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Analysis of Process Parameters to Improve Power Plant Efficiency

T.Sudhakar[1], Dr.B.Anjaneya Prasad[2], Dr. K.Prahlada Rao[3]
[1]*Asst. Proffesor, MRCET Engineering College, Hyderabad, India*
[2]*Proffesor, Mech, Dept., JNTUH, Hyderabad, India.*
[3]*Principal, JNTUACEA, Anantapur, India.*

Abstract: *This research paper analyses the operational parameters of a thermal power plant to improve effectively & efficient running of the machine while ensuring a degree of compliance with statutory regulations. This study aims to identify the operational gaps associated with running operational parameter in power plant process. It is focused to detect a different thermodynamic variable involved, being multivariate and automatic. For variation of each one of this operational parameters, performance calculations are find out to configure a database of energy variation. The variable data sets now can be used as assessment criteria based on detecting deviations from a reference system that has been updated during plant-performance tests. Although the most important outcome is the highly precise and valuable information that will be obtained on the live operating mode, leading to a head improvements in the cycle efficiency and achieved in the overall control system of the thermal plant. The main aim is to detect any abnormality, reacting as quickly as possible to return the plant to a normal operation mode at best efficient manner.*

Keywords: *Heat Rate, Steam Temperature, Thermal efficiency, Load factor, Economic efficiency.*

I. Introduction

Generation of electricity is a very complex process involving many sub-processes and has multiple critical parameters. A Higher load factor generally means more output and a lesser cost per unit. So the power plant performance is very important for having higher PLF. Important factors to be consider for a plant efficiency are Thermal efficiency factors, maintenance loss, plant load factors (PLF), forced outages and plant availability factors. A decrese in Thermal efficiency leads to a higher cost of electricity generation due to more fuel usage and will also result in much higher Carbon footprints. So, it is very important to stress on the performance of thermal power plants. The performance of a thermal power plant can be expressed through some critical performance factors such as:

- Heat rate (energy efficiency)
- Thermal efficiency
- Capacity factor
- Load factor
- Economic efficiency
- Operational efficiency

So to increase the efficiency, decrease in losses must be optimized. Efficient running of the thermal unit is very crucial due to cost and reliability factors. The cost implication due to a rise in the heat rate,dm water consumption, oil consumption,. condensed back pressure, excess air etc., indicate the urgent need to control these parameters within the designed ratings. Coal fired power plant is a measure of how efficiently it converts the chemical energy contained in the fuel into electrical energy [1]. In each of these sub-processes, certain amount of energy is lost to the environment. Some of the fuel is not burned completly, some of the energy is lost out through the stack and also rejected to the cooling tower, some of the kinetic energy and mechanical energy produce heat instead of electricity, and finally, some of the electricity that is produced is used by these sub-processes. The heat rate of a thermal power plant is the amount of chemical energy in the coal that must be required to produce one unit of electrical energy. Heat rate is expressed in kcal/kWh. If a power plant able to convert 100% of the chemical energy in the fuel into electricity, the thermal plant would have a heat rate of 860 kcal/kWh. Unfortunately, due to the losses explained above, a modern conventional power plant might have at best a design full load heat rate of the order of 2200 kcal/kWh, which is about 39% efficient.

Heat rate monitoring is focused on identifying heat rate gaps and then identifying and implementing corrective actions to eliminate the efficiency loss. In this approach, heat rate deviations from expected or design levels are identified and quantified.

Methodology

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1.1 Aim

The main aim of the study is to identify areas where Heat and energy losses are occurring and develop them for efficient and effective improvement in a thermal
power plant

1.2 Objectives

The object to satisfy this are

- To conduct Heat rate analysis of the overall plant and determine the efficiencies and heat losses of all the major components in the power plant.
- Select and develop the areas where Heat energy losses are being experienced.
- Determine the costs and payback periods for the new technologies suggested for efficiency improvement.

1.3Scope

The study scope encompasses three major tasks, Heat rate and energy analysis and the identification of methods to, reduce the Heat losses of power plant and the determination. of their associated costs involved with the installation of the possible measure to cater for the problem.

