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Thermodynamic analysis of 120 mw thermal power plant and generate correction curves for extraction line pressure drop (heater no.5) with the help of designed computer aided software

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ABSTRACT

The thermal power plants are designed based on required conditions (like quality of steam, pressure and temperature of steam e.t.c.), but actually inlet conditions are not as per the design 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. These constraints are leakages, installation errors etc. So due to these conditions, the designed power and heat rate are never achieved. Due to these variations in the power output from plants, it is always a matter of disputes. So the correction curves for power and heat rate are generated for pressure drop in extraction line 5, as a parameter at different conditions. These curves indicate that if operating conditions are 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 by using computer aided software for pressure drop in extraction line 5.

List of Symbols, Abbreviation and Nomenclature

Ex_1 = Extraction Quantity after Expansion in HP Turbine for Heater No. 6 (kg/sec).

Ex_2 = 1^{st} Extraction Quantity from IP Turbine for Heater No. 5 (kg/sec).

Ex_3 = 2^{nd} 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 = 1^{st} Extraction Quantity from LP Turbine for Heater No. 2 (kg/sec).

Ex_6 = 1^{st} 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 1^{st} Extraction from IP Turbine (KJ/kg).

h_5 = Enthalpy of Steam After 2^{nd} Extraction from IP Turbine (KJ/kg).

h_6 = Enthalpy of Steam at Outlet from IP Turbine (KJ/kg).

h_7 = Enthalpy of Steam After 1^{st} Extraction from LP Turbine (KJ/kg).

h_8 = Enthalpy of Steam After 2^{nd} 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 1^{st} & 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).

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 1^{st} Extraction of Steam from IP Turbine (kg/sec).

W_4 = Mass Flow Rate After 2^{nd} 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 1^{st} Extraction of Steam from LP Turbine (kg/sec).

W_7 = Mass Flow Rate After 2^{nd} Extraction of Steam from LP Turbine (kg/sec).

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 –

(a) Boiler.

(b) Steam Turbines – High pressure turbine, Intermediate pressure turbine and Low pressure turbine (number of turbines - 3).

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(c) Condenser.
(d) Feed Water Pump – Pump after condenser and Pump after deaerator (number of pumps - 2).
(e) Feed Water Heaters – 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 (number of heaters - 6).

In the boiler, water converts into high pressure and temperature steam by the constant pressure heating process. Then high pressure and temperature steam enter into a high pressure steam turbine, in which steam expands and some amount of steam extract to feed the 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. [1]

Humbert F. Claude [2] has been worked on step-by-step approach to the evaluation and life extension of feed water heaters. Linda Riley, Carroll Willsie and Claude Humbert [3] have been worked on a feed water heater. Schaarschmidt Andreas, Jenikejew Eduard and Nitch Greg [4] have been worked on power plant to improve the performance by an elaborate design process.

