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Research Article

Exergy Analysis of 120MW Thermal Power Plant with Different Condenser Back Pressure and Generate Correction Curves

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Abstract

The thermal power plants are used to generate power. The thermal power plants are designed based on required conditions (like a good quality of steam, pressure and temperature of steam e.t.c.), but actually inlet conditions are not as per the designed conditions. In practical situations, when power plants are installed there are lots of constraints. This tends to reduce or increase output power and heat rate of thermal power plants. Due to these conditions, the designed power and heat rate are never achieved. Variations in the power outputs from plant are always a matter of disputes. So the correction curves for power and heat rate are generated for different conditions of condenser back pressure. These curves indicate that if operating conditions vary, then power output and heat rate also vary. This paper deals with the generation of the correction curves for 120 MW thermal power plant.

Keywords: *Condenser Back Pressure, Power Output, Heat Rate, Correction Curve for power, Correction curve for heat rate.*

1. Introduction

This paper is based on 120 MW thermal power plant, so a brief description of 120 MW thermal power plant is given as under:

Thermal power plant consists of five major components –

•Boiler.

•Steam Turbines – High pressure turbine, Intermediate pressure turbine and Low pressure turbine.

•Condenser.

•Feed Water Pump – Pump after condenser and Pump after deaerator.

•Feed Water Heater – one feed water heater for high pressure turbine, two feed water heater for intermediate pressure turbine and three feed water heater for low pressure turbine.

In the boiler, water converts into high pressure and temperature steam by the constant pressure heating process. Then high pressure and temperature steam enters into a high pressure steam turbine, in which steam expands and some amount of steam extract for feed water heating process. Then steam enters into an intermediate pressure turbine, in which steam expands and some amount of steam again extract for feed water heating process. And finally steam enters into a low pressure turbine, in which steam expands and some amount of steam again extract for feed water heating process. After passing through the low pressure turbine steam is converted into saturated water. Then water enters into the boiler with the help of a pump. (Yadav R et al,2007) A layout of thermal power plant.

Bekdemir Sukrii, Ozturk Recep and Yumurtac Zehra have been worked on condenser optimization in steam power plant. Sharda G. G. and Batra K. R. have been worked on super thermal power station to improve the performance of the plant by distribution control system technology. Bednorz Richard and Henken Fritz have been worked on modernization of turbine and condenser for improving the performance of power plant. Kaushik Prabhakar and Khanduja Dinesh have been applied six sigma DMAIC methodologies in thermal power plants. Amir Vosough, Alireza Falahat, Sadegh Vosough , Hasan Nasr Esfehani, Azam Behjat and Roya Naseri Rad have been worked on condenser to improve the efficiency of power plant. Mateen Abdul Sk. and Roa Nageswara Amar N. have been done structural and thermal analysis of the condenser by finite element analysis. Carvalho L.M. and Cristiani P., have been analyzed the corrosion in condenser tubes. This paper deals with the generation of correction curves for 120 MW thermal power plant. These curves indicate that if input condition are changes, then power output changes. These curves help as a reference or as a document to prove the design of thermal power plant.

