Power Management
in
Captive Cogeneration Plant

A Project Report

Submitted by

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in partial fulfillment for the award of the degree
of

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PEDC'06

NATIONAL CONFERENCE ON POWER ELECTRONICS & DRIVES

08 th MARCH 2006

CERTIFICATE

This is to certify that Mr/Ms/Mrs. K. DEEBAA *has participated and presented a paper titled* Power management in captive cogeneration plant using industrial drive *in the NATIONAL CONFERENCE ON POWER ELECTRONICS & DRIVES, PEDC'06 organized by Department of Electrical & Electronics Engineering, A.C.College of Engineering & Technology, Karaikudi-4 under Technical Education Quality Improvement Programme (TEQIP) on 8th March, 2006.*

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ABSTRACT

The Indian Industry is a blend of variety of different vintage, varied technologies, capacities and Efficiencies. The Industry also had continuously undertaken improvement opportunities wherever possible and increased their efficiencies and is comparable with the best in the world.

To replicate these efforts and achieve National level improvement there is a need to widely disseminate the information on the major energy conservation projects implemented by these efficient plants. Towards achieving the above objective, this project has been prepared. This project deals with the reduction of power consumption in Captive Cogeneration Plant which is present in paper mill.

The Captive Cogeneration plant is self power producing plant which supplies a part of power to meet the power demand in paper mill. The main power consumption in Captive Cogeneration plant is the auxiliary equipment's power consumption. By reducing this power consumption the net power production gets enhanced. This can be achieved by using optimizing techniques in order to reduce the cost of product obtained in an industry.

The energy consumption per unit output should reduce in order to enhance the plant efficiency. The optimizing technique used here is usage of high efficient unit, usage of energy efficient motor, cycle efficiency improvement and usage of best optimizing tool **Variable Frequency Drive.**

This process helps in decreasing the auxiliary consumption, which results in proper usage of power and this tends the reduce in accessing of power from grid. This results in obtaining of cost benefit product from industry, which could be helpful to society.

ஆய்வுச்சுருக்கம்

இந்திய தொழிற்சாலை ஒரு மிகப்பெரிய அளவிலும், பொருளாதாரத்திலும், வளர்ச்சியிலும் மற்ற நாடுகளை விட வேறுபட்டுள்ளது. இப்பொழுதுள்ள தொழிற்சாலை மிகவும் வளர்நது வரும் நிலையிலும், பெருகிக் கொண்டு வரும் நிலையில் உள்ளதால் உலகிலேயே சிறந்த இடத்தை பிடித்துள்ளது.

திறமையை வெளிப்படுத்தி இந்திய நாட்டின் முன்னேற்றத்திற்காக நிறைய கண்டுபிடிப்புகள் நடந்து வருகிறது. இந்திய அளவில் முன்னேற்றத்திற்காக இந்த திட்ட அறிக்கை ஆய்வு செய்யப்பட்டுள்ளது.

இந்த விளக்கவுரையின் மூலம் காகிததொழிற்சாலையின் இருஇணைப்பு வாரியத்தின் மின்சார சேமிப்பு என்பதை விளக்கவுள்ளது. இருஇணைப்பு வாரியத்தின் மூலம் காகித தொழிற்சாலைக்கு மின்சாரம் அனுப்பப்படுகிறது. இந்த மின்சாரத்தை தேவைக்கேற்ப உபயோகித்து மேற்கொண்டு தேவைப்படும் மின்சாரத்தை மின்சார வாரியத்திலிருந்து எடுத்துக் கொள்ளப்படுகிறது.

இந்த இருஇணைப்பு வாரியத்தில பெரும் மின்சாரத்ததை உபயோகிப்பது தனிப்பட்ட சிறு சிறு மின்சார உபயோகிக்கும் கருவி மூலமாக குறைத்தால் மின்சாரத்தை சேமிக்க முடியும். ஒரு யூனிட்டுக்கு செலவாகும் மின்சாரத்தை குறைத்தால் வாரியத்தின் உற்பத்தியை அதிகரிக்கலாம். சிறந்த முறையில் மின்சாரத்தை சேமிக்கும் முறையாக வேகமாற்று கருவி மூலம் சரிவர மின்சாரத்தை பயன்படுத்தலாம். மிக சிறந்த முறையில் உபயோகிக்கும் மோட்டர், மிகசிறந்த கருவியை உபயோகிப்பதால் மின்சாரத்தை சேமிக்கலாம். இதன் மூலம் பொருளாதார வளர்ச்சி அடையலாம்.

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E_1 : Extraction 1 of steam turbine

E_2 : Extraction 2 of steam turbine

C : Condensate of steam turbine

h_0 : Steam enthalpy at turbine inlet at pressures p_0 and temperature t_0 kcal/kg

h_1 : Steam enthalpy at turbine Extraction 1 pressures p_1 and temperature t_1 kcal/kg

h_2 : Steam enthalpy at turbine Extraction 2 pressures p_2 and temperature t_2 kcal/kg

h_3 : Steam enthalpy at turbine Exhaust pressures p_3 and temperature t_3 kcal/kg

E_{stage} : Efficiency per stage in %

W_{net} : Net Power Output KW

Q_1 : Rate of Heat input kJ/s

W_T : Power Output obtain from the Turbine kW

W_P : Power Output obtain from the Pump kW

P_{E1} : Power at Extraction 1 of the Turbine kW

P_{E2} : Power at Extraction 2 of the Turbine kW

P_C : Power at Exhaust of the Turbine kW

K_{E1} : Constant for Extraction 1 of steam turbine

K_{E2} : Constant for Extraction 2 of steam turbine

K_c : Constant for Exhaust of steam turbine

Q : Flow of water in pump (m^3/s)

h_d : Discharge head (m)

P : Suction Pressure (psi)

h_s : Suction head (m)

ρ : Density of the induced draft (kg/m^3)

g : Acceleration due to gravity (m^2/s)

HP : Pump Horsepower (hp)

GPM : Flow rate in gallons per minute

P_2 : Discharge pressure (psi)

CHAPTER 1

POWER SUPPLY TO PAPER INDUSTRY-AN INTRODUCTION

1.1 INTRODUCTION:

Today's world is focusing on the usage of power with high efficient and with the less cost. Energy scenario in India, where power cost are increasing and the gap between demand and supply from installed capacities is wide, it is imperative for new industries to plan Captive power generation.

Cogeneration in captive power will provide high efficient production of power in Industry. Conventional power generation, on average, is only 35% efficient; up to 65% of power is released as waste heat. More recent combined cycle generation can improve this to 55% excluding losses for the transmission and distribution of electricity.

Cogeneration reduces this loss by using the heat for industry, Commerce & home heating/cooling. Cogeneration is the simultaneous generation heat and power from a single primary source fuel as shown in Figure 1.1. This produces high efficient system with great reliability.

FIGURE 1.1 DEFINITION OF COGENERATION SYSTEM

Such an application where the electrical power and process heat requirement are meet from the fuel is termed as Cogeneration. So this Cogeneration plant offers 80-92% efficiency.

This project deals with the reduction of Power Consumption in Cogeneration plant at "SESHASEYEE PAPER AND BOARDS" by optimization techniques in order to reduce the cost of product obtained in an industry.

1.2 COMPANY PROFILE:

"M/S., SESHASAYEE PAPER & BOARDS" was incorporated in 1960. The company is promoted and managed by Seshasayee group. The main Business Profile of Seshasayee Paper & Boards is Erode (Tamil Nadu). The company's plants are located in paper and paperboard.

"M/S.,SESHASAYEE PAPER & BOARDS" is planning to set up an Implementing unit, a 55,000 tonne expansion of the paper & boards plant at Pallipalayam (Salem, Tamil Nadu). at a cost of Rs 187 crores."M/S.,SESHASAYEE PAPER AND BOARDS LTD" will set up a new pulp mill with enough capacity to meet its present requirement and any expansion it may consider later.

The company is also getting into contract farming of pulp wood plantations, which would be a captive source of wood. According to company officials, the board has, in principle, approved the investment for the pulp mill but the details are being worked out. The new pulp mill, which will replace the existing one, will double Seshasayee Paper's pulping capacity to about 500 tones a day, enough to handle even future expansion. The existing mill, which produces about 240 tones of pulp, meets about 75 per cent of its pulp requirement and the balance is met through imports. Its paper mill produces about 330 tones of paper a day. The pulp mill and a 20-megawatt (MW) captive power plant that were recently commissioned represent significant advantages to the company.

The power plant represents a saving of about Rs 1,500 in energy cost on every tones of paper. For a mill that produces about 1.20 lakh tones paper a year, the savings are huge. Similarly, raw material will also be produced in-house, which means that the company will not have to depend on imported pulp, and can insulate itself from price rise and fluctuations.

The modern pulp mill will offer other advantages such as environmental compliance. Also tied in with this project are additional facilities that will help recover steam and generate power. The company is optimistic about its performance for the coming year with the market expected to be buoyant and costs under control.

The company is tying up with farmers for cultivating casuarinas and eucalyptus, which can be used for making pulp. By November, it would have about 3,000 acres under the scheme and it is targeting 6,000 acres for the next year.

The company has reported a profit after tax (PAT) of Rs 6.58 crores on sales of Rs 354.29 crores for the year ended March 31, 2005. This is against a PAT of Rs 19.66 crores on sales of Rs 344.20 crores last year.

The company has attributed the drop in profit to the 20 - 25 per cent hike in the cost of fuel and raw materials, including wood, bagasse, coal and lignite. Also, the reduction in value of duty entitlement passbook licenses and the increase in employee cost following a wage settlement had driven up costs.

It produced 1.18 lakh tones (1.17 lakh tones) of paper and sold its entire production to achieve nil stock on March 31, 2005. The board has recommended a divided of Rs 1.80 (18 per cent) a share for 2004-05.

1.3 POWER SUPPLIED TO PAPER INDUSTRY:

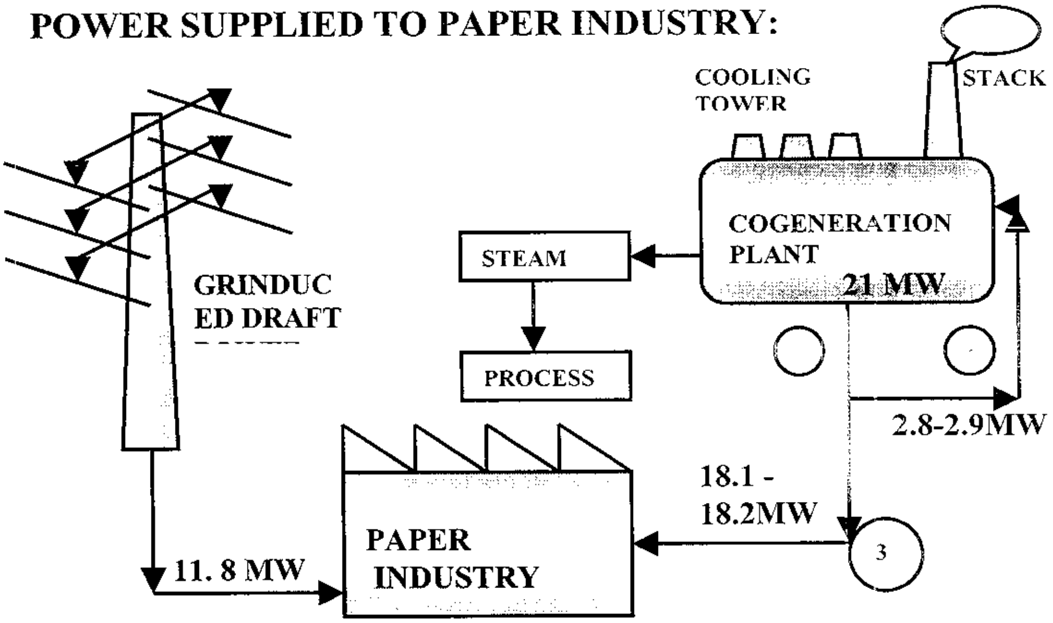


FIGURE 1.2 PAPER INDUSTRY POWER SUPPLY DIAGRAM

1 - Total Power Generation

2 - Station Power Consumption

3 - Net Power Available

$$\left\{\begin{matrix}\text{Net Power}\\ \text{Available}\end{matrix}\right\} = \left\{\begin{matrix}\text{Total Power}\\ \text{Generation}\end{matrix}\right\} - \left\{\begin{matrix}\text{Station}\\ \text{Power Consumption}\end{matrix}\right\}$$

The Paper Industry access about 30 MW of Power. The Captive Cogeneration present will produce total power generation of 21 MW within which about 2.8 -2.9 MW of Power required for the Auxiliary equipment present to generate Power. Nearly 18.1-18.2 MW of power supplied to the Paper Industry. The rest power demand from the grid power supply , about 11.8 MW as shown in Figure 1.2.

1.4 OBJECTIVE:

The Main objective of this project,

- To reduce the Station power consumption in Cogeneration plant by using Optimizing Techniques..
- To enhance the Net power production.
- For productivity Enhancement.

- Reduce the cost of Power and reduce accessing of grid Power.
- To produce Cost Benefit Quality Product ,this could be helpful to Society.

1.5 ENERGY EFFICIENT SUPPORTING PROJECT:

Cogeneration as a Technology has been in existence for over several decades now, but was not given due attention by the industrial sector as a cheap power and fuel were abundantly available .

However, after the 1970s, the Energy crisis has forced industries to adopt energy efficient technologies and reduce excessive dependency on external energy supply. The energy efficient technology, cogeneration felt increasingly today in India because of increased energy shortage.

This project support the efficient technology ,Cogeneration to be more efficient by using optimizing tool for the equipments in cogeneration plant.

1.6 SECTOR COVERAGE:

This project covers the sector of "M/S.,Seshasayee Paper and Boards Cogeneration Plant" Cogeneration is an Energy Efficient Technology as it utilizes the low grade exhaust heat from the steam turbine for process heating.

This enhances the efficiency of Energy utilization from 35% in the Conventional power generating system to 70 – 90 % in the Cogeneration system.

The steam turbine used in "M/S.,Seshasayee Paper and Boards Cogeneration Plant" Are "Double Extraction Cum Condensing".