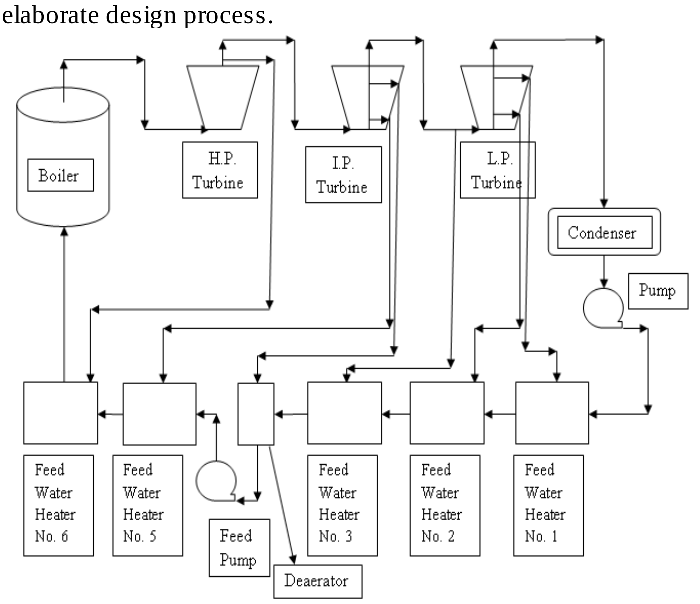


Figure 1 – Layout of a thermal power plant

Schimon Rene, Simic Dragan, Haumer Anton, Kral Christian and Plainer Markus [5] have been worked on a simulation of the components of a thermal power plant. Dr. Quinkertz Rainer, Ulma Andreas, Gobrecht Edwin and Wechsung Michael [6] have been worked on operational flexibility and improve efficiency of the plant. Kaushik Prabhakar and Khanduja Dinesh [7] have been applied six sigma DMAIC methodologies in thermal power plants. Xu Cheng, Hary R. Winn, Robert A. Beveridge and Jefferey J.Williams [8] have been worked on cascade shell and tube type feed water heater. Becker R. Bryan and Pearce E. Richard [9] have been worked on life management and its applications on a feed water heater. This paper deals with the generation of correction curves for 120 MW thermal power plant with the help of computer aided software. The work is based on exergy analysis of thermal power plant (if the inlet conditions are different then power output will be different from the designed power). So correction curves are generated for pressure drop in the extraction line for feed water heater 5. These curves help as a reference or as a document to prove the design of thermal power plant. A layout of 120 MW thermal power plant -

2. Methodology

Flow function has been calculated with the relationship between mass flow rate, pressure and specific volume [10]. Power has been calculated with the relationship between mass flow rate and enthalpy drop in the turbine [11]. And heat rate has been calculated with the relationship between total heat addition in boiler and net power output from the power plant [11].

$FF = W/(P/V)^{1/2}$ 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. Extraction line pressure drop for heater number 5 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 the extraction line pressure drop for heater number 5.

2.1 Calculations

Some important datas for designed condition are as under [10] – Pressure = 125.1 x 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

1 $W_1 = (W' - L_1 - L_2 - L_3 - L_4)$ Eq. (4)
$= (363.313 - 4.55 - 0.152 - 1.12 - 0.39) \times (10^3/3600) = 357.101 \times (10^3/3600)$ kg/sec

2 $W_2 = (W_1 + L_1 - L_5 - L_6 - Ex_1)$ Eq. (5)
$= 357.101 + 4.55 - 0.84 - 0.3 - 23.86 = 336.651 \times (10^3/3600)$ kg/sec

3 $W_3 = (W_2 - Ex_2 - L_7 - L_8)$ Eq. (6)
$= 336.651 - 15.23 - 1.32 - 0.362 = 319.739 \times (10^3/3600)$ kg/sec

4 $W_4 = (W_3 - Ex_3)$ Eq. (7)
$= 319.739 - 20.53 = 299.209 \times (10^3/3600)$ kg/sec

5 $W_5 = (W_4 - Ex_4)$ Eq. (8)
$= 299.209 - 7.68 = 291.529 \times (10^3/3600)$ kg/sec

6 $W_6 = (W_5 - Ex_5 - L_9)$ Eq. (9)
$= 291.529 - 14.14 - 0.15 = 277.239 \times (10^3/3600)$ kg/sec

7 $W_7 = (W_6 - Ex_6)$ Eq. (10)
$= 277.239 - 12.66 = 264.579 \times (10^3/3600)$ 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 x 10^3 KW or <u>120 x 10^3 KW</u>

Some important equations for heat rate calculation are as under [10]-

1 $HR = Q / P_{net}$ Eq. (12)

2 $HR = (Q_1 + Q_2) / P_{net}$ Eq. (13)

3 $Q_1 = W'\ (h_1 - h)$ Eq. (14)

4 $Q_2 = W_2\ (h_3 - h')$ Eq. (15)

HR = 249477.61/120 x (4.18/3600)

HR = **<u>2.4138 KJ/KW – sec</u>**

3. Software Methodology

In this method correction curve for power and heat rate at different conditions have been generated by software (without manual calculation). The software development is based on visual basic 6.0. [12] [13]