2. Methodology

Flow function has been calculated with the relation bet-

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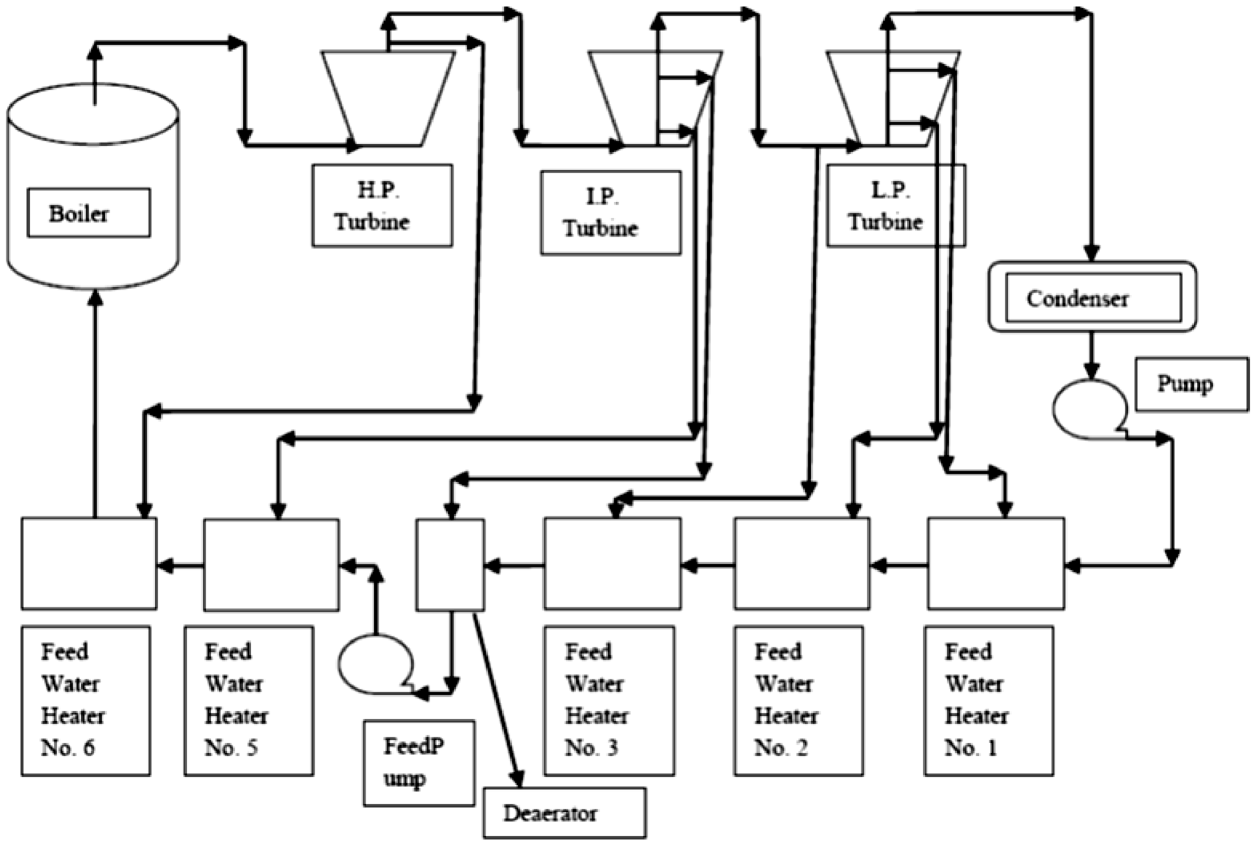

Figure 1 – Layout of 120MW thermal power plant

-ween mass flow rate, pressure and specific volume. Power has been calculated with the relation between mass flow rate and enthalpy drop in the turbine. And heat rate has been calculated with the relation between total heat addition in boiler and and net power output from power plant. (Cotton K.C et al,1993)

Flow Function = $W/(P/V)^{1/2}$ Eq.(1)

Power = (Mass flow rate) x (Enthalpy drop in the turbine) Eq. (2)

Heat rate = (Total heat addition in boiler) / (Net power) Eq. (3)

First of all, the flow function has been calculated (which is constant for all the conditions) with the help of a flow function formula. Pressure, volume and mass flow rate have been taken from the design condition. Condenser back pressure has been selected as a parameter and with the help of calculated flow function, the mass flow rate has been calculated. Then different mass flow rates have been calculated for high pressure turbine, intermediate pressure turbine and low pressure turbine by considering leakages and extraction quantities. With the help of relationship between mass flow rate and enthalpy drop in turbine, power has been found. Then net power has been calculated with consideration of mechanical losses and generator efficiency. Then heat rate has been calculated from the relationship between total heat addition in the boiler (summation of heat addition in boiler for steam generation and heat addition in super heater for superheating) and net power. These steps have been repeated and different power and heat rate have been calculated for different conditions. Then correction factors have been found for power and heat rate with the help of designed power and heat rate. Then finally correction curves have been generated for condenser back pressure at different conditions.

2.1 Calculation for Ideal Condition

Some important data for designed condition are as under (BHEL Bhopal)
Pressure = 125.1×10^5 N/m^2, Temperature = 537.78°C, Specific volume = 0.0186 m^3/kg, Mass flow rate of steam = 100.916 kg/sec, then Flow Function = 4430.126.
Power = 120 MW and Heat rare = 2.4138 KJ/KW-sec (unitless).

