on Hydraulic coupling method and one is on variable frequency drive method. Readings are averaged for fifteen days for all parameters of the pump and the pump efficiency has been calculated using the above formulae.

The readings of flow rate of pump are shown in the Table 1.

2.4 CALCULATIONS FOR PUMP EFFICIENCY

1. Total head (hs - hd) = 2117m, density ρ = 1000, g =9.81m\s2.

Motor efficiency = 95%

Shaft power = motor input x motor efficiency

= 4200 kw x .95 = 3990 kw

Water flow rate q=335.44 m3/hr = 335.44/3600 m3/s

Hydraulic power = q x (hs-hd) x ρ x g

= (335.44/3600) x 2117 x 1000 x 9.81/1000

= 1935.09 kw

Pump efficiency = hydraulic powerx100 / shaft power

= 1935.09kw x 100/3990 kw

= 48.50%

2. Total head (hs-hd) = 2117m, density ρ = 1000, g =9.81m/s2.

Motor efficiency = 95%

Shaft power = motor input x motor efficiency

= 4200 kw x .95 = 3990 kw

Water flow rate q = 414.66m3/hr = 414.66/3600 m3/s

Hydraulic power = q x (h_d – h_s)x ρ x g

= (414.66/3600) x 1820.64 x 1000 x 9.81/1000

= 2394.20 kw

Pump efficiency = hydraulic powerx100 / shaft power

= 2394.20 kw x 100/3990 kw

= 60.10%

Date	BFP 9A	BFP 9B	BFP 10A	BFP 10B
13.2.2010	336	420	396	410
14.2.2010	333	416	394	416
15.2.2010	343	418	396	397
16.2.2010	326	409	398	420
17.2.2010	335	425	393	421
18.2.2010	350	404	396	415
19.2.2010	346	428	407	413
20.2.2010	323	409	398	415
21.2.2010	327	403	401	413
AVERAGE	335.44	414.66	397.66	413.55
Efficiency	48.50	60.10	57.49	59.97

TABLE1 **CALCULATION OF BOILER FEED PUMPS EFFICIENCY BASED ON FLOW RATE OF WATER (m^3/hr)**

3. VARIABLE FREQUENCY DRIVE SYSTEM:

The load commutated inverter is static adjustable frequency drive system that controls a synchronous machine from near to rated speed. The rectifier is a thyristor bridge whose gating is controlled to produce a dc voltage at its output. The output of rectifier is fed through filter whose function is to smoothen the current and keep it continuous over the operating range of system. The filter output is fed into inverter bridge which provides variable frequency at the stator terminals of synchronous motor. The inverter bridge and rectifier bridge use the same power hardware and are controlled by microprocessor based electronics. A brushless exciter coupled to the motor shaft usually excites the synchronous motor field. A brushless exciter is a wound rotor induction machine whose rotor voltage is rectified to supply field current to synchronous machine.

Synchronous speed is directly proportional to frequency. By varying the frequency we can control the motor speed

$N = 120f / P$ (1)

The Figure 4 shows the variable frequency drive system

3.1 RATING OF VARIABLE FREQUENCY DRIVE AND SCOOP SYSTEM

SYNCHRONOUS MOTOR

POWER = 3900 KW

FREQUENCY = 88.82 HZ

POWER FACTOR = 0.9

SPEED RANGE = 1325 TO 5400RPM

CONNECTION = 2Y,2 X 2300V, 2X 568 A

EXCITATION 51V, 291A

SYNCHRONOUS EXCITER = 32 KW

INPUT 415V, 58V, 50 HZ

Rating of hydraulic coupling

INDUCTION MOTOR

POWER = 4200 KW

FREQUENCY = 50 HZ

STATOR VOLTAGE = 6600 V

STATOR CURRENT = 425 A

FULL LOAD SLIP = 2.1 %

MINIMUM SCOOP = 30%

AMBIENT TEMPERATURE = 50^0C

TEMP RISE OVER = 70^0C

Table 2 shows the comparison between scoop control method and VFD system for energy consumption[3].