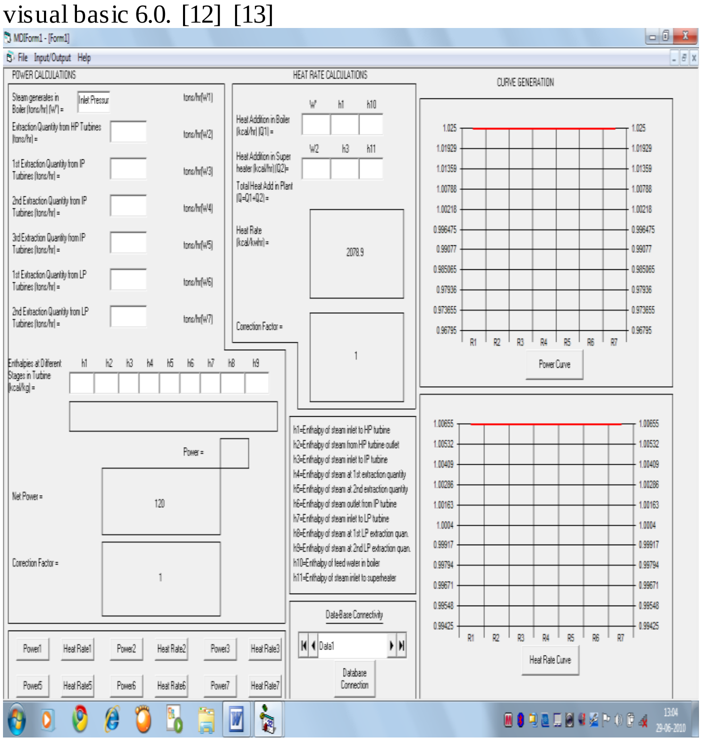


Figure 2 – Software for generation of correction curve for power and heat rate

4. Result

Table 1 – Table for Power and Heat Rate

Sr. No.	Extraction Line Pressure Drop	Power (in x 10^3KW)	Correction Factor	Heat Rate (in KJ/KW-sec)	Correction Factor
1	2%	120.067	0.9994	2.4134	1.0004
2	3%	120.045	0.9996	2.4135	1.0002
3	4%	120.022	0.9998	2.4137	1.0001
4	5%	120.000	1.0000	2.4138	1.0000
5	6%	119.977	1.0002	2.4139	0.9997
6	7%	119.954	1.0004	2.4140	0.9995
7	8%	119.931	1.0006	2.4141	0.9993

Curve 1 – Correction Curve for Power and Heat Rate

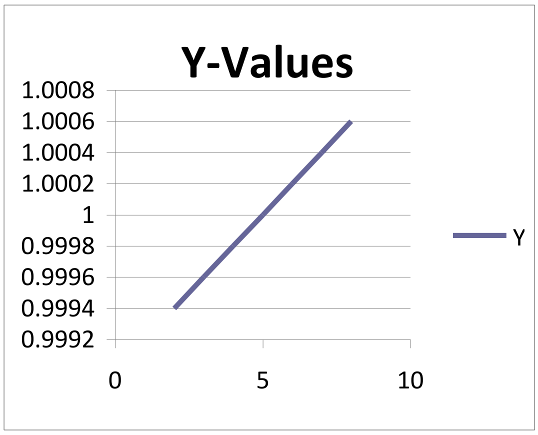
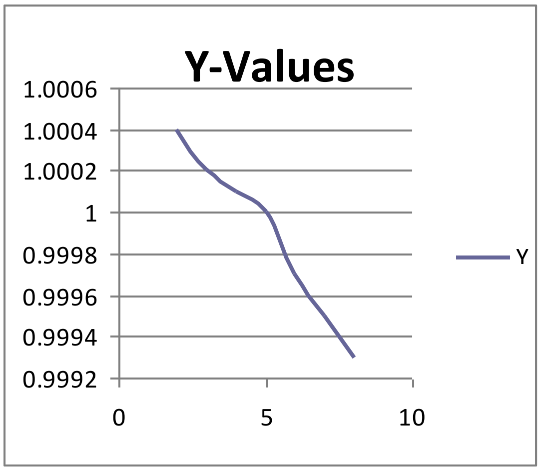


Figure 3 – Correction curve for Power



X axis – Different pressure drops in extraction line 5

Y axis – Correction factor

Figure 4 – Correction curve for Heat Rate

5. Conclusion

Thermal power plant design is correct, can be proved by the correction curves for different pressure drops in the extraction line for 120MW thermal power plant. For example, if pressure drop in extraction line 5 is 7%. Then the power output will be,

= 1.0004 x 119.954

= 120 x 10^3 KW

Here, 1.0004 is the correction factor which is taken from the output correction curve for different pressure drops in the extraction line for power. Thus plant design is correct.

6. 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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