2.2 Power Calculation

- $W_1 = (W' - L_1 - L_2 - L_3 - L_4)$ Eq.(4)

$= (363.313 – 4.55 – 0.152 – 1.12 – 0.39) \times 10^3/3600 = 357.101 \times 10^3/3600$ kg/sec

- $W_2 = (W_1 + L_1 - L_5 - L_6 - Ex_1)$ Eq. (5)

$= (357.101 + 4.55 – 0.84 – 0.3 – 23.86) \times 10^3/3600 = 336.651 \times 10^3/3600$ kg/sec

- $W_3 = (W_2 - Ex_2 - L_7 - L_8)$ Eq. (6)

$= (336.651 – 15.23 – 1.32 – 0.362) \times 10^3/3600 = 319.739 \times 10^3/3600$ kg/sec

- $W_4 = (W_3 - Ex_3)$ Eq. (7)

$= (319.739 – 20.53) \times 10^3/3600 = 299.209 \times 10^3/3600$ kg/sec

- $W_5 = (W_4 - Ex_4)$ Eq. (8)

$= (299.209 – 7.68) \times 10^3/3600 = 291.529 \times 10^3/3600$ kg/sec

- $W_6 = (W_5 - Ex_5 - L_9)$ Eq. (9)

$= (291.529 – 14.14 – 0.15) \times 10^3/3600 = 277.239 \times 10^3/3600$ kg/sec

- $W_7 = (W_6 - Ex_6)$ Eq. (10)

$= (277.239 – 12.66) \times 10^3/3600 = 264.579 \times 10^3/3600$ kg/sec

P = HP Turbine $\{W_1 (h_1 - h_2)\}$ + IP Turbine $\{[W_2 (h_3 - h_4)] + [W_3 (h_4 - h_5)] + [W_4 (h_5 - h_6)]\}$ + LP Turbine $\{[W_5 (h_6 - h_7)] + [W_6 (h_7 - h_8)] + [W_7 (h_8 - h_9)]\}$ Eq. (11)

P = 122.714 MW

P_{net} = (122.714 – 0.69) X 0.983 = 119.95 MW or 120 MW

2.3 Heat Rate Calculation

$HR = Q / P_{net}$ Eq. (12)
$HR = (Q_1 + Q_2) / P_{net}$ Eq. (13)
$Q_1 = W' (h_1 - h)$ Eq. (14)
$Q_2 = W_2 (h_3 - h')$ Eq. (15)

HR = 363.313 (822.22 – 234.74) + 336.651 (846.68 – 739.63) /120 (4.18/3600) KJ/KW-sec
HR = (249477.61/120) (4.18/3600) KJ/KW-sec
HR = 2.4138

3. Results

Table 1 – Table for Power

Sr. No.	Pressure (in bar)	Power (in MW)	Correction Factor
1	0.07	122.783	0.9773
2	0.09	121.075	0.9911
3	0.1036	120	1
4	0.11	119.525	1.0039
5	0.13	118.191	1.0153
6	0.15	117.005	1.0255

Table 2 – Table for Heat rate

Sr. No.	Pressure (in bar)	Heat Rate (in KJ/sec)	Correction Factor
1	0.07	2.3591	1.0231
2	0.09	2.3924	1.0089
3	0.1036	2.4138	1
4	0.11	2.413	1.0003
5	0.13	2.4507	0.9849
6	0.15	2.4756	0.975

Correction Curve 1 - Correction Curve For Power

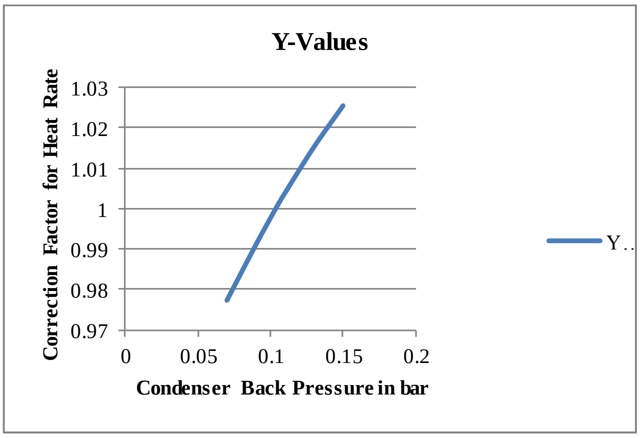

Figure 2 – Correction curve for condenser back pressure for power

Correction Curve 2 - Correction Curve For Heat Rate

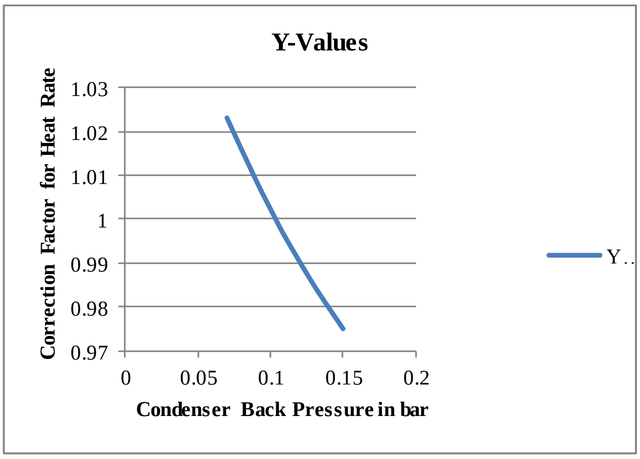

Figure 3 – Correction curve for condenser back pressure for heat rate

Conclusion

Thermal power plant design is correct, can be proved by the correction curves for condenser back pressure. For example, if condenser back pressure is 0.15 kg/cm^2 then power output will be,

= 1.0255 x 117.005= 120 MW
Here, 1.0255 is the correction factor which is taken from the output correction curve for power at different conditions of condenser back pressure.