The system operates on "Rankine Cycle", and works on the characteristics of "Topping Cycle", where a high temperature fluid drives an Engine to produce Electricity, Low temperature heat is used for Process Heating required for Paper Mill. M/S.,Seshasayee Paper and Boards Cogeneration Plant model is shown in the Figure 1.3

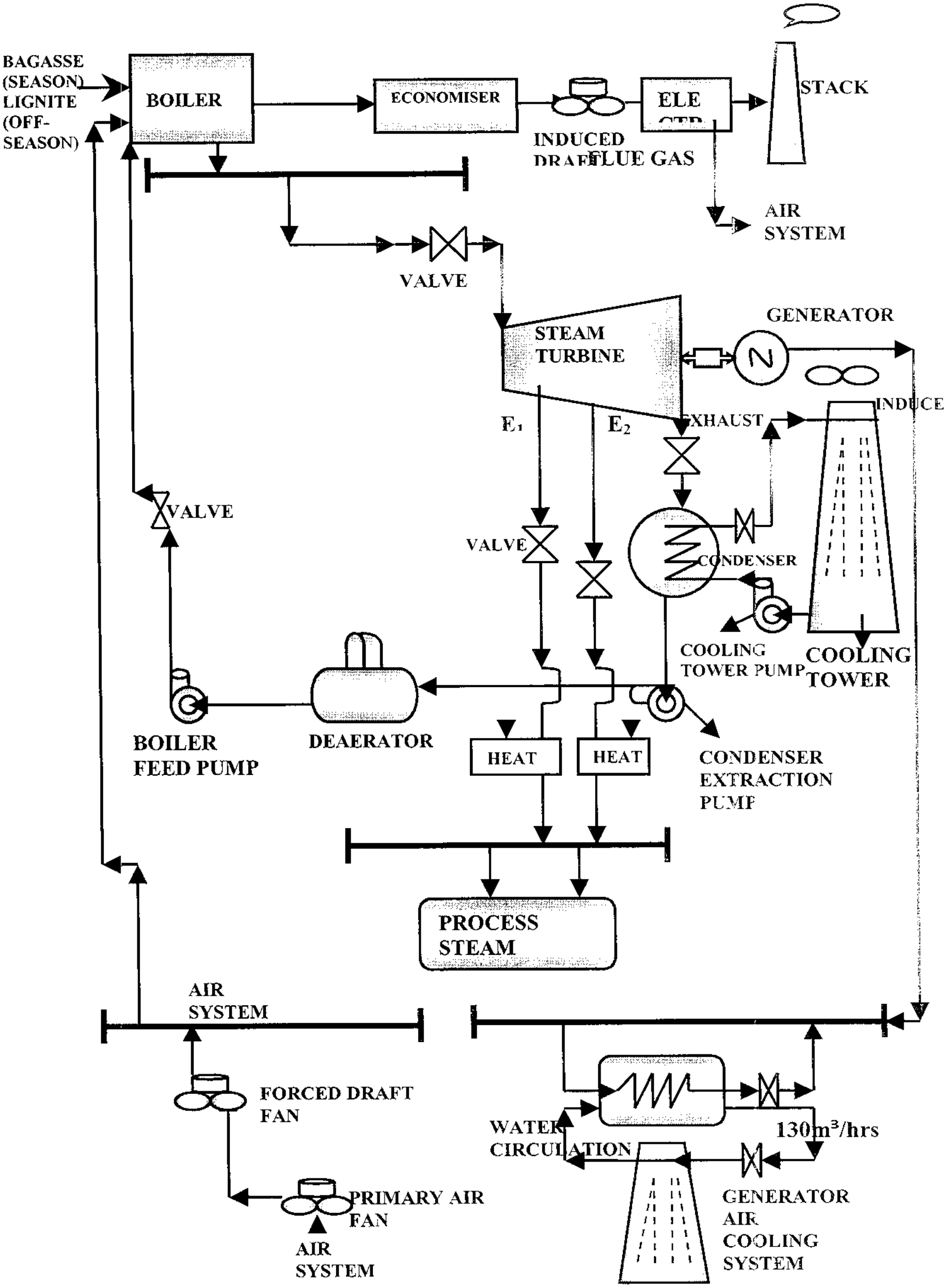


FIGURE 1.3 SCHEMATIC REPRESENTATION OF CAPTIVE COGENERATION PLANT

1.7 KEY AREAS OF ENERGY CONSUMPTION:

From the Figure 1.4 key areas constitute the distribution and wastage of Total Energy.

1.7.1 BOILER:

As far as the boiler is concerned about 14% of the input energy is lost. Due to design factor and the varying quality of coal, certain amount of inefficiency is in evitable. However continuous monitoring of the boiler performance helps keeping these looses within the accepted levels.

The recently installed captive co-generation plant consists of a high pressure atmospheric bubbling fluidized bed steam generator (hereafter termed as boiler) and a matching 21 MW double extraction condensing steam turbine.

In this boiler, the crushed coal is injected into the fluidized bed just above air distribution grid at the bottom of the bed. The air from the forced draft fan flows upward through the grid from the air plenum into the bed where combustion of local occurs. The combustion products leaving from the combustion chamber is having a large number of carbon particles and it is collected ink cyclone separator and it is again fed back to the bed.

The high pressure boiler is firing coal as fuel for generating rated steam at the rated steam pressure (105 bars) and temperature (510 ° C).

The boiler is connected to the steam turbine through the heavily insulated high-pressure main steam pipeline.

There is provision for part by passing of the high-pressure steam located at the boiler exit. The small amount of steam at high pressure and temperature is led to pressure reducing de-super heating unit, from where the medium pressure steam is taken for process use or low-pressure power generation.

1.7.2 TURBINE:

It is about 47% of the input energy is lost as steam at the turbine end alone, this steam could be used for process heating in order to reduce the losses.

1.7.3 AUXILIARY CONSUMPTION:

From the net output of 38% about 4-5% is consumed, as the auxiliary power required generating the output. These system include coal handling, fuel oil handling, Water pumping, compressors, fans, pumps, lighting etc., Only part of this consumption contribute to actual generation. Remaining consumption is very much under the control of engineers. Correct adoption of operating practices.

Correct monitoring of the parameters, Correct loading of different units etc., can result in sizeable amount of savings in the auxiliary consumption resulting in reduced consumption of coal, reduced production of CO_2 and reduce in cost of energy supplied.

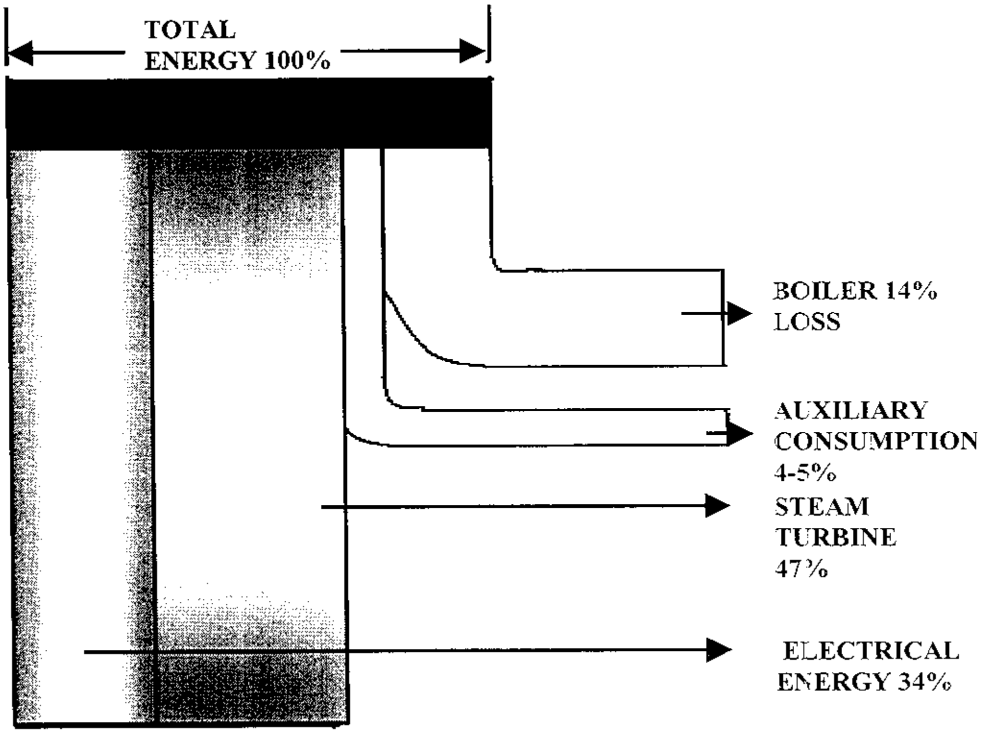


FIGURE 1.4 DISTRIBUTION AREAS OF ENERGY CONSUMPTION

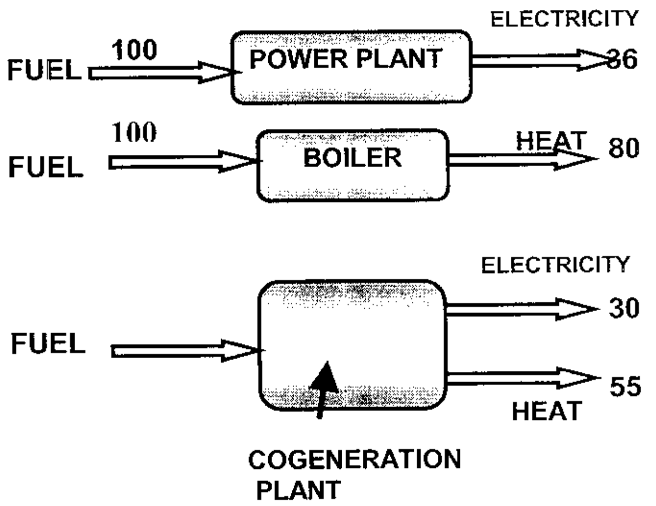
CHAPTER 2

CAPTIVE COGENERATION PLANT-A STUDY

2.1 COGENERATION SYSTEM:

Cogeneration is defined as the concurrent generation of process heat and motive power in an Industry by the sequential use of energy from a common fuel source; depending on the quality of process heat required.

2.2 DIFFERENCE BETWEEN CONVENTIONAL POWER PLANT AND COGENERATION PLANT:



TOTAL EFFICIENCY

$\eta = (36 + 80)/ 200 = 0.58$
$= 0.58 \times 100 = 58\ \%$

$\eta = (30 + 55)/ 100 = 0.85$
$= 0.85 \times 100 = 85\ \%$

Cogeneration produce about 25-50% higher Efficiency than Conventional Power Plant.

2.3 TYPES OF COGENERATION SYSTEMS:

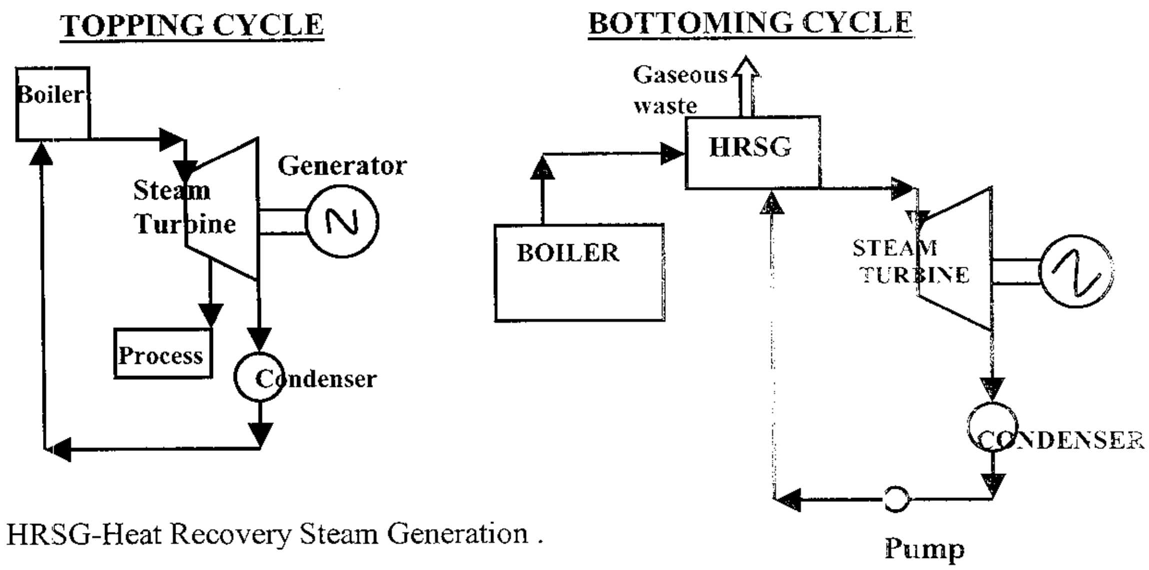
Depending on the "Quality of Process Heat Required". It may be divided on

- **TOPPING CYCLE**
- **BOTTOMING CYCLE**
- **COMBINED CYCLE**

2.3.1 TOPPING CYCLE:

In Topping systems, a high temperature fluid drives an Engine to produce Electricity, while Low temperature heat is used for thermal processes or space heating as shown in Figure. 2.1

Eg; Sugar mill, Paper mills, etc.,



HRSG-Heat Recovery Steam Generation .

FIGURE 2.1 TOPPING CYCLE AND BOTTOMING CYCLE.

2.3.2 BOTTOMING CYCLE:

In Bottoming systems, high temperature heat is first produced for a process and after the process hot gases are used either directly to drive boiler , which drives a steam turbine generator as shown in Figure 2.1.

Eg: cement kiln , glass works, etc.,

2.3.3 COMBINED CYCLE:

The term "combined cycle" is used for systems consisting of two thermodynamic cycles, which are connected with a working fluid and operate at different temperature levels. The high temperature cycle [topping cycle] rejects-heat, which is recovered and used by the low temperature cycle [bottoming cycle] to produce additional electrical [or mechanical] Energy, thus increasing the electrical efficiency.

Depending on the "Types Of Prime Mover" it is divided as shown in Table 2.1.

TABLE 2.1 TYPES OF COGENERATION BASED ON TYPES OF PRIME MOVER

PRIME MOVER	FUEL USED	SIZE RANGE (MWe)	HEAT POWER RATIO	ELECTRICAL GENERATING EFFICIENCY	TYPICAL OVERALL EFFICIENCY	HEAT QUALITY
Pass out steam Turbine	Any fuel	1 to 100 +	3:1 to 8:1+	10 -20 %	Up to 80 %	Steam at 2 press or more
Back pressure steam turbine	Any fuel	0.5 to 500	3:1 to 10: 1+	7-20%	Up to 80%	Steam at 2 press or more
Combined Cycle Gas Turbine	Gas Biogas LPG Naphtha	3 to 300+	1:1 to 3:1*	35-55%	73-90%	Medium grade steam high temperature hot water
Open cycle gas turbine	Gas Biogas Naphtha	0.25 to 50+	1.5:1 to 5: 1*	25 -42%	65-87%	High grade steam high temperature hot water
Compress. Ignition Engine	Gas Biogas Naphtha	0.2 to 20	0.5:1 to 3:1 Alfa value 0.9-2	35 -45%	65-90%	Low pressure steam low and medium temperature hot water
Spark Ignition Engine	Gas Biogas Naphtha	0.003 to 6	1:1 to 3:1 Alfa value 0.9-2	25-43%	70-92%	Low and Medium temperature hot water

*Highest heat: power ratios for these systems are achieved with supplementary firing

2.3 BENEIFTS OF ADOPTION OF HIGH EFFICIENT COGENERTATION SYSTEMS:

The installation of high efficiency systems results in the following benefits:

Capital cost: A Cogeneration plant is about 25% cheaper than a conventional one.

Implementation period: A cogeneration plant can be setup and commissioned with in 12 to 18 months.

Profitability: Pay back period of 3 years, at current state electricity board off – take tariff rates.

Fuel conservation: Larger dependence on fossil fuels like coal coupled with relatively pollution-free operation. This technology enhances the efficient of energy utilization from 35% in the conventional power generation system to 70-90% of cogeneration system.

2.4.1 CHEAP SOURCE OF POWER :

Industries that use economic cogeneration systems even without supplying to the utility usually pay off their investment within three years.