II. Heat Rate Improvement Activities:

There are many regions where heat rate improvements are possible at many plants. Most of these improvements require little effort and expense. These regions are typical opportunities for improving efficiency, reducing maintenance, and obtaining other additional benefits.

Heat Rate of the plant can be improved by improving the following areas.

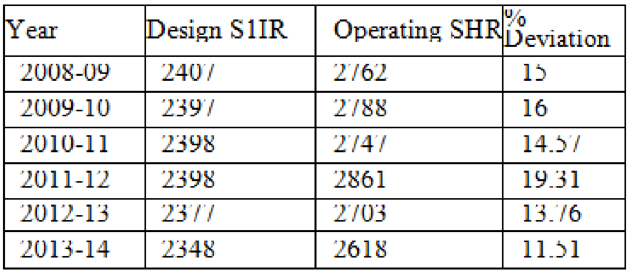
- Improved Condenser Cleanliness
- Stopping Condenser Air In-leakage
- Improved Cycle Isolation: Arresting the high temp steam & water leakages / drains from any system.

Milling System: Maintain Optimum air flow, Mill O/L temp, fineness etc.

- Optimized Furnace 0_2 Operation.
- Attemperation Valves Passing
- Instrument Calibration for accurate results &readings.
- Maintains Boiler Cleanliness
- Flue Gas Analysis: Maintain High Excess Air in the prescribe limits.
- Reduction of High Exit Gas Temperature
- Maintain HP/IP/LP Efficiency at design value

Various equipment deteriorates with respect to the time and as a result plant's efficiency decreases. We needed perfect analysis of deterioration, their impact on unit efficiency (and in turn cost) and generation of appropriate corrective action for restoration of efficiency. Generlly, some main operating parameters and some performance indices are required to monitor performance. The process of equipment and system modelling and analysis of the shortfall in efficiency of individual component and their impact on the heat rate has become very important in the utilities. Now in this paper we will discuss about the some key performance parameter improvement which will affect the Heat Rate improvement thus reduce$^-$ the cost. Heat rate monitoring is focused on identifying heat rate gaps and then identifying and implementing corrective actions to eliminate the efficiency loss.In this approach, heat rate deviations from expected or design levels are identified and quantified. Station Heat Rate (SHR) is an important factor to assess the Efficiency of a thermal power station. Efficiency of thermal power station (TPS) is a function of station heat rate and it is inversely proportional to SHR. Station heat rate improvement also helps in reducing pollution from thermal power stations.

Table1



Year	Design S1IR	Operating SHR	% Deviation
2008-09	2407	2762	15
2009-10	2397	2788	16
2010-11	2398	2747	14.57
2011-12	2398	2861	19.31
2012-13	2377	2703	13.76
2013-14	2348	2618	11.51

In this way, Performance Evaluation Division of CEA had devised a Performa to monitor the various parameters of efficiency of thermal power stations. On monitoring, the data of station heat rate parameters had been received from 67 TPS during the year 2008-2009. The data on the operating station heat rate(SHR) parameters so received have been compiled & analysed for instituting an incentive scheme on Improved Station Heat Rate (SHR) and have been compared with design SHR of the thermal power station. All the stations analysed have used coal as the primary fuel to generate power and oil as secondary fuel for starting purposes. The analysis has been carried out on the station basis. The Station may comprise of any size of units.

III. Formulation Of The Problem

A fossil fuelled power station is a collection of subsystems. Bad performance in one subsystem affects the rest because of the close interrelationship between them. The knock on effect of off design performance in one subsystem can affect the overall plant economics. The costs of the plant occur as operations and Maintenance (O & M) revenue, capital revenue or lost revenue from reduced plant Output. While (O & M) costs are unavoidable and are therefore budgeted items, poor system performance can fastly consume a “reasonable” budget and lead to major over runs. The same is true of unanticipated capital expenses. Poor combustion results in unburned fuel and an increased Heat Rate (HR). Thus the amount of fuel energy (Kcal) required to generate one kilowatt hour of saleable electrical energy is increased. Such increases in HR have the immediate effect of raising fuel costs and are generally indicative of other performance problems.

