

## Research Article

## Thermodynamic Analysis of 120 MW Thermal Power Plant by Designed Computer Aided Software for Different Inlet Temperature Conditions and Generate Correction Curves

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### Abstract

*The thermal power plants are used to generate power. 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. Due to these conditions, the designed power and heat rate are never achieved. Variations in the power output from plants is always a matter of disputes. So the correction curves for power and heat rate are generated for inlet temperature as a parameter at different conditions. These curves indicate that if input temperature conditions vary, then power output and heat rate also vary. It means plants design is correct. This paper deals with the development of a computer aided software and generate correction curves for 120 MW thermal power plant.*

**Key words:** Inlet Temperature, Power Output, Heat Rate, Correction Curves, Software based on the Visual Basic 6.0 language

### 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 (number of turbines - 3).
- Condenser.**
- Feed Water Pump** – Pump after condenser and Pump after deaerator.
- 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 heater - 6). (Yadav R et al,2007)

Humbert F. Claude(2000) 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 have also been worked on optimization of feed water heater. Rosenkranz Jens and Dr. Wichtmann Andreas have been worked on super critical and ultra-super critical steam parameters and its effect on the coal-fired power plants. Schimon Rene, Simic Dragan, Haumer Anton, Kral Christian and Plainer Markus have been worked on simulation of components of a thermal power plant. Murau Peter and Dr. Schottler Michael have been worked on how to achieve low emissions from thermal power plants. Adhikary D. D., Bose G. K., Chattopadhyay S, Bose D. and Mitra S have been worked on reliability, availability and maintainability of coal fire thermal power plant. Alam J. and Akhtar N. M., have been worked on utilization of fly ash in different areas. For a 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 inlet temperature at different conditions. These curves indicate that if input conditions are changing, then power output changes. These curves help as a reference or as a document to prove the design of thermal power plant.

### 2. Methodology

Calculations have been done with the relationship given as under ( Cotton K.C et al,1993)

$$\text{Power} = (\text{Mass flow rate}) \times (\text{Enthalpy drop in the turbine})$$

Eq. (1)

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$$\text{Heat rate} = (\text{Total heat addition in boiler}) / (\text{Net power}) \quad \text{Eq. (2)}$$

$$\text{Flow function} = W/(P/V)^{1/2} \quad \text{Eq. (3)}$$

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. Inlet temperature 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 inlet temperature at different conditions.

In this method the power has been found by the relationship between mass flow rate and enthalpy drop in the turbine and then heat rate has been found. For calculations, some important values and equations are as under -

Pressure =  $127.61 \times 10^5 \text{ N/m}^2$ , Temperature =  $537.78^\circ\text{C}$ , and  $V = 0.0186 \text{ m}^3/\text{kg}$ . then Flow Function = 4430.126,  $P = 125.1 \times 10^5 \text{ N/m}^2$  and Mass Flow Rate = 100.92 kg/sec. Power = 120 MW and Heat rare = 2.4138 KJ/KW-sec [10].

$$W_1 = (W' - L_1 - L_2 - L_3 - L_4) \quad \text{Eq. (4)}$$

$$W_2 = (W_1 + L_1 - L_5 - L_6 - EX_1) \quad \text{Eq. (5)}$$

$$W_3 = (W_2 - EX_2 - L_7 - L_8) \quad \text{Eq. (6)}$$

$$W_4 = (W_3 - EX_3) \quad \text{Eq. (7)}$$

$$W_5 = (W_4 - EX_4) \quad \text{Eq. (8)}$$

$$W_6 = (W_5 - EX_5 - L_9) \quad \text{Eq. (9)}$$

$$W_7 = (W_6 - EX_6) \quad \text{Eq. (10)}$$

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

$$HR = Q / P_{\text{net}} \quad \text{Eq. (12)}$$

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

$$Q_1 = W' (h_1 - h) \quad \text{Eq. (14)}$$

$$\text{And } Q_2 = W_2 (h_3 - h') \quad \text{Eq. (15)}$$

Correction curves for power and heat rate at different conditions have been generated by software (without manual calculation). The software has been developed on the basis of visual basic 6.0 and with the help of this software correction curves have been generated automatically. [11]