2.4.2 LOW GESTATION PERIOD:

Cogeneration plants can normally be commissioned within two years from the conception of the project. Coal thermal power plants normally take about five years before commissioning, whereas gas based power plants normally take about three years before commissioning. Under the current situation of extreme power shortages. Cogeneration potential should be exploited to bridge the gap between demand and supply and preference should be given to cogeneration which is not only a long term option but also environmentally sound.

2.4.3 LOW POLLUTION LEVEL:

All stages of energy conversion paths normally result in emissions; the most critical pollutants are CO_2,SO_2 ,NO_2 and particulates. These are significantly reduced due to low fuel consumption levels in Cogeneration systems.

CHAPTER 3

FOCUS AREAS AND ENERGY CONSUMPTION IN COGENERATION POWER PLANT

3.1 ENERGY CONSUMPTION IN COGENERATION POWER PLANT:

The target energy consumption for captive cogeneration plant

Specific Electrical Energy consumption: 1.97 -2.991 MW

Specific Thermal Energy Consumption: 4200- 4500 Kcal /kg

The break up of specific electrical energy consumption is as Shown in Table 3.1:

TABLE 3.1 ELECTRICAL ENERGY CONSUMPTION

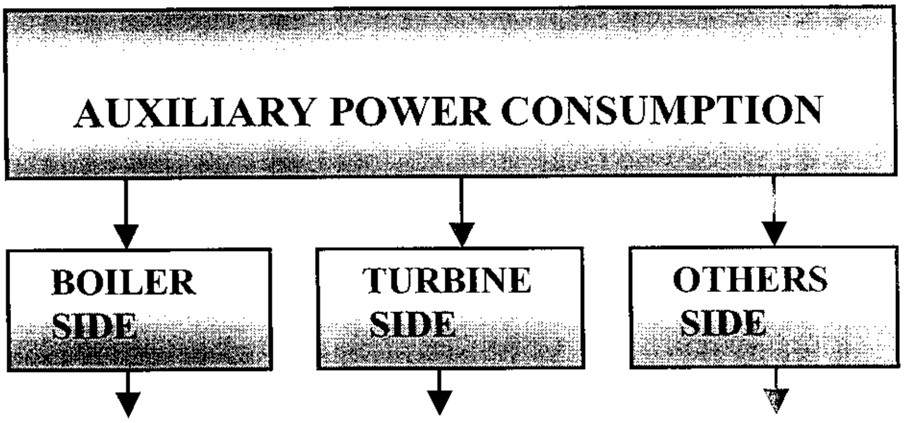
SECTION /EQUIPMENT	ELECTRICAL ENERGY
Coal feeding system	0.005-0.007 MW
Ash handling system	0.002-0.003 MW
Boiler feed pump	0.70-0.88 MW
Forced Draft fan	0.55-0.70 MW
Induced Draft fan	0.19-0.32 MW
PA fan	0.05-0.082 MW
Electrostatic Precipitator	0.02-0.06 MW
Cooling Water pump	0.20-0.40 MW
Cooling tower fans	0.05-0.15 MW
Condenser extraction pump	0.01-0.04 MW
Generator air cooling system .	0.20-0.28 MW
Total Power Consumption	1.977-2.991 MW

The break up of specific Thermal energy consumption is as in Table 3.2:

TABLE 3.2 THERMAL ENERGY CONSUMPTION

SECTION /EQUIPMENT	THERMAL ENERGY
Boiler outlet	815 kcal /kg
Steam Turbine Inlet	806 kcal/kg
Steam Turbine Extraction 1	673 kcal /kg
Steam Turbine Extraction 2	633 kcal /kg
Steam Turbine Exhaust	499 kcal /kg
Economiser	535 kcal /kg
Stack	256 kcal /kg
Total Thermal Consumption	4217 kcal /kg

3.2 AUXILIARY POWER CONSUMPTION:



- B.F PUMP
- FD FAN
- INDUCED DRAFT FAN
- PA FAN
- COAL HANDLING PROCESS
- ASH HANDLING PROCESS
- ELECTROSTATI

- COOLING WATER PUMPS
- COOLING TOWER FANS
- CONDENSATE PUMP
- GENERATOR COOLER

- COMPRESSOR

FIGURE 3.1 AUXILIARY POWER CONSUMPTION

3.3 FOCUS AREAS FOR ENERGY CONSERVATION:

The following are the focus areas and the key aspects for Energy conservation in Captive Cogeneration Plant.

- **STEAM TURBINE:**

  Power Gain in switching from Medium to Low pressure Steam.

  Power Gain in switching from Low pressure to Exhaust.

- **BOILER FEED PUMP:**

  Utilization of Energy Efficient Pump.

- **FORCED DRAFT FANS:**

  Utilization of Energy Efficient Motor for the Fans.

- **INDUCED DRAFT FANS:**

  Utilization of Energy Efficient Motor for the Fans.

  Installation of Variable Frequency Drive for the Motor.

- **PRIMARY AIR FANS:**

  Utilization of Energy Efficient Motor for the Fans.

  Installation of Variable Frequency Drive for the Motor.

- **COOLING TOWER FANS:**

  Utilization of Energy Efficient Motor for the Fans.

  Installation of Variable Frequency Drive for the Motor.

  Cutting off 1 out of 3 fans during night shift

  Various steps in Cutting off fans and Installation of VFD.

- **COOLING TOWER PUMP:**

  Utilization of Energy Efficient Pump.

  Utilization of Energy Efficient Motor.

- **CONDENSER EXTRACTION PUMP :**

  Utilization of Energy Efficient Pump.

- **ELECTROSTATIC PRECIPITATOR :**

  Cutting off one out off three fields.

CHAPTER 4

STEAM TURBINE

4.1 STEAM TURBINE:

Steam turbine is the equipment which converts high pressure steam to low pressure by Expansion process.

Turbine may be classified as

4.1.1 STEAM TURBINE.

- Back pressure steam turbine
- Extraction cum condensing steam turbine
- Total condensing steam turbine

4.1.2 GAS TURBINE

4.1.1 STEAM TURBINE have been used as prime movers for Industrial Cogeneration systems for many years. High-pressure steam turbine raised in a conventional boiler is expanded either the turbine to produce mechanical energy, which may then be used to drive an electric generator. The power produced depends on how much the steam pressure can be reduced through the turbine before being required to meet site heat energy needs. This system has higher overall efficiency achieving up to 84%. greater than a gas turbine or reciprocating engine driven cogeneration system.

The higher the turbine inlet pressure, the greater the power output, but higher steam pressures entail progressively greater boiler capital and running costs. Optimum pressure therefore depends on the size of the plant and the required process steam pressures. Steam cycles have the great advantage that the associated boiler plant can be designed to operate on virtually any fuel, including gas, heavy fuel oil coal, resides and municipal or other wastes, and are often capable of operating on a range of fuels. All conventional process plant steam turbines are axial flow turbo machines in which the steam flows parallel to the shaft axis. These turbines may be single stage or multi stages.

In **single stage turbines**, steam expands through a set of nozzles only once. They are most suited for smaller applications where a few horsepower of Power (say 50 to 150 HP) is required.

In **multi stage turbines**, where the power is very high (say 1000 to 2000 HP).Multi stage turbines have two or more expansions through a set of nozzles in each stage.

When the exhaust steam from any turbine is above atmospheric pressure, the turbine is called **Non-Condensing.** When the exhaust steam is below atmospheric pressure, this is called **Condensing Turbine**.

The overall Turbine Efficiency per Stage may defined as

$$\mathbf{E}_{\text{stage}} = (h_0 - h_1) / (h_0 - h_1`)$$

Where h_0 - Enthalpy at inlet of the turbine in kcal/kg

h_1 - Enthalpy at outlet of the turbine in kcal /kg.

$h_1`$ - Actual Enthalpy observed at outlet of the turbine in kcal /kg

4.1.2 GAS TURBINE

The fuel gas is supplied to the turbine instead of steam will gives the Gas turbine. It requires more maintenance and is costlier than steam turbine

4.1.2.1 PERFORMANCE CALCULATION:

The capacity of a steam plant is often expressed in terms of steam rate or **Specific Steam Consumption (S.S.C)**.It is defined as the rate of steam flow(kg/s) required to produce unit shaft output.

$$\textbf{Steam rate} = (3600/W_{net})\ \text{kg/kWh}$$

Where W_{net} = Net Work done

The Cycle Efficiency is sometimes expressed alternatively as heat rate, which is the rate of heat input required to produce unit shaft output.

$$\textbf{Heat rate} = Q_1/ W_T - W_P = 3600 / \eta \quad \text{kg / kWh}$$

Figure.4.1 shows extraction cum condensing steam turbine used in paper industry and Figure 4.2 shows the T-S and H-S diagram.

4.2 STEAM TURBINE WITH EXTRACTION CUM CONDENSING TURBINE:

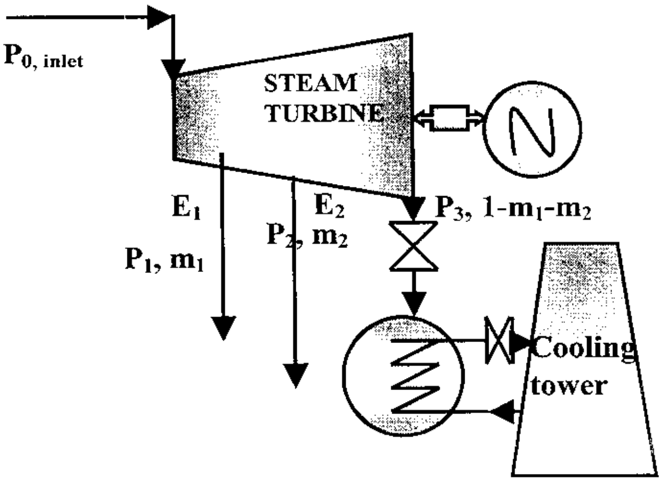


FIGURE 4.1 STEAM TURBINE WITH EXTRACTION CUM CONDENSER SYSTEM

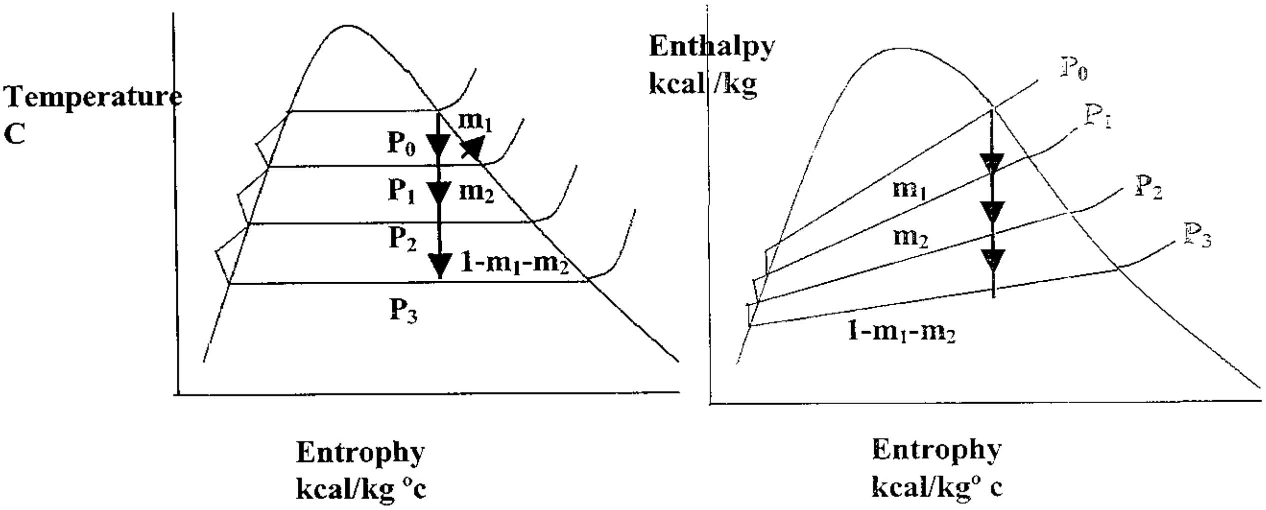


FIGURE 4.2 T-S DIAGRAM H-S DIAGRAM FOR EXTRACTION CUM CONDENSING STEAM TURBINE

4.3 TURBINE PRESSURE SURVEY

In order to monitor internal condition of turbine, record of steam pressure at various locations can give useful information.

Pressure measurement is carried our for

- Curtis wheel
- High Pressure exhaust
- Medium Pressure Inlet
- Steam extractions
- Low Pressure Exhaust.

Carrying out pressure survey at some periodic intervals & plotting the same is necessary to detect any variance regarding the internal condition of turbine.

The linear relationship between stage pressures at different load is shown in Figure 4.3 for a 20 MW turbine, which is plotted during acceptance test, known as optimum value. Over a period of run, turbine pressure is noted & plotted.

If it lies above, the optimum line for particular load, it is an indication of general wear throughout the turbine due to worn diaphragm seals or blade tip seals as indicate in Figure 4.3.However, if there is restriction at any location to steam flow, the effect will be to cause 'Kink' in the pressure as indicate in Figure .4.3.It is recommended to carry out such pressure survey at reasonable time interval with calibrated pressure gauges keeping load, pressure, with heater in service and plotted along with pressure line during acceptance test to detect any variance.

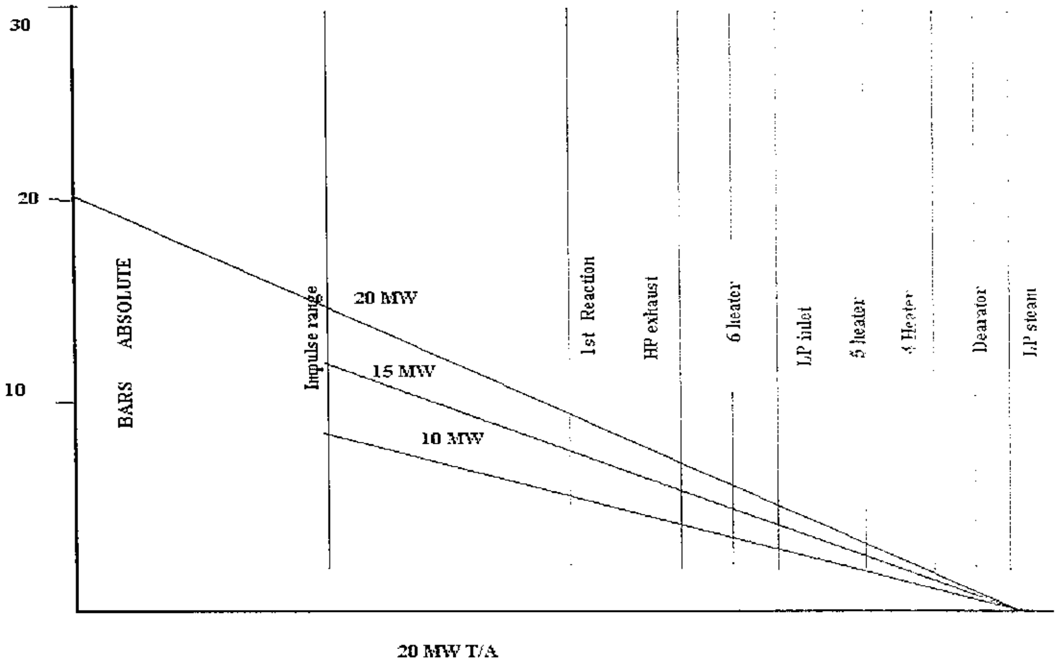


FIGURE 4.3 EFFECT OF RANGE OF LOADINGS ON PRESSURE SURVEY DIAGRAM

Figure.4.3.indicates the effect of feed heater out of service on pressure survey. A discontinuity on pressure line is observed. The pressure in Input pressure turbine and low pressure turbine will increase whereas in high pressure turbine decreased to have the same MW output. It is to be noted that a particular turbine may have various defects simultaneously. For example in a turbine which has a general wear & say restriction to flow at earlier stages due to damage from debris psi the strainers, is indicated by 'Kink'

4.4 ENERGY BALANCE

$$\mathbf{E_i} = \mathbf{w_0\ xh_0 — \{w_1x[h_0-h_1]=w_2x[h_0-h_2]=c_0x[h_0-h_3]\}}$$

where h_0 - Steam enthalpy at pressures p_0 and temperature t_0

h_1 - Steam enthalpy at pressures p_1 and temperature t_1

h_2 - Steam enthalpy at pressures p_2 and temperature t_2

h_3 - Steam enthalpy at pressures p_3 and temperature t_3 respectively.