Normally, some main operating parameters are affecting the overall efficiency of Boiler & Turbine, Thus affects the Heat Rate. So it is important to run the unit closer to design parameter.

Now we will discuss the effect of temperature at different areas of Steam & Flue gas cycle to improve the plant performance.

- Effect of Main Steam Temperature:
- Effect of RH- Temperature.
- Effect of RH spray flow:
- Feed water Temperature
- Flue gas exit temperature.

Normally thermal power plant works on principle of the Rankine Cycle shown in Fig. 2[5]The cycle consists of four processes: (1-2) Isentropic compression on pump; (2-3) Constant pressure heat addition in a boiler; (3-4) Isentropic expansion in a turbine; (4-1) Constant pressure heat rejection in a condenser.

To improve this cycle some factors, Can be considered like decreasing the condenser pressure, superheating the steam to high temperatures, increasing the boiler pressure, reheating Rankine cycle or by using regenerative Rankine cycle where feed water is heated by extracted steam from the turbine.

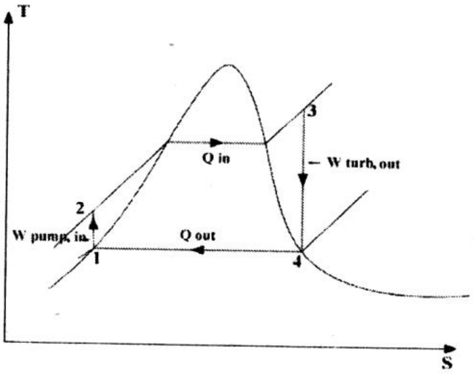


Fig. 1

3.1. Effect of main Steam inlet temperature:

Enthalpy of steam is a function of pressure and temperature. At lower Temperature, enthalpy will be lower, than work done by the turbine will be low, so turbine efficiency will be low, and hence steam consumption for the required output will be higher

1) Turbine Efjiciency-Calculation

$$\text{Turbine Efficiency (\%)} = \frac{\text{Actual Enthalpy drop}}{\text{Isentropic Enthalpy drop}} \times 100$$

$$= \frac{h_{in} - h_{out}}{h_{in} - h_{isen}} \times 100$$

Where

h_{in} = Enthalpy of Steam at Cylinder Inlet conditions h_{out} = Enthalpy Steam at Cylinder Outlet conditions h_{isen} = Isentropic Enthalpy

Main steam temperature before Emergency Stop Valve - day average of 24 hrs of all the available temperature points located before ESV is to be taken for calculation. This average value of temperature is to be compared with expected temperature.

(Expected temperature = Design Temperature)

The difference will be taken for Heat rate deviation calculationbased on customized correction curves. [Customized correctioncurves are given by OEM to be used].

Sample calculation (Column wise w.r.t Daily HR Deviation Report)

Design M.S Temperature = 537. °C

Expected M.S Temperature = 537 °C

Actual M.S Temperature - 529 °C

Variance (Exp. -Act. M.S Temp) =8°C

Turbine HR Correction Factor = 0.998 from Curve

Design Turbine HR = 2045 K.cal/kWh

Design Boiler η = 87.3 %

HR Deviation = (2045/(86.8/100)) * (1 -0.998)

= 4.71 kcal/kWh

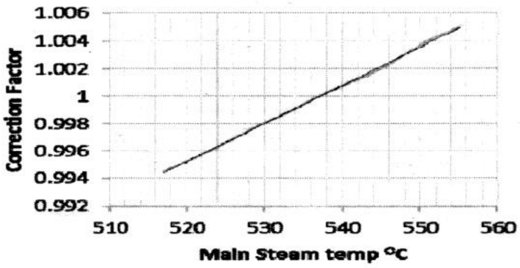


Fig. 2 Correction Curve for MS Temperature

1) Reasons of variation in Main Steam Temperature:

a) Effect on Enthalpy Drops of Different Stages

- Enthalpy decrease in each HP stages increase with rise in MS Temperature

b) Effect on Losses of Different Stages

- Nozzle & Moving Blade Losses increase with Temperature rise.
- Profile loss & Cumulative loss increase with Temperature rise.

c) Effect on Efficiencies of Different Stages

- HP Stages efficiencies remain almost constant at different temperatures

d) Effect on Internal Power of Different Stage

- Internal power of HP stages increases with increased temperature

e) Effect on Cycle Efficiency & Heat Rate of Different Stages

- *Cycle Efficiency deteriorates and Heat Rate increased with lower Main Steam Temperature.*

3.2 Hot Reheat Temperature:

Hot Reheat Temperature before Interceptor Valve - Day average of 24 hrs of all the available temperature points located before Interceptor Valve is taken for calculation. This average value of temperature is to be compared with expected temperature.