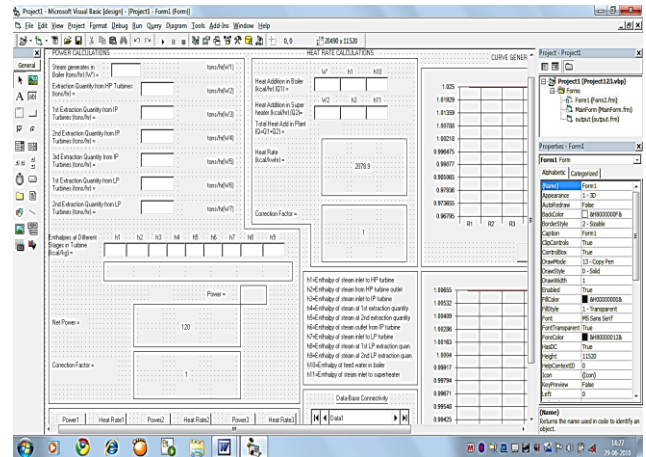


Figure 1 Software for generation of correction curves for power and heat rate

### 3. Result

Table 1 – Table for power variations with temperature

| Sr. No. | Temperature (in °C) | Mass Flow Rate (in $\times 10^3/3600$ kg/sec) | Power (in MW) | Correction Factor |
|---------|---------------------|---|---------------|-------------------|
| 1       | 507.78              | 373.264                                       | 120.644       | 0.9946            |
| 2       | 517.78              | 369.911                                       | 120.47        | 0.996             |
| 3       | 527.78              | 366.498                                       | 120.196       | 0.9983            |
| 4       | 537.78              | 363.313                                       | 120           | 1                 |
| 5       | 547.78              | 360.244                                       | 119.853       | 1.0012            |
| 6       | 557.78              | 357.284                                       | 119.638       | 1.003             |
| 7       | 567.78              | 354.424                                       | 119.53        | 1.0039            |

Table 2 – Table for heat rate variations with temperature

| Sr. No. | Temperature (in °C) | Total Heat Input (in $\times 4.18/3600$ KJ/sec) | Heat Rate (in $\times 4.18/3600$ KJ/KW-sec) | Correction Factor |
|---------|---------------------|---|---|-------------------|
| 1       | 507.78              | 252891.664                                      | 2096.1                                      | 0.9917            |
| 2       | 517.78              | 251824.624                                      | 2090  | 0.9946            |
| 3       | 527.78              | 250565.201                                      | 2084.7                                      | 0.9972            |
| 4       | 537.78              | 249468  | 2078.9                                      | 1                 |
| 5       | 547.78              | 248452.56                                       | 2073  | 1.0028            |
| 6       | 557.78              | 247408.123                                      | 2067.9                                      | 1.0053            |
| 7       | 567.78              | 246465.553                                      | 2061.9                                      | 1.0082            |

**Correction Curve for Power an Heat Rate**

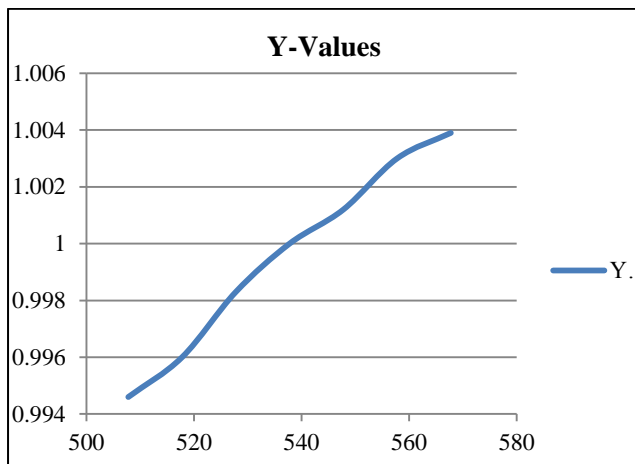
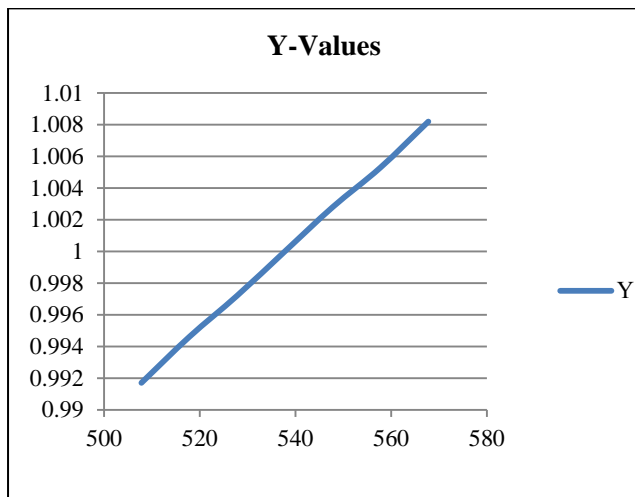


Figure 2 – Correction curve for inlet temperature for power



X axis – Inlet temperature for high pressure turbine in °C and Y axis – Correction factor

Figure 3 – Correction curve for inlet temperature for heat rate

**Conclusion**

Power plant design is correct, can be prove by the generation of correction curves for inlet temperature at different conditions for 120MW thermal power plant. For example, the inlet condition of steam into the high pressure turbine is 517.78°C. Then the power output will be,

$$= 0.9960 \times 120.470 \text{ MW} = 120 \text{ MW}$$

Here, 0.9960 is the correction factor which is taken from the output correction curve for inlet temperature for power. Thus plant design is correct. And use of software, no manual calculations required, so time consumes.

**Future Scope**

(1) Such type of software can be developed in which only inlet pressure & 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 find out power, heat rate for all types & capacities of power plant, and generates correction curves for different parameter at different conditions for capacities of power plant.

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