4.5 OUTPUT:

$$\mathbf{E_0} = \mathbf{860 \times P}$$

where P - is the Power output in kWh

860 - Conversion factor,

E_0 - Energy outlet kcal/hr.

4.6 TURBINE EFFICIENCY [ACTUAL]:

$$\mathbf{E_{ff} = [E_0/E_I] \times 100}$$

As a thermal prime mover, the efficiency of a turbine is the useful work energy that appears as shaft power and is presented as a percentage of the chargeable hear energy. The overall thermal efficiency of a steam turbine is given by W/JQ where W is the shaft work in ft-lb or kg-meter. This leads to several expressions for thermal efficiency as follows where a number of extraction rates are carried out in a steam turbine, the efficiency is given by

$$\mathbf{E_{ff} = \frac{2545}{w \times h_I - [w'_a \times h_a + w'_b \times h_b + w'_c \times h_c + \ldots\ldots] - w_2 \times f_s^{\,2}}}$$

where w = inline steam in t/hr

w'_a = Extraction steam stage I in kg/hr

w'_b = Extraction steam stage II in kg/hr

w'_c = Extraction steam stage III in kg/hr

w_2 = Exhaust steam in kg/hr

h_a = Enthalpy of steam at inlet conditions kCal/kg

h_b = Enthalpy at stage I extraction conditions kCal/kg

h_c = Enthalpy at stage II extraction condition kCal/kg

h_f^2 = Enthalpy at exhaust condition kCal/ kgs

In "M/S.,SASHASEYEE PAPER AND BOARDS" steam turbine is used.

The detail data for the steam turbine uses in SPB is shown in Table 4.1.The steam turbine used in SPB is Double extraction cum condensing Steam Turbine .It has two extractions E1 AND E2 with condensate. The high pressure steam entering the steam turbine generates power in the generator section. The steam at Extraction 1 (Medium pressure) and Extraction 2(Low pressure) are used for process(paper as well as pulping sectors)

4.7 ALGORITHM DEVELOPMENT:

ALGORITHM has been developed in order to obtain the Power output

$$\mathbf{P_{E1} = f\,[W_{IN}, W_{E1}]}$$

$$\mathbf{P_{E2+exh} = f\,[(W_{IN} - W_{E1}), (W_{E2} + W_{EXH})]}$$

$$\mathbf{P_{EXH(c)} = F\,[W_C]}$$

Algorithm generation for the above cases, By apply in engineeri8ng concepts we have derived the algorithms as below, building a block accept; is used in formality, developing the algorithm.

- For pure condensate:

  Limits : 20 -55 TPH

  P_c = Lowest power + (C-lowest steam rate) Kc............Equation .1

- For extraction E_1:

  Limits : 0- 30 TPH

  $P_{E1} = K_{E1} \times E_1$..Equation.2

- For Extraction E_2 :

  Limits: 0-60 TPH

  $P_{E2} = K_{E2} \times E_2$...Equation.3

From Equation.1,2.and 3

Total Power	$\mathbf{P_T}$	=	$\mathbf{P_{E1} + P_{E2} + P_C}$
Mass Of Steam Rate	$\mathbf{W_{IN}}$	=	$\mathbf{W_{E1} + W_{E2} + W_{E3}}$

Extraction E1 and E2 can be multiply by a constant which will be K_E, This constant can be 0.122,0.191 and 0.325.

With this ALGORITHM, Power could be obtained at any point of Extraction and condensing at the given steam rate.

With this the Total Power could be easily identified for the respective Steam rate give at the inlet. Extraction E2 Specific Steam Calculation is Shown in Table 4.2.

4.8 STEAM TURBINE DATA:

TABLE 4.1 STEAM TURBINE DATA

Steam Flow at Inlet, TPH	105 TPH
Steam Inlet Pressure, bar	105 bar
Steam Inlet Temperature ,° C	500 ,° C
1st Extraction flow, TPH	25 TPH
Extraction 1st Pressure , bar	12 bar
Extraction Temperature ,° C	267.5 ,° C
2nd Extraction flow, TPH	45 TPH
Extraction 2nd Pressure , bar	5.5 bar
Extraction Temperature ,° C	168° C
Exhaust flow, TPH	37 TPH
Exhaust Pressure , bar	0.093 bar
Exhaust Temperature ,° C	45 ,° C

4.9 CALCULATION OF SPECIFIC STEAM CONSUMPTION AT EXTRACT E_2:

TABLE 4.2 EXTRACTION E2 SPECIFIC STEAM CALCULATION

	STEAM FLOW TPH	STEAM ENTHALPY kcal/ Kg	HEAT CONTENT Mcal/hr
HEAT IN	73	804	59.18

E2	60	670	40
CONDENSATE	13	40	0.547
POWER GENERATION			12

- Heat in- Heat out - 59.18-0.5440 - 18.36 MCal/hr
- Turbine heat rate - 18.36/12 - 1530kCal/kWh
- Specific Steam Consumption - Steam Inlet / Power Generation - 73.5/12= 6.125 TPH/MW

Similarly for Extraction E1 and for Condensate C the Specific steam consumption has been calculated and this is denoted in Figure 4.4

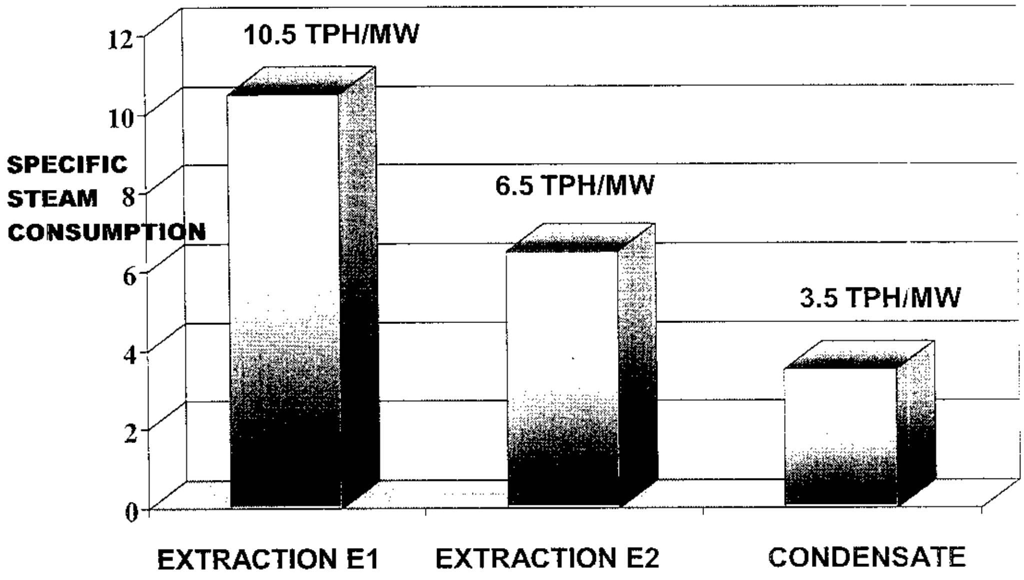


FIGURE 4.4 SPECIFIC STEAM CONSUMPTION

4.10 OPTIMIZING TECHNIQUE USED:

The optimizing technique used in steam turbine is:

- Power Gain in switching from Medium Pressure to Low pressure Steam is shown in Table 4.3
- Power Gain in switching from Low pressure to Exhaust in Table 4.4
- Power gain in switching from E1 to Exhaust is shown in Table 4.5

CASE 1 POWER GAIN IN SWITCHING FROM MEDIUM PRESSURE TO LOW PRESSURE STEAM.

TABLE 4.3 POWER GAIN IN SWITCHING FROM MEDIUM PRESSURE TO LOW PRESSURE STEAM

STEAM RATE (TPH)	POWER $_{PE1}$ (MW)	POWER P_{E2} (MW)	$\Delta P= P_{E2}-P_{E1}$ (MW)	POWER GAINED MW/ TPH
1	0.121	0.191	0.07	0.07
3	0.363	0.573	0.21	0.07
5	0.605	0.955	0.35	0.07
7	0.847	1.337	0.49	0.07
11	1.331	2.101	0.77	0.07
13	1.573	2.483	0.91	0.07
15	1.815	2.865	1.05	0.07
17	2.057	3.247	1.19	0.07
21	2.541	4.011	1.47	0.07
23	2.783	4.393	1.61	0.07
25	3.025	4.775	1.75	0.07
27	3.267	5.157	1.89	0.07
30	3.63	5.73	2.1	0.07

4.10.1 ALGORITHM:

$P_{E1} = K_{E1} \times E_1$

$P_{E2} = K_{E2} \times E_2$

$\Delta P = P_{E2} - P_{E1}$

P_C = Lowest Power+ (C – Lower steam rate) Kc

Power gained in Switching from M.P to L.P steam = 0.07 MW/TPH.

CASE 2 POWER GAINED IN SWITCHING FROM LOW PRESSURE TO EXHAUST

TABLE 4.4 POWER GAINED IN SWITCHING FROM LOW PRESSURE TO EXHAUST

STEAM RATE (TPH)	POWER PE_2 (MW)	POWER P_c (MW)	$\Delta P= P_c-PE_2$ (MW)	POWER GAINED MW/ TPH

1	0.191	0.325	0.134	0.134
3	0.273	0.975	0.402	0.134
5	0.955	1.625	0.67	0.134
7	1.337	2.2755	0.938	0.134
11	2.101	3.575	1.474	0.134
13	2.483	4.225	1.742	0.134
15	2.865	4.875	2.01	0.134
17	3.247	5.525	2.278	0.134
21	4.011	6.825	2.814	0.134
23	4.393	7.475	3.082	0.134
25	4.775	8.125	3.35	0.134
27	5.157	8.775	3.618	0.134
30	5.73	9.75	4.02	0.134

Power gained in Switching from L.P steam to Exhaust = 0.134MW/TPH.

CASE 3 POWER GAIN IN SWITCHING FROM E1 TO EXHAUST.

TABLE 4.5 POWER GAIN IN SWITCHING FROM E1 TO EXHAUST

STEAM RATE (TPH)	POWER PE$_1$ (MW)	POWER P$_c$ (MW)	ΔP= P$_c$-PE$_1$ (MW)	POWER GAINED MW/ TPH
1	0.121	0.325	0.204	0.204
3	0.363	0.975	0.612	0.204
5	0.605	1.625	1.02	0.204
7	0.847	2.275	1.428	0.204
11	1.331	3.575	2.244	0.204
13	1.573	4.225	2.652	0.204
15	1.875	4.875	3.06	0.204
17	2.057	5.25	3.468	0.204
25	3.025	8.125	5.100	0.204
27	3.267	8.775	5.508	0.204
30	3.63	9.75	6.12	0.204

Power gained in Switching from Medium pressure steam to Exhaust =0.204MW/TPH

4.11 STATION STEAM CONSUMPTION

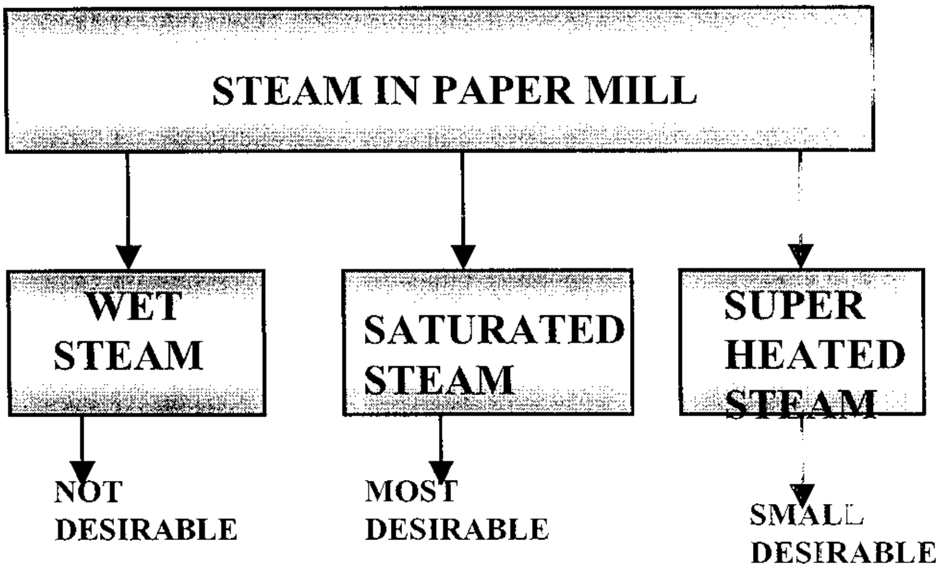


FIGURE 4.5 STATION STEAM CONSUMPTION

Power saved by using Optimizing Technique = 0.134 MW/TPH

CHAPTER 5

BOILER FEED PUMP

5.1 BOILER FEED PUMP:

This is the largest capacity auxiliary absorbing nearly 3 to 4 % of gross power generated. These pumps should be run only when necessary during shut down in planned manner avoiding frequent start/stop since this can strain motor windings. Other guidelines for meticulous use of the pump in enumerated below. After shutting down of Pressure greater than Fuel/fuel oil fired unit, fill the boiler drum up to upper limit & put Boiler Feed Pump out of service. Since residual temperature in the furnace is not very high.

5.2 BOILER FEED PUMP OPERATION:

In case operating pressure of boiler is reduced during shutting down to the extent that condensate booster pump [C.B.P] can be used, use of Boiler feed pump there alter during shut down should be avoided condensate booster pump. to be used for boiler filling and for hydraulic test. During hydraulic test above 15 kg/cm^2 pressure Boiler feed pump. to be used Pressure raising can be done by reciprocating plunger pumps and/or H.P. water jetting [which is used for condenser tube cleaning] if available

Such high capacity Boiler feed pump when provided drafted with variable speed drive like hydraulic coupling auto working of scope tube of coupling should be ensured so that Boiler feed pump. speed is kept minimum possible for maintaining drum level of boiler, since power absorbed by Pump is proportional to cube of speed.

Auto operation of drum level control when not available, repute manual mode operation is used and Boiler Feed Pump speed should be adjusted in optimum manner such that throttling across feed control valve [F.C.V] is unduly not increased. This will result in less erosion at feed control valve and Boiler feed pump. need to work at reduced speed. It is evident that power absorbed by the pump is proportional to cube of speed.