(Expected temperature = Design Temperature). The difference of temperature Will be taken for Heat rate deviation calculation based on customized correction curves. [Customized correction curves are given by OEM is used].

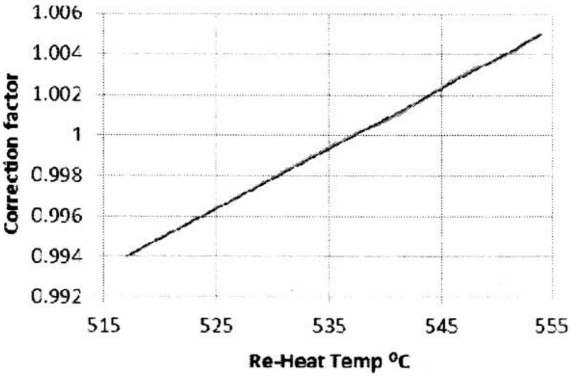


Fig. 3 Correction wise w.r.t. Daily HR Deviation

Sample calculation (Column wise w.r.t Daily HR Deviation Report)
Design HRH Temperature = 538 °C
Expected HRH Temperature = 538 °C
Actual Temperature = 537 °C
Variance (Exp -Act. HRH Temp) = -1.0 °C
Turbine HR Correction Factor = 0.998 from Curve
Design Turbine HR = 2000 Kcal /k Wh
Design Boiler η = 87.3 %
HR Deviation = 2045/(87.3/100) * (1-0.998)
= 4.71 kacal/kWh

1) Reasons of variation in Re-heat Steam Temperature:

a) Effect on Enthalpy Drops of Different Stages
- Enthalpy decrease in each Intermediate and Low Pressure stages increase with rise in RH Steam Temperature.

b) Effect on Losses of Different Stages
- Nozzle & Moving Blade Losses increase withTemperature rise
- Profile loss & Cumulative loss increase with Temperature rise

c) Effect on Efficiencies of Different Stages
- Slight improvement in Stage Internal Efficiencies at lower Re- Heater steam temperature

d) Effect on Internal Power of Different Stage
- Internal power of both IP & LP stages
- increase with increase RH steam temperature

e) *Effect on Cycle Efficiency & Heat Rate of n Different Stages*
- Cycle Efficiency deteriorates and Heat Rate increased with lower Reheat Steam Temperature.

3.3 Superheat Attemperation

Super Heater (S/H) attemperation to the boiler – Day average of 24 hrs is to be taken for calculation.This average value of S/H attemperation to be compared with expected S/H attemperation.

The difference of the average value of the day and expected value of S/H attemperation is to be taken for Heat rate deviation calculation based on customized correction curves.

Customized/OEM correction curves are to be used.

Sample calculation (Column wise w.r.t Daily HR Deviation Report)
Design S/H Attemperation = 0 t/hr.
Expected S/iLAttemperation = 28.3 t/hr
Actual S/H Attemperation = 46 t/hr
(Variance Exp.- Act. Attemp) = -17.7 t/hr
= -3 % of Main Stream Flow

Turbine HR Correction Factor = 0.999 from Curv
Design Turbine HR = 2045 Kcal/kWh
Design Tested Boiler η = 87.3 %
HR Deviation = 2045/ (87.3/100)*(1-0.999)
= 2.3kcal/kWh