Future Scope

(1) Such type of software can be developed in which only inlet pressure and inlet temperature enters, and then the software will generate correction curves for different parameter at different conditions for 120MW power plants.
(2) Such type of software can be developed by which power and heat rate can be found for different capacities of power plant, and generates correction curves for different parameter at different conditions for different capacities of power plant.

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List of Symbols, Abbreviation and Nomenclature

Ex_1 = Extraction Quantity after Expansion in HP Turbine for Heater No. 6 (kg/sec).
Ex_2 = 1st Extraction Quantity from IP Turbine for Heater No. 5 (kg/sec).
Ex_3 = 2nd Extraction Quantity from IP Turbine for Deaerator (kg/sec).
Ex_4 = Extraction Quantity after Expansion in IP Turbine for Heater No. 3 (kg/sec).
Ex_5 = 1st Extraction Quantity from LP Turbine for Heater No. 2 (kg/sec).
Ex_6 = 1st Extraction Quantity from LP Turbine for Heater No. 1 (kg/sec).
FF = Flow Function
h = Enthalpy of Feed Water at Inlet of Boiler (KJ/kg).
h' = Enthalpy of Steam Before Entering Super heater (KJ/kg).
h_1 = Enthalpy of Steam at Inlet of HP Turbine (KJ/kg).
h_2 = Enthalpy of Steam at Outlet from HP Turbine (KJ/kg).
h_3 = Enthalpy of Steam at Inlet to IP Turbine or Outlet from Super heater (KJ/kg).
h_4 = Enthalpy of Steam After 1st Extraction from IP Turbine (KJ/kg).
h_5 = Enthalpy of Steam After 2nd Extraction from IP Turbine (KJ/kg).
h_6 = Enthalpy of Steam at Outlet from IP Turbine (KJ/kg).
h_7 = Enthalpy of Steam After 1st Extraction from LP Turbine (KJ/kg).
h_8 = Enthalpy of Steam After 2nd Extraction from LP Turbine (KJ/kg).
h_9 = Enthalpy of Steam at Outlet from LP Turbine (KJ/kg).
L_1 = Steam Used for Reducing Pressure Difference b/w 1st & Last Stage of HP Turbine (kg/sec).
L_2 = Leakage before Entering Steam in HP Turbine (kg/sec).
L_3 = Leakage before Entering Steam in HP Turbine (kg/sec).
L_4 = Leakage Before Entering Steam in HP Turbine (kg/sec).
L_5 = Leakage after Steam Expand in HP Turbine (kg/sec).
L_6 = Leakage after Steam Expand in HP Turbine (kg/sec).
L_7 = Leakage before Entering Steam in IP Turbine (kg/sec).
L_8 = Leakage before Entering Steam in IP Turbine (kg/sec).
L_9 = Leakage before Entering Steam in LP Turbine (kg/sec).
Q_1 = Heat addition in Boiler (KJ/kg).
Q_2 = Heat addition in Superheater (KJ/kg).
V = Specific Volume of Steam for 120MW Power Plant (design condition) (m³/kg).
W = Mass Flow Rate of Steam for 120MW Power Plant (design condition) (kg/sec).
W' = Mass Flow Rate Generated in Boiler at Different Conditions (kg/sec).
W_1 = Mass Flow Rate at Inlet of HP Turbine (kg/sec).
W_2 = Mass Flow Rate at Inlet of IP Turbine (kg/sec).
W_3 = Mass Flow Rate After 1st Extraction of Steam from IP Turbine (kg/sec).
W_4 = Mass Flow Rate After 2nd Extraction of Steam from IP Turbine (kg/sec).
W_5 = Mass Flow Rate at Inlet of LP Turbine (kg/sec).
W_6 = Mass Flow Rate After 1st Extraction of Steam from LP Turbine (kg/sec).
W_7 = Mass Flow Rate After 2nd Extraction of Steam from LP Turbine (kg/sec).