When drum level is maintained by remote manual control, proper attention is necessary to avoid possibility of high drum level and opening of emergency blow down valve and incur loss of heat, Demineralized water and additional power consumption.

Boiler feed pump should be put into service when there is a demand of water to the boiler as more water than the boiler demand is recycled through deaerator during very low demand of water.

In case two nos. of Boiler feed pump each of 50% boiler duty condition are provided drafted no of Boiler feed pump to be kept in service should commensurate with load on boiler.

5.3 POWER REQUIRED FOR PUMPING:

The power consumption of a pump depends on the total increase in head between the suction and discharge sources and the Efficiency of the pump. Using Bernoulli equation, the shaft work for pumping a liquid between two stations a and b is defined by

$$W_s = [h_b - h_a] \;/\; E_{ff}$$

Where h_b and h_a are head developed in sections a and b, E_{ff} is the pump Efficiency.

5.4 AFFINITY LAWS:

Centrifugal pumps obey the following laws:

- Capacity of the pump varies directly with impeller diameter and speed
- The head varies as the square of impeller diameter and speed.
- The horse power varies as the cube of impeller diameter and speed

5.5 PUMP HORSE POWER:

The formula that is used for calculating the pump horse power is given by

$$HP = \frac{GPM \times [P_2 - P_1]}{1715 \times E_{ff}}$$

This is represented in metric units by the equation

$$HP = \frac{36.530721 \times m^3/hr \times [P_2 - P_1]}{1000 \times E_{ff}}$$

where P_2 and P_1 are discharge and suction pressure in kg/cm^2

E_{ff} is pump efficiency.

HP is the hydraulic horse power of the pump.

Hydraulic power P_h = $(Q \times h_d - h_s \times \rho \times g) / 1000$

5.6 PUMP SHAFT POWER:

$$P_s = P_h \times \eta_{pump}$$

Electrical Input Power = Pump shaft Power (Ps)/η_{pump}

Figure5.1 shows curves for centrifugal pump having two options viz. constant speed throttle control and variable speed. From the figure it can be revealed that during part load operation, power absorbed by pump is much lesser at reduced speed operation than that by throttle control. From aforesaid comparison it is induce that there is considerable power saving by variable speed operation. Such analysis can be made with the help of manufacturer taking in to consideration pump characteristics / design in order to arrive at conclusion. Efficient improvement in boiler feed pump is shown in Table 5.1

The pump capacity and head are interrelated and governed by system resistance and pump characteristic curves. working of two or more pumps of different capacities in parallel sharing part load of system is commonly noticed. In this case total discharge at particular head is sum of individual discharge capacity will be less than sum of individual pump. Common practice for water supply installation system is to go in for overhead tank and two or three pumps operated in parallel to feed the tank. Either frequent start or stop of pump is necessary for catering to variation in demand of water from tank and high cost of space requirement of tank installation is involved. Frequent, start or stops of high capacity pump and motor is not desirable. In above situation variable speed drive proposal may prove to be attractive and does not need storage tank.

For economic feasibility of installing variable speed drives the following factors should be taken in to consideration.

- System requirements in terms of flow and discharge head during varying demand.
- Total variance in demand over a period say day or month.
- Cost involved in modifying the system
- Necessary down time for carrying out modification and consequent loss of production.

Figure.5.1 indicate the variable speed and constant speed operating point giving discharge flow Q2 by throttling the discharge valve, with system resistance R2.Both the operating points are on same pump characteristic C1.

The discharge flow can be reduced by changing the speed of the pump and new pump characteristic will be C2. O3 is the operating point giving same discharge flow Q2 with resistance from R1.

Figure5.1. indicate the relation between discharge and the power input to the pump. Power consumption by throttling discharge valve will shift from P1 to P2. where as by changing the speed it will shift from P1 to P3.

It can be seen from the curve that during part load operation power absorbed by pump is much less than that by throttle control.

Usage of Variable Frequency drive in Boiler Feed Pump leads to high initial cost , requires high investment due to the presence of High Tension area. Inorder to work with it High Tension side should converted to Low Tension side this leads to high cost , so this is process is strictly not followed.

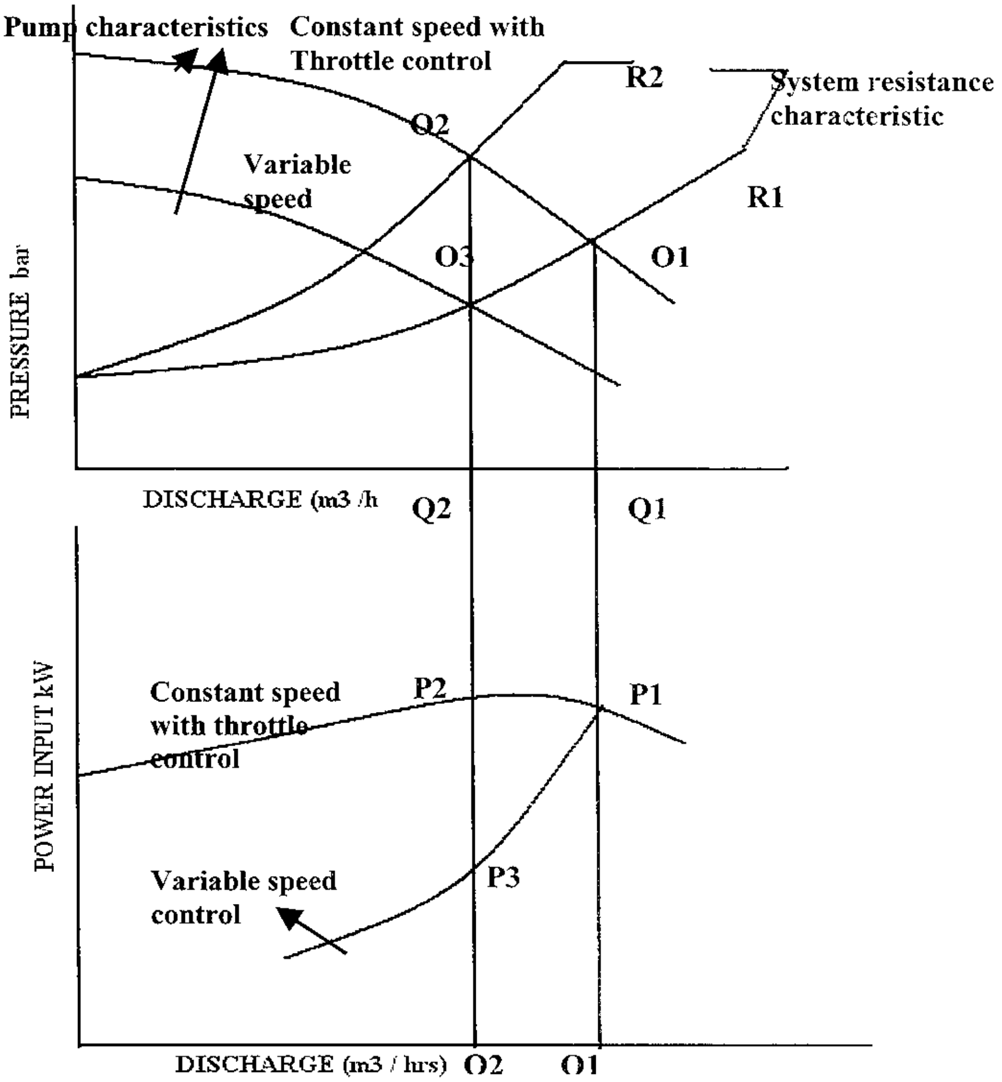


FIGURE 5.1 PERFORMANCE OF PUMP ON VARIABLE SPEED

5.7 OPTIMIZING TECHINIQUE IN BOILER FEED PUMP

5.7.1 EFFICIENCY IMPROVEMENT

DATA : Flow (Q) = 126.85 m3/hr,

Head(H) = 1428m

η_P = 61.8%

η_{motor} = 95.6%at full load

5.7.2 ALGORITHM:

Power = **(QH/ η_P x367)/ η_{motor}. kW**

Correction factor = 367

TABLE 5.1 EFFICIENCY IMPROVEMENT IN BOILER FEED PUMP

By improving the efficiency η_{motor}=95.6% η_{motor}=94.3% η_{motor}=92.2%

Serial No.	Efficiency of pump	Power Consumption at Full load (MW)	Power consumption at load 75% (MW)	Power consumption at 50% load (MW)
1	61.8	0.835	0.858	0.877
2	62	0.832	0.844	0.863
3	63	0.819	0.830	0.849
4	64	0.806	0.817	0.836
5	65	0.794	0.805	0.823
6	66	0.782	0.793	0.811
7	67	0.770	0.781	0.799
8	68	0.759	0.769	0.787
9	69	0.748	0.758	0.775
10	70	0.737	0.747	0.764
11	71	0.727	0.737	0.753
12	72	0.717	0.726	0.743
13	73	0.707	0.716	0.733
14	74	0.697	0.707	0.723
15	75	0.688	0.697	0.713

At 100 % load ,Power saved =0.835-0.688 =0.147 MWx24000

=3528 Units /day

At 75 % load ,Power saved =0.858-0.697 =0.161 MWx24000

=3864 Units /day

At 50 % load, Power saved =0.877-0.713 =0.164 MWx24000

=3936 Units /day

CHAPTER 6

INDUCED DRAFT FAN

6.1 INDUCED DRAFT FAN

As indicated in auxiliary rating table, Induced draft fan consumes sizeable power next to B.F.P. Following steps are recommended for reducing auxiliary consumption

- During light up and low load operation of unit keep only one pair of Induced Draft /Forced Draft /Primary Air fans in service (Assuming that performance of air preheated is satisfactory and air infiltration in second pass and Electrostatic Precipitator. is reasonably very low and desired air parameters can be maintained).
- If any of the fans are provided with variable speed drive, during any part load operation or light up of boiler further, reduction in auxiliary consumption is possible.
- In case of shut down of unit, normally natural cooling is to be resorted to, i.e. do not keep Induced draft fan in service. However if forced cooling is to be resorted to (i.e. to reduce boiler pressure for attending some leaks in boiler pressure parts). After 6 hrs. From shut down put one Induced draft fan in service with necessary loading. During pressure part repairs boiler, some cooling of enclosure is necessary for facilitating repairs by maintenance personnel. During repair work only one Induced draft fan can be kept in service, instead of entire duration of shut down and induced draft fan should be switched of when maintenance staff is not working and it should be ensured in consultation with maintenance personnel. Natural draft of chimney can also be used during prolonged shut down by keeping Induced draft fan damper full open and obviate need of keeping Induced draft fan in service.
- Very often, the major contributory factor for undue loading on Induced draft fan, is infiltration of air due to leaks because of erosion at furnace enclosure, second pass body, ducts, air preheaters (tube leaks),Electrostatic precipitator. body, Deepings peep holes open (due to negligence) not ensuring tight shut off of inspection windows etc. Measuring oxygen in flue gas at different locations in gas pikes or pressurizing the system by air, leady spots can be induced draftentified using shut down, which are subsequently required to be plugged

during shut down. For every one ampere additional loading above normal load by High Tension motors operating at 6.6KV results in 9.13 kWh additional power consumption per hour. In actual case of 110MW Power Factor Unit (BHEL) if Induced draft fan loading at full load increases by 10amperes above normal current loading in each Induced draft fan due to air infiltration, the power consumption increases by 18/2.68 kWh per hour and 131.453 MWh in month of 30 days.

- During start up operation, one pair of Induced Draft and Forced Draft fans is to be put into service. Due to passing of discharge dampers and other inter connection damper the stand by fans rotate in reverse direction and need to put both the pairs simultaneously in service arises. This results in recycling of air and gas unduly. Isolating gate type dampers is a solution to the problem in such a situation.

6.2 ENERGY CONSERVATION MEASURES IN FANS:

The following the various ways through which energy conservation is possible in Industrial Fans:

- Use Variable Speed controls if Flow requirement and pressure requirement changes continuously.
- Avoid leakages from flange joints and holes in the duct/casting due to corrosion or erosion.
- Ensure correct radial gap and axial overlap between inlet cone and impeller shroud.
- Check the alignment and belt tightness periodically.
- Check the feasibility of replacing low efficiency fans or its impeller in existing system with higher efficiency
- Energy saving in Fans can be achieved by using methods like
- Damper control, guidance control, Blade pitch control and Speed Control.
- Check fan location with respect to equipment.
- Avoid losses due to inlet box/bends/elbows/reducers on discharge side. Efficiency Improvement is Shown in Table 6.1

6.3 VARIABLE SPEED DRIVERS FOR FANS:

For fans, static head is negligible in many cases. Figure.6.1 shows amount of saving achievable. Pressure Flow [Δ P,Q] characteristics of fan is given by curve 1. System characteristic is given by curve 2. Normal operating point is A1 flow of Q1 and power taken equal 1.0. for reducing flow to Q2, damper control will take fan to point B1 and power require of 0.83.

System pressure requirement at Q2 is only A3. Pressure B1 – A3 is dropped across the damper. If speed of fan is reduced to 65%, new fan characteristic is 1b. Since power requirement α cube of speed available,

$$P \alpha N^3$$

Power required = (0.65x 0.65x0.65)=0.27.
Power required = (0.75x0.75x0.75) =0.42.
Power required = (0.85x0.85x0.85)=0.61.

Operation by variable speed leads to a reduction in power required from 27% to 61% a saving of 40 % to 70%. A fan characteristic at variable speed operation is shown in Figure.6.1 which also shows its efficiency curves. It can be seen that just like pumps, compared top throttling for reduced flows, reduced speed operation leads to higher fan efficiency.

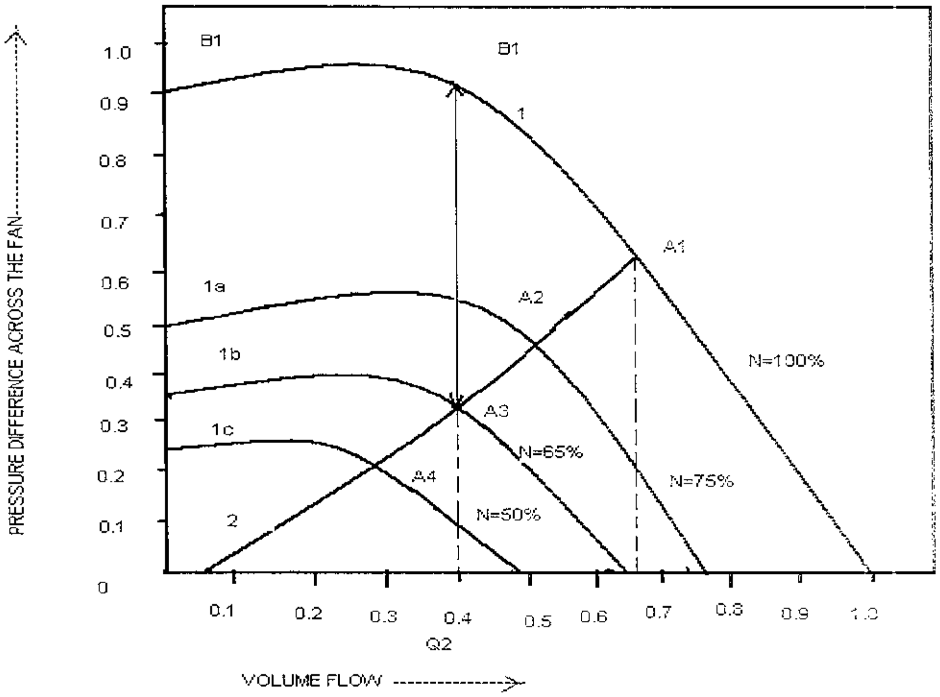


FIGURE 6.1 FAN CHARACTERISTIC AT VARIABLE SPEED OPERATION

6.4 OPTIMIZING TECHNIQUE IN INDUCED DRAFT FAN

6.4.1 EFFICIENCY IMPROVEMENT

DATA: Volume - 40.38 m^3 /sec

Head - 244 mm water column

Efficiency η_f - 76.75 ,η_{motor} - 95%at full load

6.4.2 ALGORITHM:

Power consumption = (V x Δ P) / (102 x η_F) / η_{motor} KW

Correction factor = 102.