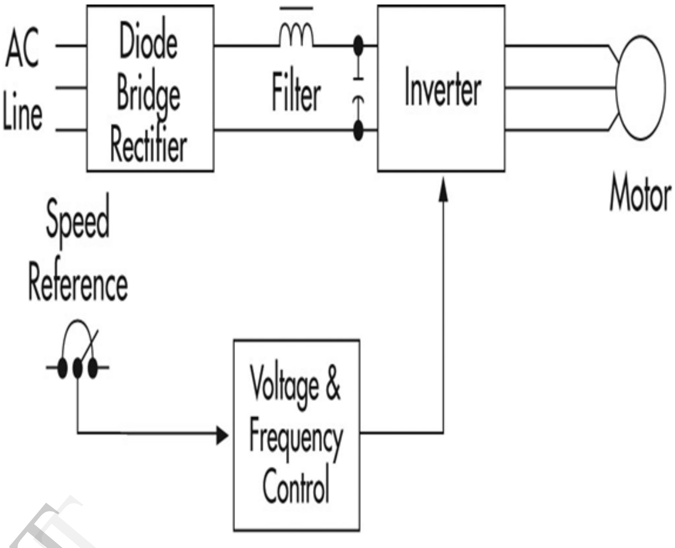

Fig4 Variable frequency drive system

DATE	SCOOP CONTROL(kw)	VFD SYSTEM (kw)
25.3.2010	3460	2750
26.3.2010	3760	3670
27.3.2010	3210	3160
28.3.2010	2840	3000
29.3.2010	3210	3160
30.3.2010	3240	3010
31.3.2010	3410	2720
1.4.2010	3670	3430
2.4.2010	2980	3140
3.4.2010	3160	3250
4.4.2010	3800	3420
Average	3348.10	3155.40

Table 2 COMPARISON BETWEEN SCOOP CONTROL METHOD AND VFD SYSTEM FOR ENERGY CONSUMPTION

3.2 PAYBACK PERIOD OF VFD SYSTEM

Average load Of BFP for scoop control 3348.1KWH

Average load Of BFP for VFD control 3155.4 KWH

Energy savings per hour =3348.1 – 3155.4 = 192KWH

Annual Energy savings = 192 x 24 x 365= 16,81,920 KWH

Extra investment for VFD = Rs.50, 00,000

Generation cost per kw = Rs1.45

Payback period = 2 years.

4. COMPRESSED AIR SYSTEM:

Air compressors account for significant amount of electricity used in Indian industries. Air compressors are used in a variety of industries to supply process requirements, to operate pneumatic tools and equipment, and to meet instrumentation needs. Only 10 – 30% of energy reaches the point of end-use, and balance 70 – 90% of energy of the power of the prime mover being converted to unusable heat energy and to a lesser extent lost in form of friction, misuse and noise.

4.1 TYPES OF COMPRESSORS

Compressors are broadly classified as: Positive displacement compressor and Dynamic compressor. Positive displacement compressors increase the pressure of the gas by reducing the volume. Positive displacement compressors are further classified as reciprocating and rotary compressors.Dynamic compressors increase the air velocity, which is then converted to increased pressure at the outlet. Dynamic compressors are basically centrifugal compressors and are further classified as radial and axial flow types[4].

1.Positive displacement type

a. Reciprocating Compressor for general applications

b. Rotary Compressor for high speed applications

2. Dynamic type

Centrifugal Compressor for high capacity applications

Reciprocating compressors are also available in variety of types:

• Lubricated and non-lubricated

• Single or multiple cylinders

• Water or air-cooled

• Single or multi stage

The Figures5 and 6 shows the different type of air compressors

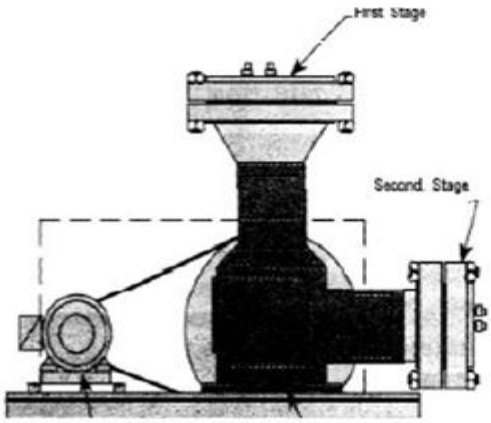

Fig5 Reciprocating air compressor

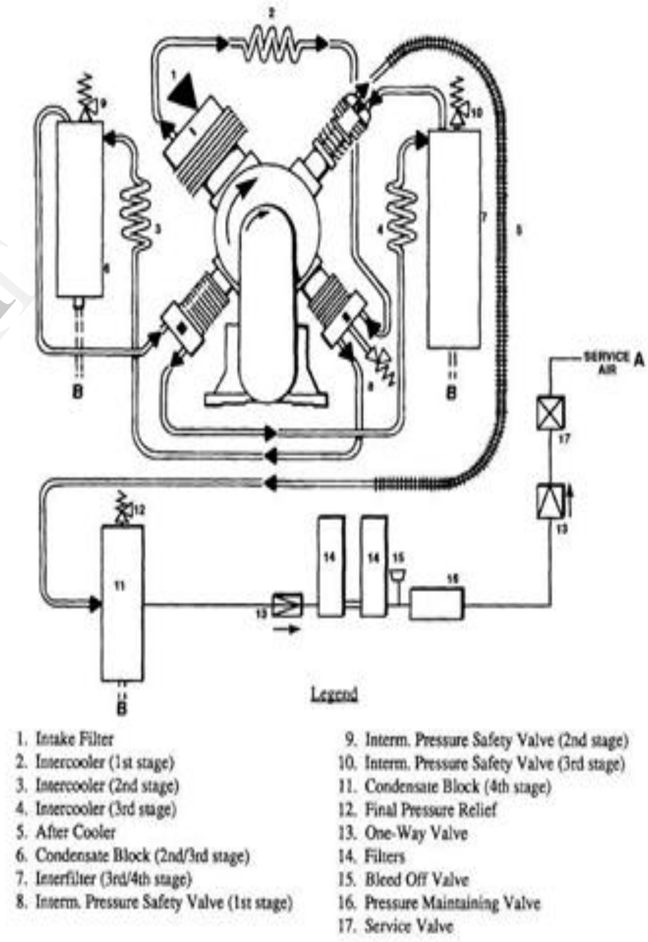

Fig6 Multistage air compressor

4.2 FORMULAE FOR CALCULATING EFFICIENCY, LEAKAGE LOSSES

FAD = V x (P2 - P1) / (Po x T) (1)

Volumetric efficiency = Free Air Delivery /compressor displacement (2)

Leakages (m^3/min) = FAD x T1 / (T1 + T2) (3)

4.3CALCULATIONS FOR COMPRESSOR EFFICIENCY

Normal rating of the compressor = 200 kw

Rated efficiency = 82 %

Rated Free air discharge = 32 m^3/min

Free air discharge Q = (8-1) x 10.5 /1 x 2.5

= 29.4 m^3/min

Compressor displacement = 38.87 m^3/min

Volumetric efficiency = 29.4/38.87

= 0.7567

= 75.67%

4.4 ENERGY CONSERVATION OPPORTUNITIES IN AIR COMPRESSOR SYSTEM

1.Ensure air intake to compressor is not warm and humid by locating compressors in well ventilated area or by drawing cold air from outside. Every 4°C rise in air inlet temperature will increase power consumption by 1 percent.

2. Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm Water column pressure drop across the filter.

3. Keep compressor valves in good condition by removing and inspecting once every six Months. Worn-out valves can reduce compressor efficiency by as much as 50 percent.

4. Install manometers across the filter and monitor the pressure drop as a guide to replacement of element.

5. Minimize low-load compressor operation; if air demand is less than 50 percent of compressor capacity, consider change over to a smaller compressor or reduce compressor speed appropriately (by reducing motor pulley size) in case of belt driven compressors.

6. Consider the use of regenerative air dryers, which uses the heat of compressed air to remove moisture.

7. Fouled inter-coolers reduce compressor efficiency and cause more water condensation in air receivers and distribution lines resulting in increased corrosion. Periodic cleaning of intercoolers must be ensured.

8. Compressor free air delivery test (FAD) must be done periodically to check the present operating capacity against its design capacity and corrective steps must be taken if required[5].

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Biographies:

G.R.Mahesh was born in India in 1992. He is pursuing B.Tech final year in KL University in Electrical and Electronics Engineering and attained specialization in ENERGY SYSTEMS. His field of interest is Energy Systems and Power Systems. He is presently working as **Student Convenor** of **ENERGY CLUB** in K L University, Elected as **Executive Council Member** from the Department of EEE and conducted workshops in and around A.P, **Vice Chairman** of EYE CROSS FOUNDATION, a social service organisation.

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M.V.Giridhar was born in India in 1992. He is pursuing B.Tech final year in KL University in Electrical and Electronics Engineering and attained specialization in ENERGY SYSTEMS. His field of interest is Energy Systems. He is presently working as Secretary of ENERGY CLUB in K L University, Secratary of EYE CROSS FOUNDATION, a social service organisation