TABLE 6.1 EFFICIENCY IMPROVEMENT IN INDUCED DRAFT FAN

S.NO	EFFICIENCY %	POWER CONSUMPTION MW
1	74	0.137
2	75	0.135
3	76	0.133
4	76.5	0.1329
5	77	0.132
6	77.5	0.131
7	78	0.130
8	78.5	0.1295
9	79	0.128
10	80	0.127
11	81	0.125

By improving the efficiency

At 100 % load ,power saved =0.137-0.125 =0.012 MWx24000= 228 Units /day

6.4.3 VARIABLE FREQUENCY DRIVE USAGE IN INDUCED DRAFT FAN:

Power Consumption before using VFD = 0.25x24000 = 6002 Units /Day.

Power consumption after using VFD = 0.25 x 0.30 = 0.075 MW

Power saved after using VFD = 0.25 - 0.075 = 0.175 MW

= 0.175x24000 = 4200 Units /Day.

Power saved after using VFD = 4200 Units/Day.

CHAPTER 7

PRIMARY AIR FAN

7.1 PRIMARY AIR FAN OPERATION:

- When only one Primary Air fan is available for service, because of passing of isolating dampers of the other Primary Air fan, sizeable air is leaking through the fan. This reduces the number of mills which can be kept in service and reduces the generation. Isolating gate type dampers can minimize such problem.

- Tube leakage at tubular air heater, leaky air duct joints and passing of pyrite hopper valves of mill result in increased loading of Primary Air fan. In order to maintain the rated Primary Air header pressure, because of aforesaid problems, loading on fan increases more than optimum and results in wastage. Efficiency improvement in primary air fan is shown in Table7.1

7.2 OPTIMIZING TECHNIQUE IN PRIMARY AIR FAN

7.2.1 EFFICIENCY IMPROVEMENT

DATA: Flow = 545 m^3 /min

Head = 905 mm

Efficiency η_f = 60.05 %

η_{motor} = 92%at full load

7.2.2 ALGORITHM:

Power consumption = (Q x H) / (102 x η_F) / η_{motor} kW

TABLE 7.1 EFFICIENCY IMPROVEMENT IN PRIMARY AIR FAN

S.No	EFFICIENCY %	POWER CONSUMPTION MW
1	60	0.146
2	61	0.143
3	62	0.141
4	63	0.139

5	64	0.136
6	65	0.134
7	66	0.134
8	67	0.130
9	68	0.128
10	69	0.126
11	70	0.125
12	72	0.121
13	73	0.120
14	74	0.118
15	75	0.116

By improving the efficiency

At 100 % load, power saved = 0.141-0.116 =0.025 MWx24000
= 600 Units /day

7.2.3 VARIABLE FREQUENCY DRIVE USAGE IN PRIMARY AIR FAN:

Power Consumption before using VFD = 0.07x24000 = 1680 Units /Day.

Power consumption after using VFD = 0.07 x 0.30 = 0.021 MW

Power saved after using VFD = 0.07 -- 0.021 = 0.0490 MW
= 0.049x24000 =1175 Units /Day.

Power saved after using VFD = 1176 Units/Day.

CHAPTER 8

FORCED DRAFT FAN

8.1 FORCED DRAFT FANS:

Utilization of Energy Efficient Motor for the Fans. In mechanical draught or natural cooling towers, air is moved through the fill by one or more fans driven by motors. As in stream generators, the fans could be of the forced draught (FD) type or induced draught (Induced draft) type. The Forced draught fan is mounting on the lower side of the tower. Since it operates on cooler air, it consumes less power. However, it has the disadvantages of (a) air distribution problems in the fill (b) leakage, and (c) recirculation of the hot and moist air back to the tower. Efficiency improvements in forced draft fan is shown in Table 8.1

8.2 OPTIMIZING TECHNIQUE USED FOR FORCED DRAFT FAN

8.2.1 EFFICIENCY IMPROVEMENT

DATA: Flow	-	3700 m^3 /min
Head	-	900 mm
Efficiency η_f	-	65.05 %
η_{motor}	-	95 %at full load

8.2.2 ALGORITHM:

Power consumption = **$(Q \times H) / (102 \times \eta_F) / \eta_{motor}$**

TABLE 8.1 EFFICIENCY IMPROVEMENTS IN FORCED DRAFT FAN

S.NO	EFFICIENCY %	POWER CONSUMPTION MW
1	65	0.881
2	66	0.867
3	67	0.854
4	68	0.842
5	69	0.830
6	70	0.818
7	71	0.806
8	72	0.765
9	73	0.784
10	75	0.763

By improving the efficiency

At 100 % load, power saved = 0.881-0.763 =0.118 MWx24000
= 2832 Units /day

Power saved in Forced draft fan = 2832 Units /day

CHAPTER 9

COOLING TOWER

9.1 COOLING TOWER

Cooling tower cool the warm water discharged from the condenser and feed the cooled water back to the condenser. The cooling tower is having three independent cells with common water basin. The water from the cool basin is pumped through Cooling Water. pump to a common header took the condenser ,air cooled generator and tube-oil cooler.

Two pumps would be in service at all times of operation of captive cogeneration plant the motors related to all the Cooling Water pumps are of high tension .it is a good practice to rotate the three pumps in turn.

The warm water from the above units is returned to a common header from where the water is branched off and sprayed in the three cells from the top.

Induced draft fans are located at the top of three cell in order to enhance the cooling potential. The fans are connected to low tension motors all the three fans have independent power connection for switching of any or all of these units. They, thus, reduce the Cooling Water demand in the power plant. They can be either wet type or dry type.

9.1.1 WET COOLING TOWERS

Wet cooling tower have a hot water distribution system that showers or sprays water evenly over a lattice of horizontal slats or bars called fill or packing.

The fill thoroughly mixes the falling water with air moving through the fill as the water splashes down from one fill level to another by gravity. Outside air enters the tower through louvers on the side of the tower. Intimate mixing of water and air enhances heat and mass transfer (evaporation), which cools the water.

More the water evaporates; more will be the cooling since the latent heat of evaporation is taken from water itself (evaporative cooling). Cold water is collected in a concrete basin at the bottom of the tower, from where it is pumped back to the condenser. Hot and moist air leaves the tower from the top.

Air entering the tower is unsaturated and as it comes in contact with the water spray, water continues to evaporate till the air becomes saturated. So, the minimum temperature to which water can be cooled is the adiabatic Saturation or wet bulb temperature of the ambient air. The humid air while moving up comes in contact with warm water spray and so the air temperature rises.

A cooling tower is specified by (a) approach (b) range, and (c) cooli8ng efficiency. The approach (A) is defined as the difference between the exit temperature of Cooling Water and the wet bulb temperature of the ambient air,

$$\mathbf{A} = \mathbf{f_{c2}\text{-}f_{wb}}$$

Warm water from the condenser enters the cooling tower at temperature t_{c1} and is cooled to temperature $t_{c2,}$

Higher than the minimum value, the wet bulb temperature,

T_{wb} , and this unattainable temperature difference is the approach. The approach varies from 6°c to 8°c.

The cooling range or simple range (R) is defined as the difference in temperatures of the incoming warm water (t_{c1}) and the exiting cooled water (t_{c2}) , or

$$\mathbf{R} = \mathbf{t_{c1} - t_{c2}}$$

It is the range by which warm water from the condenser is cooled. The rang we varies from 6°c to 10°c.

The cooling efficiency is defined as the ratio of the actual cooling of water to the maximum cooling possible, or

η cooling = actual cooling /maximum cooling possible = tc1 –tc2/tc1-twb.

The approach, range and cooling efficiency are the performance parameters of cooling towers.

9.2 PERFORMANCE PARAMETERS:

The parameters which are useful for determining the performance of cooling towers are the Temperature Range and Temperature Approach.

9.2.1 TEMPERATURE RANGE:

It is the difference between the cooling tower cold inlet and our let temperatures.

9.2.2 TEMPERATURE APPROACH:

It is the difference between the cooling tower cold water temperature and the ambient wet bulb temperature.Though both parameters should be monitored, the “Approach” is a better indicator of cooling tower performance; lower the approach, better is the performance.

9.2.3 AUTOMATIC ON – OFF SWITCHING:

The cooling tower fan operation is controlled mainly by ambient climatic conditions. The design of the tower is usually done for most extreme conditions of weather [high wet bulb temperature] which occur only during 2 or 3 months in a year. A typical case study of a 4 cell tower with a range of 8.3 C and a 100 million Btu/hr. heat load revealed interesting data. Each fan consumed 16KW and hence a total of 64 kW power for the cooling tower. Based on year round weather data, detailed analysis was made to predict total fan power requirement tower for one year operating cycle in the form of demand curve.

It has been found that the number of fans operating can be reduced without sacrificing on the required cold water temperature as the ambient conditions change. The step change demand curve predicted earlier could be met with by sequential ON-OFF switching of four fans.

It was found in the study that only about 25% o f the time, the total power demand as required with all four fans running. It has been found that total energy consumption of 560,640 kWh can be effectively reduced to 353,400 KWH in a year. This results in a savings of 37% of energy consumed in the typical 4 cell tower considered.

Cooling tower fan automatic switching devices, based on sump temperature sensing, is available as a standard product. For plants with large vapor compression chiller loads, the sump temperature control settings should be kept low [3 ° C approach] to ensure that the condensers get cooler water; reduction in condensing temperature will drastically reduce the compressor power, which is generally likely to be significantly more than the cooling tower fan power. However, even in these systems, the fans can be switched off if the approach is less than 3 °.C. For plants with Water-LiBr absorption chillers, the temperature setting criterion can be based on the lower limit of Cooling Water temperature permitted by the manufacturer to guard against crystallization of Lithium Bromide.

9.3 COOLING TOWER FANS:

- Utilization of Energy Efficient Motor for the Fans.
- Installation of Variable Frequency Drive for the Motor.
- Cutting off 1 out of 3 fans during night shift.

9.3.1 VARIOUS STEPS IN CUTTING OFF FANS AND INSTALLATION OF VARIABLE FREQUENCY DRIVE.

The present system envisages the following:

- Exhaust steam leaving the steam turbine at vacuum is condensed in the surface condenser.
- Cooling Water flows inside the tubes, whereas steam is condensed on tube exterior.
- Condensed steam is returned as condensate for reuse in the High Pressure.
- Warm water leaving the condenser is returned to the Cooling Tower for Natural Cooling [with Fans in service]
- Cooling Tower consists of Multiples cells[3 in number] with each cell has
- Sensible heat is converted as water vapour which escapes to the landscape through the cell top.
- The cycle of cooling continues.

9.4 CORRECTIVE STEPS TO MAINTAIN ECONOMICAL VACUUM:

- During part and full load operation, keep minimum possible required steam pressure at ejectors and take other steps for Cooling water system to prevent under cooling of condensate.
- In case there is reduction in vacuum during very low load operation the reason is air ingress at drain and air venting system of Low Pressure feed heater system. The air ingress locations are to detected and plugged (during some opportunistic shut down of plant say for 5-6 days duration) by conducting turbines plant hydraulic test.
- Condenser cleaning during annual statutory shut down for boiler turn around.
- Chlorination (shock dozing) or use in case of problems of micro-organisms and algae in Cooling water system (Cooling water exposed to sun light accelerates growth of algae).
- Ensure availability of sufficient no of Cooling water pumps and Cooling Tower fans.
- Do not allow content in Cooling water system more than 500 p.p.m. (it is assumed here that chlorides in deep bore well raw water as 250p.p.m and make up of Cooling water in turn through nazeolite softeners which uses

borewell water), that is cycle of concentration should not be more than two. In case it is increasing drain of some Cooling water from system, although the same water can be used for ash-slurry system or other purpose4 instead of wasting the same.

- Clean Cooling Tower pump and Cooling water forebay during annual shut down.
- Cooling water should be reasonably basic and not acidic to prevent corrosion problems.
- Periodically monitor condenser performance.

9.5 REASON FOR EXCESS CONSUMPTION OF POWER IN COOLING TOWER FAN:

- Maintaining of vacuum at -0.9 pressure leads to increase of power due to variation.
- Excess capacity
- Under loading condition
- Depend upon the surrounding climate. During summer cooling required is more than in winter and night time.

9.6 APPROACHES FOR ENERGY SAVING IN COOLING TOWER FAN:

- Efficient improvement
- Installation of Energy saving device-VARIABLE FREQUENCY DRIVE
- Switching off fans during night shift
- Operation of two fans instead of three fans during winter season.

Installation of on/off temperature control for cooling tower fan. Figure 9.1 power saved when cooling tower fan working under two fan

9.7 COOLING TOWER FAN WHEN WORKING UNDER TWO SHIFT:

Rating: Three fans working under

Vacuum = 0.91psi,

Velocity = 3000 m3/sec

Power = 0.145MW (3fans)

TABLE 9.1 COOLING TOWER FAN WORKING UNDER TWO SHIFT

SERIAL NO.	SHIFT	AVERAGE POWER OF 3 FANS UNITS/DAY	AVERAGE POWER OF 3 FANS UNITS/DAY	AVERAGE POWER SAVING UNITS/DAY.
1	A	1500-1570	1510-1540	---------
2	B	1550-1630	1520-1570	---------
3	C	1530-1590	1400-1430	100-160

Average power saved = 100 -160 Units/day.

Switching off the fan just for the night shift = 100-160units/day.

MONTHLY SAVING:

- 1 of 3 fans off for a shift every day = (100-160)x31

= 3100-4960 Units/month.

ANNUAL SAVING:

- 1 of 3 fans off for a shift every day = (3100-4960)x12

= 37200-59000units.

Cooling tower fan working under two shift is shown in Table 9.1and Cooling tower fan working under two fans is shown in Table 9.2

9.8 COOLING TOWER FAN WHEN WORKING UNDER TWO FANS

TABLE 9.2 COOLING TOWER FAN WORKING UNDER TWO FANS

SERIAL NO.	SHIFT	AVERAGE POWER OF 3 FANS UNITS/DAY	AVERAGE POWER OF 2 FANS UNITS/DAY	AVERAGE POWER SAVING UNITS/DAY.
1	A	1500-1570	1340-1360	160-130
2	B	1550-1630	1400-1430	80-200
3	C	1530-1590	1380-1440	150

Average power saved = 300-570 units/day.

Saving in effect with 1 of the cooling tower fans being switched off is expected to result in power saving = [100-187]x3=300-570 units/day.

MONTHLY SAVING:

- 1 of 3 fans off for continuous basis = (300-570)x31
  = 9300-17000 Units/month.

ANNUAL SAVING:

- 1 of 3 fans off for continuous basis = (9300-17000)x12
  = 110000-204000 Units/year.

9.8.1 COOLING TOWER FAN WHEN WORKING UNDER TWO FANS

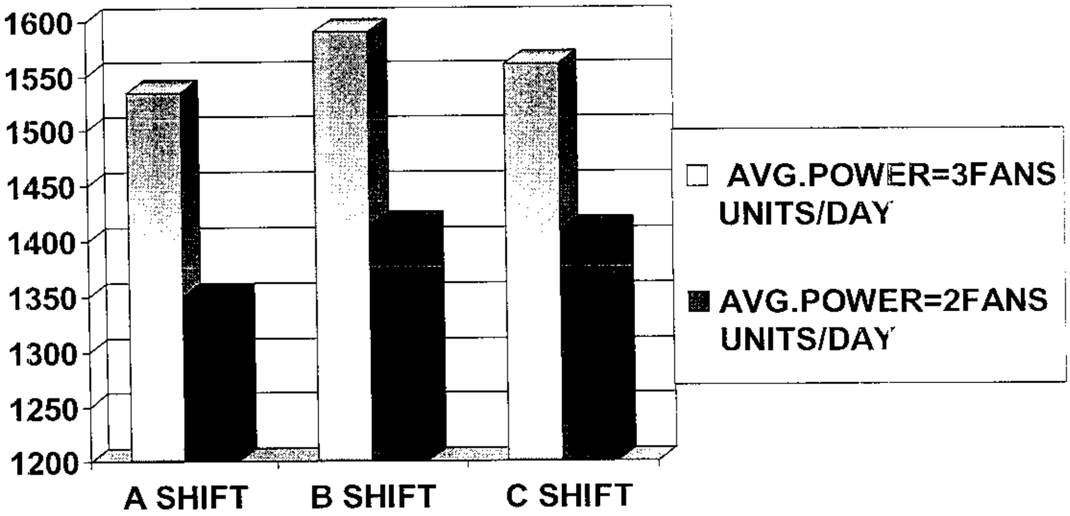


FIGURE 9.1 POWER SAVED WHEN COOLING TOWER FAN WORKING UNDER TWO FAN

9.9 COOLING TOWER FAN UNDER VARIABLE FREQUENCY DRIVE

Power consumed by CT fan = 3000units/day.
= 3000/(24x1000)
= 0.125 MW

Power consumed after using VFD = 3000x0.30
= 900units/day.
= 0.0375MW

Power saved after using VFD = 3000-900
= 2100units/day.
= 0.0875MW

Power saved annually = 781200units

Cooling tower under summer season is shown in Table 9.3 ,Cooling tower under summer season night condition is shown in Table 9.4, Cooling tower under winter season day condition is shown in Table 9.5 and Cooling tower under winter season night condition is shown in Table 9.6.

9.10 CASE STUDY UNDER VARIOUS CLIMATIC CONDITION

9.10.1 COOLING TOWER UNDER SUMMER SEASON DAY CONDITION:

Rating of motor: 45kW, 37 kW, 45 KW.

TABLE 9.3 COOLING TOWERS UNDER SUMMER SEASON DAY CONDITION

Rating of motor: 45Kw ,37 Kw ,45 KW.	**CASES**	**POWER CONSUMPTION BEFORE CONDITION**	**POWER CONSUMPTION AFTER CONDITION**	**POWER SAVED**
Case 1	FAN 1- , FAN 2 , & FAN 3- **WORKING**	32 +29+32 =93 =93x4000 **=372x10^{3}Units**	(32) +29+32 =93 =93x4000 **=372 x10^{3}Units**	----
Case 2	FAN 1 – **Using VFD,** FAN 2 , & FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	(0.30 x32)+29+32 =70x4000 **=280x10^{3}Units**	**92.0x10^{3}Units**
Case 3	FAN 2 – **Using VFD** FAN 1 , & FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	32+(0.30x29)+32 =72.7x4000 **=290.8x10^{3}Units**	**81.2x10^{3}Units**
Case 4	FAN 1 – **OFF,** FAN 2 , & FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	=29+32 =61x4000 **=244x10^{3}Units.**	**128x10^{3}Units**

9.10.2 COOLING TOWER UNDER SUMMER SEASON NIGHT CONDITION:

Rating of motor: 45kW ,37 kW ,45 kW.

TABLE 9.4 COOLING TOWER UNDER SUMMER SEASON NIGHT CONDITION:

	CASES	**POWER CONSUMPTION BEFORE CONDITION**	**POWER CONSUMPTION AFTER CONDITION**	**POWER SAVED**
Case1	FAN 1- **working ,** FAN 2 – **off during night alone** &	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	32 +(0.65x29)+32 =82 x4000 **=328.0x10^{3}Units**	**44.0 x10^{3}Units**

	FAN 3 **WORKING**			
Case 2	FAN 1 – **Using VFD on night shift,** FAN 2 , & FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	(0.30 x0.32x32 +(0.65x32)+29+32 =84x4000 **=336.9x10^{3}Units**	**36.00x10^{3}Units**
Case 3	FAN 2 – **Using VFD on night shift,** FAN 1 , & FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	32+(0.30x0.32x29)+ (0.65x29)+32 =85.3x4000 **=341.2x10^{3}Units**	**30.80x10^{3}Units**
Case 4	FAN 1 – **working** FAN 2 **-off** FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	=32+32 =64x4000 **=256x10^{3}Units.**	**116x10^{3}Units**

9.10.3 COOLING TOWER UNDER WINTER SEASON DAY CONDITION:

Rating of motor: 45kW ,37 kW ,45 kW.

TABLE 9.5 COOLING TOWER UNDER WINTER SEASON DAY CONDITION:

	CASES	POWER CONSUMPTION BEFORE CONDITION	POWER CONSUMPTION AFTER CONDITION	POWER SAVED
Case 1	FAN 1**- off** , FAN 2 – **using VFD** & FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	(0.30x29)+32 =40.7x4000 **=162.8x10^{3}Units**	**209 x10^{3}Units**
Case 2	FAN 1 – **Using VFD on day shift,** FAN 2 , & FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	(0.30 x0.65x32) +(0.32x32)+29+32 =77.5x4000 **=310.0x10^{3}Units**	**62.2x10^{3}Units**
Case 3	FAN 2 – **Using VFD on day shift,** FAN 1 , & FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^{3}Units**	32+(0.30x0.65x29)+ (0.32x29)+32 =78.94x4000 **=315.7x10^{3}Units**	**56.32x10^{3}Units**
Case 4	FAN 1 – **working on**	32 +29+32 =93 =93x4000	=(0.30x32)+32 =41x4000	**208x10^{3}Units**

	VFD FAN 2 -**off** FAN 3 **WORKING**	**=372 x10^3Units**	**=164x10^3Units.**	

9.10.4 COOLING TOWER UNDER WINTER SEASON DAY CONDITION:

Rating of motor: 45kW ,37 kW ,45 kW.

TABLE 9.6 COOLING TOWER UNDER WINTER SEASON NIGHT CONDITION

	CASES	POWER CONSUMPTION BEFORE CONDITION	POWER CONSUMPTION AFTER CONDITION	POWER SAVED
Case 1	FAN 1-**OFF During night shift,** FAN 2 , & FAN 3- **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^3Units**	(0.65x32) +29+32 =80 =81x4000 **=324 x10^3Units**	**48.0x10^3 Units**
Case 2	FAN 1 – **Using VFD on night shift** FAN 2 -**off** FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^3Units**	(0.30x0.32x32)+(0.65x 32)+32 =55x4000 **=220.0x10^3Units**	**152.0x10^3Units**
Case 3	FAN 2 – **Using VFD on day shift,** FAN 1-**off** FAN 3 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^3Units**	(0.30x0.65x29) +(0.32x29)+32 =46x4000 **=184.0x10^3Units**	**188.0x10^3Units**
Case 4	FAN 1 – **OFF,** FAN 3- **using VFD on day shift** FAN 2 **WORKING**	32 +29+32 =93 =93x4000 **=372 x10^3Units**	=29+(0.30x0.65x32+ (0.32x32)= =45x4000 **=180x10^3Units.**	**192.0x10^3Units**
Case 5	FAN1 OFF during day shift. FAN 2,FAN 3- WORKING	32 +29+32 =93 =93x4000 **=372 x10^3Units**	=29+32+ (0.32x32)= =66x4000 **=264x10^3Units.**	**108.0x10^3Units**

The Best Case

During Summer day:
FAN 1 –OFF,
FAN 2 , & FAN 3 WORKING power saved: 128x10^{3}Units

During summer night:
FAN 1 –Using VFD on night shift,
FAN 2 , & FAN 3 WORKING power saved :36.00x10^{3}Units

During winter night:
FAN 2 –Using VFD on day shift,
FAN 1-off FAN 3 WORKING power saved: 188.0x10^{3}Units

During winter day:
FAN 1 –working on VFD
FAN 2 -off FAN 3 WORKING power saved: 208x10^{3}Units

Total Power Saved :336 x10^{3}UNITS.

9.11 INSTRUMENTS

In the system ,the pressures and temperature of Cooling Water leaving and entering the cooling tower are measured .however, we do not have any specific instrumentation controls available. The temperatures are measure using dial thermometers and the pressures by dial gauges and less sensitive and accurate.

As per the instructions, hourly recording of the pressures and temperatures are being carried out. There is no provision for measuring the Cooling Water flow rate.

The outlet temperature of water from cooling tower is measured by thermometer. The readings are noted manually. In this cooling system there are three fans and three pumps (one standby) air in operation. The fans are in Low Tension and pumps are in High Tension.

Initially all the three fans run without fail, without any connection to the ambient conditions-be it day, night-summer, rainy or winter. It was decided as an experimental measure to cut off one of the fans (switching off the fan) during late night and yet maintain the condenser vacuum. However, with the onset of winter, it was felt that there could be some more power saving, if one could go in for control automaton, instead of the present manual operation.

Thus the project was selected aiming at control automation of the facets related to the Cooling Water system.

It is planned to be done in 2 phases viz.,

- Through judicious monitoring of the fans in location at the plant premises.
- Later extend the same took Cooling Water pump power saving exercise.

The present project plan is to optimize on power saving through_

- All fans in operation
- One of the three fans switched off
- 2 of 3 fans switched off
- Profile adjustment of the fans depending on the requirement and yet maintaining the desire constant condenser vacuum.
- Going in for Energy Efficient Motors

Overall power consumption in the cooling system is 1.5%. To reduce the power consumption, number of fans to operate is according to the outlet temperature of water from the cooling tower and vacuum in the condenser. The vacuum must be maintained in the range of 0.9 – 0.91 ata. Present practice is in winter and night time the atmospheric temperature is quite low. So, the outlet temperature reduction is large. Now, to optimize the power consumption one fan is shutdown and other two fans are in operation. If temperature increases beyond the limit then the third fan is also in operation.

The flow rate to the cooling tower in constant. If at all the flow rate varies [which is not the case as the constant damper throttling is being done], the temperature in the outlet is also varied. In the present system if the temperature varies number of fans in operation is changed manually. But it is false operation.Pressure gauge is installed in each of the three pumps .In the event of deposit /scaling inside the condenser tubes, there is every likelihood the flow would drop; resulting in increased water outlet.

9.12 COOLING TOWER PUMP:

- Utilization of Energy Efficient Pump.
- Utilization of Energy Efficient Motor.

Fluid handling systems are normally specified with large factors of safety. When actual system head is less than specified, pump will operate with flow higher than required and power will be wasted. If throttling control is used, power wastage is very high. Use of variable speed drives can a\change the pump characteristics by the following relation ships.Efficient improvement is shown in Table 9.7. Pump characteristics can be plotted at reduced speed (N) by this relationship

$$\text{Flow} \ \alpha \ N$$
$$\text{Head} \ \alpha \ N^2$$
$$\text{Power} \ \alpha \ N^3$$

9.13 COOLING WATER PUMP OPERATION

As indicated earlier, for a110MW unit, after B.F.P. and I.D. Fan this is the third largest capacity auxiliary. The number of Cooling Water pumps, to be kept in service for unit system should be in accordance with load on the unit. Where there is a common pumping facility of Cooling Water to no of units, according to total load on the units, Cooling Water pumps should be kept in service.

During light up and low load, operation of unit (in case two 50% duty Cooling Water pumps provinduced drafted) only in Cooling Water pump should be kept into service. Normally turbine plant manufactures give guidelines as to when last Cooling Water pump can be put out of service based on design and lay out of plant.

After the turbine is shutdown one Cooling Water pump is normally kept in service for cooling which can not be ignored. If there is alternative arrangement available of small capacity pump for cooling the Lubrication oil, large capacity Cooling Water pump can be put out of service. If such arrangement is not provinduced drafted last Cooling Water pump can be switched off after switching off SOP. Heat content of turbine rotor gets partly dissipated through shaft and bearings.

Valves at condensers in Cooling Water system can be throttled (to a certain extent) to regulate flow of Cooling Water Plants where Induced draft. /Forced draft type cooling tower are provinduced drafted, sizeable saving in auxiliary consumption can be achieved. Nos of fans to be kept in service should commensurate with maintaining optimum vacuum during different load conditions, unit Cooling Water inlet temperature and Cooling Water flow.

Numbers of Cooling Water pumps in service can be decided drafted based on vacuum of units. Improvement of heat rate by increasing Cooling Water flow to be compared with power absorbed by pumps in order to get over-all economy. Seasonal variation in ambient conditions to be taken it o consideration for requirement of number Cooling Water pumps. For example during winter, even with less Cooling Water flow, vacuum can be attained. The above practice may lead to the problem of scale formation in condenser tubes. By switching off one Cooling Water pump, Cooling Water velocity will be reduced. The soluble and insoluble impurities content in Cooling Water settle down in the tubes and gets heated which in turn form scales. Certain; impurities form adherent scale, difficult to remove the same even be acid cleaning. Hence care should be taken while operating the unit with less number of Cooling Water pumps.

9.14 OPTIMIZING TECHNIQUE USED IN COOLING TOWER PUMP

9.14.1 EFFICIENCY IMPROVEMENT

DATA: Flow = 1800 m^3/ hrs
Head = 120 m
Pump Input = 162.4 KW
η = 78%
Pump output = 144.08 wp
Speed = 1481 rpm
η_{motor} = 95%

9.14.2 ALGORITHM:

Power = (QH/ η_P x367)/ η_{motor}. KW

Correction factor = 367

TABLE 9.7 EFFICIENCY IMPROVEMENTS IN COOLING TOWER PUMP

S.NO	EFFICIENCY %	POWER CONSUMPTION MW
1	78	0.794
2	79	0.784
3	81	0.784
4	84	0.738
5	86	0.720
6	87	0.712
7	89	0.691
8	90	0.688
9	92	0.673
10	93	0.666

By improving the efficiency

At 100 % load, power saved =0.794-0.666 =0.128MWx24000= 3072 Units /day

Power saved in Cooling tower pump = 3072 Units /day

CHAPTER 10

CONDENSER EXTRACTION PUMP

10.1 CONDENSER EXTRACTION PUMP

Utilization of Energy Efficient Pump.

10.2 PUMP CHARACTEISTICS

Typical performance characteristics are [a] head or pressure v/s flow, [b] power v/s flow and [c] efficiency v/s flow.

The following important points may be noted for pumps,

- The pump head or pressure deceases with increase in flow.
- The pump efficiency increases with flow, reaches a maximum and then decreases again. Please note the difference between the pump efficiency and the motor efficiency curve. At 50% load, the motor efficiency will not be very different from that at full load, whereas pump efficiency at 50% flow may be 20 percentage points lower than at the design flow. This is also applicable to fans and blowers.
- Due to reduction inefficiency at flows lower than rated flow, power does not drop significantly at low flows for p[pumps and fans, when the lower flows are achieved at very low flows i.e. lower than 25% of the rated flow. However, motors can operate at no load without any problem, consuming about 5% of the rated power
- The system head flow ,the system head consists of a static head and friction head [due top flow in pipes or ducts]. The actual operating point would be determined by the intersection of pump characteristic and system characteristic. In most cases, it is difficult to determine the system characteristic with very great accuracy. Efficiency Improvement in condensate extraction pump is shown in Table 10.1

Pump shaft power **P** = $(Q.\rho.g.H) / 1000 \times \eta_p$

10.3 OPTIMIZING TECHNIQUE USED IN CONDENSER EXTRACTION PUMP:

10.3.1 EFFICIENCY IMPROVEMENT

DATA: Flow = 1500 m^3/ hrs

Head = 46 m

Pump Input = 162.4 KW

η = 75%

Pump output = 134.08 wp

NPSH = 6.8 m

Speed = 1451 rpm

η_{motor} = **95%**

10.3.2 ALGORITHM:

Power = **(QH/ η_P x367)/ η_{motor}. KW**

Correction factor = 367

TABLE 10.1 EFFICIENCY IMPROVEMENTS IN CONDENSER EXTRACTION PUMP

S.NO	EFFICIENCY %	POWER CONSUMPTION MW
1	75	0.263
2	76	0.260
3	77	0.257
4	78	0.253
5	79	0.250
6	80	0.247
7	81	0.244
8	82	0.241
9	83	0.238
10	85	0.232

By improving the efficiency

At 100 % load, power saved =0.263-0.232 =0.031MWx24000

= 744 Units /day

Power saved in Condenser extraction pump = 744 Units /day

CHAPTER 11

ELECTROSTATIC PRICIPITATOR

11.1 ELECTROSTATIC PREIPITATOR OPERATION

Working of hopper heater to be ensured for free flow of ash during dashing which reduces build up, of ash in hoppers. Non working of the heaters can result in longer ash evaluation time, and Induced Draft fan erosion.

In case of some electrical field not working, due to snapping of electrodes, same to be induced draft entified. During low system demand, particular gas path of Electrostatic Precipitator should be isolated (Based of possible isolation through dampers) for disconnecting snapped electrodes and recharging the field. This is being practiced in some plants.

11.2 ELECTROSTATIC PRECIPITATOR:

The Electrostatic Precipitator is very effective fly ash separation equipment & hence its performance must be monitored. Deterioration in Electrostatic Precipitator performance results in erosion of the Induced Draft Fan runner. Erosion of Induced Draft Fan runner results in vibration problem at fan & reduces discharge capacity of Induced Draft fan and can result in load reduction of unit.

The collecting efficiency of Electrostatic Precipitator is expressed as:

$$\dot{\eta} = 1 - e^{-|\,\mathbf{WK > SCA}\,|\,\frac{1}{2}}$$

where **WK** = **Migration velocity**

SCA = **Specific collecting area.**

$$\mathbf{SCA} = \frac{\textbf{Total gas flow area}}{\textbf{gas flow rate}}$$

Hence the collecting efficiency can be increased by increasing the collecting area and/or migration velocity. The normal collecting efficiency of Electrostatic Precipitator. [S.F. Sweden design for 110 MW BHEL Unit] is 99.8%. Though the

Electrostatic Precipitator efficiency is high, its performance play and important role on the life of Induced Draft fan, and the unit loading.

The migration velocity of the dust particle depends on

- Electrical power input.
- Receptivity of dust particle.
- Dust burden.
- Dust size and its particulate distribution.
- Temperature of inlet flue gas.
- Velocity of the gas through Electrostatic Precipitator.
- Gas quantity

The collecting efficiency thus depends on dust property. Gas characteristic and quality factor of Electrostatic Precipitator. Quality factor of Electrostatic Precipitator takes into considering draft ration configuration of electrodes, uniform gas distribution through distribution screen, alignment of electrodes & rapping cycle.

11.3 CHARACTERISTIC OF ELECTROSTATIC PRECIPITATOR

11.3.1 RESISTIVITY:

The maximum amount of electrical charge up to which particle can be charge get reduced with increase in resistivity of the particle. The migration velocity depends upon the charge of the particle. The migration velocity reduces with the increase in resistivity of the particle. This will reduce spark over voltage can improve the performance.

11.3.2 GAS TEMPERATURE:

In perfect dry gas the presence of fly ash works as a semiconductor. The gas temperature entering the Electrostatic Precipitator should be monitored. Also condensation of SO2 & H2O is not he Electrostatic Precipitator should be m desirable.

11.3.3 GAS VELOCITY AND GAS DISTRIBUTION:

Velocity of gas in Electrostatic Precipitator should be approximately 1/10 of the velocity before Electrostatic Precipitator. So as to get sufficient process time for fly ash particle for effective collection. With high velocity the amount of carry over of particles increases. The gas distribution over entire apparature of Electrostatic Precipitator should be uniform. Stratification of fly ash and gas cloud reduces the collecting efficiency.

11.3.4 RAPPING OF THE ELECTRODES:

Deposition of fly ash at collecting electrodes will deteriorate the performance of Electrostatic Precipitator. Heavy deposition on collecting electrode reduces the charging of the fly ash and spark over voltage will reduce.[Rapping cycle should be kept as per the manufacturer's recommendation.] The rapping should be such that reentraiment of the separated dust particles should be prevented to the extent possible

11.3.5 SPARK RATE:

For the optimum collecting efficiency the spark rate should be within 5 spark/min high spark rate will increase chances of wire snapping due to electrical erosion.

11.3.6 HEATING ELEMENT:

Properly working of heater providence drafted at dust collecting hoppers ensure free flow of ash since necessary temperature is maintained in induced draft above dew point the hopper

11.3.7 SUPPLY VOLTAGE:

For optimum functional efficiency the supply voltage should be maintained near about flash over level and drop in the voltage is in the event of flash over. An additional increase in voltage beyond normal operating voltage will produce disproportionate increase in current accompanied by heavy spartking and reduction in collecting efficiency.

11.3.8 SIZE OF PARTICLE:

As the size of the particle reduces, the migration velocity reduces and hence the space charge increased. This results in increased power consumption and reduces collecting efficiency. Such a situation is likely to exist in the Electrostatic Precipitator placed after mechanical dust collector and last Electrostatic Precipitator fields.

11.3.9 ALIGNMENT ERROR:

The spacing error during erection or misalignment between electrodes will reduce the corona voltage and spark over voltage. This is because of reduced migration velocity and collecting efficiency.

The fly ash hopper should be evacuated completely at regular intervals. If dust hopper filled up, it results in earthing of emitter electrode and as a result the ash to be collected on subsequent rows of hoppers. This at times results in reduced collection rate. This increase wears on Induced Draft fan and increased chimney emission.

Over a period of run, the gas distribution screen and the baffle plates get eroded due to flow of the dust laden gas. This starts erosion of electrodes and outage of Electrostatic Precipitator field.

Paper industry used Electrostatic Precipitator at Boiler induced draft as shown in Figure 11.1

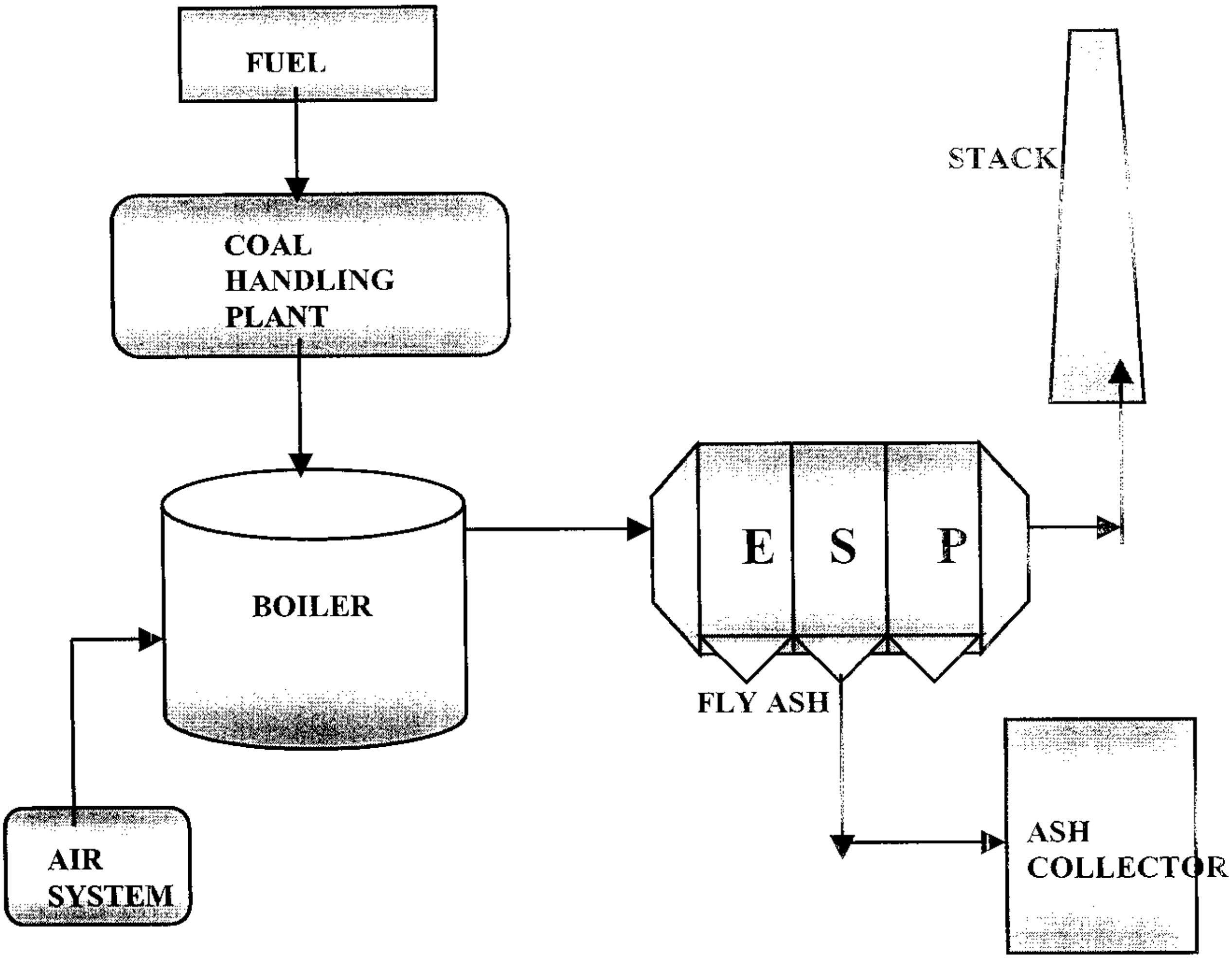


FIGURE 11.1 ELECTROSTATIC PRECIPITATOR

11.4 OPTIMIZING TECHNIQUE FOR ELECTROSTATIC PRECIPITATOR

Power Consumption per Zone = (rated kV x rated mA x Form Factor) / 0.916

= $((70 / \sqrt{2}) \times 0.8 \times 1.28) / 0.916$

= 55.3 KVA /ZONE

Installed power = 1.04xrated kV x rated mA x $(k1)^2$

= $1.04 \times 70 \times 0.8 \times (1.05)^2$

= 45.4 KW

Power Consumption by Zone 1 = 1.04x rated kV x rated mA x $(k1)^2$

= $1.04 \times 35 \times 0.45 \times 1^2 = 16.4$ kW

Power Consumption by Zone 2 = $1.04 \times 31.5 \times 0.58 \times 1.01^2 = 19.2$ kW

Power Consumption by Zone 3 = $1.04 \times 30 \times 0.64 \times 1.01^2 = 20.4$ kW

Power Consumption by all Zones = 16.4+19.2+20.4 = 56 kW

11.4.1 POWER CONSUMPTION WHEN ONE ZONE CUT OFF:

Zone 1 cut off:

Power Consumption by Zone 1 = 0 kW
Power Consumption by Zone 2 = 1.04 x31.5 x 0.58x 1.01^2 =19.2 kW
Power Consumption by Zone 3 = 1.04 x30 x 0.64x 1.01^2 =20.4 kW
Power Consumption by all Zones = 39.6 kW
= 0.039 MW x24000
= 936 Units /Day .

Power saved cutting off one field in electrostatic precipitator

= 0.056-0.039 = 0.017 Units/Day.
= 0.017x24000 = 408 Units /Day

CHAPTER 12

RESULTS OBTAINED

12.1 RESULTS IN THE STATION POWER CONSERVATION:

STEAM TURBINE:

Power saved by Using Optimizing Technique in Steam Turbine = 0.204 MW/TPH

BOILER FEED PUMP:

Power saved in Boiler Feed Pump = 0.147 MW = 3528 Units /day

INDUCED DRAFT FAN :

Power saved in Induced draft fan = 0.175 MW = 4200 Units/Day.

PA FAN:

Power saved in Primary Air fan= 0.049 MW = 1176 Units/Day.

FORCED DRAFT FAN :

Power saved in forced draft fan = 0.118 MW = 2832 Units /day

COOLING TOWER FAN:

Power saved in Cooling tower fan = 0.061MW = 1467 Units /day

COOLING TOWER PUMP:

Power saved in Cooling tower pump = 0.128MW = 3072 Units /day

CONDENSER EXTRACTION PUMP :

Power saved in Condenser Extraction Pump = 0.031 MW = 744 Units /day

ELECTROSTATIC PRICIPITATOR:

Power saved cutting off one field in electrostatic precipitator = 0.056-0.039
= 0.017 MW
= 0.017x24000
= 408 Units /Day

Thus

Total Power Saved = 22,000 Units/day = 22,000 /24,000 = 0.93 MW

CHAPTER 13

CONCLUSION

13.1 CONCLUSION AND SUGGESTION FOR FURTHER ENHANCEMENT:

Various researches are under going on throughout the world regarding Efficient use of Cogeneration Plant. In this project detailed work on Power conservation in Captive Cogeneration was done.

As a result of optimizing use of Cogeneration, the total Power saved due to this Project is about 0.98 MW.This results reducing in Power production of 0.98MW. This could enhance the Net Power production of Captive Cogeneration Plant.

This project produces the power saving of about 0.93 MW. This results in 80,35,200 Units saved annually which results in Rs.2,61,1400 Saved.This will reduce the small amount of accessing of grid power from the Electricity Board.

As a result there will be flexibility in operation. This produce efficient use of Capital Investment Future enhancement of this project is to reduce the harmonics obtained by Variable Frequency Drive and efficient use of auxiliary equipments.

Various research are undergoing on the reduction of harmonics present in Variable Frequency drive.

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