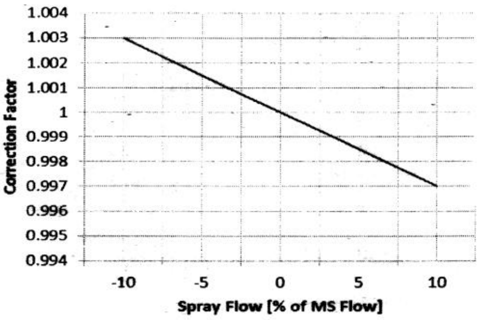


Fig. 4

3.4 Reheat Attemperation

Re- Heater (RH) attemperation to the boiler - day average of 24 hrs is to be taken for calculation. This average value of R/H attemperation to be compared with expected R/H attemperation (Expected R/H attemperation = Value corresponding to actual load is to be derived using Load vs reheat attemperation curve). The difference of the average value of the day and expected value of R/H attemperation is to be taken for Heat rate deviation calculation based on customized correction curves. Customized/OEM correction curves are to be used.

Sample calculation (Column wise w.r.t Daily HR Deviation Report)
Design R/H Attemperation = 0 t/hr
Expected R/H Attemperation = 7.82 t/hr
Actual R/H Attemperation = 18 t/hr
Variance (Exp. - Act.Attemp) = -10.2 t/hr
= -1.7 % of Main Stream Flow
Turbine HR Correction Factor = 0.9968 (From Curve)
esign Turbine HR = 2000 Kcal/kWh
Design Boiler η = 87.3 %
HR Deviation = 2045/(87.3/100)*(1 -0.997)
= 7.02 kcal/kWh

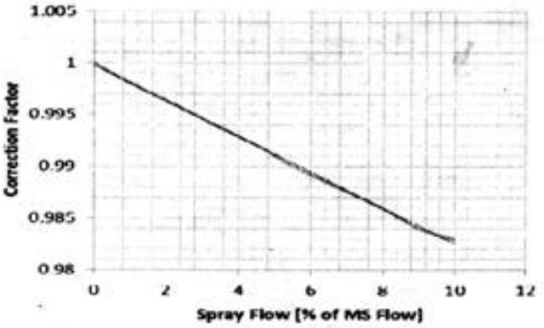


Fig.5

3.5 Feed Water Temperature:

The Feed water temperature at top HP Heater outlet after joining of HP Heater bypass line, based on daily 24 hrs averages is to be taken for calculation. This average value of Feed water temperature is to be compared with the expected value of Feed water temperature (Expected FW temperature = Feed water temperature corrected for load, derived from curve between feed water temperature vs load) The difference of Average value of Day and Expected value of Feed water temperature is to be taken for Heat rate deviation calculation based on customized correction curves. Customized/OEM correction curves are to be used

Sample calculation (Column wise w.r.t Daily HR Deviation Report)

Design Feed Water Temperature = 248 °C
Expected FW Temperature = 236 °C
Actual FW Temperature = 233 °C
Variance (Exp. -Act. FW Temp) = 3 °C
Turbine HR Corr. Factor at 236 °C = 0.996 from Curve
Turbine HR Corr. Factor at 233 °C = 0.995 from Curve
Design Turbine HR = 2045 kcal/kWh
Design Boiler η = 87.3 %
HR Deviation = (2045/ (87.3/100))*(0.996-.995)
= 2.3 kcal/kWh

3.6_APH Exit Temperature:

It's important to ensure that the online measurements of air and flue gas temperatures are representative of average temperatures in the duct. In 500 MW units, the flue gas sampling and temperature measurement should be done in the common flue gas duct of Primary and Secondary air heater outlet on each side. At present the flue gas temperature is monitored only at outlets of each air heater and an average value of 24 Hrs based on assumed proportions of flue gas flow through primary and secondary air heaters, is used for efficiency calculation.

Table2

S. N	Parameters	Deviation	Average HR loss kcal/kWh	Typical range of HR Loss kcal/kWh
1	*Main Steam Temperature(°C)*	1	0.64	0.32-0.77
2	*Reheat Temperature(°C)*	1	0.59	0.41-0.86
3	*Super heater Spray (Tones /hr)*	10	0.28	0.15-0.35
4	*Reheat Spray (Tones /hr)*	10	2.46	1.1-4.19
5	*Exit Gas Temperature(°C)*	1	1.2	0.95-1.91

Note:
So, if we take coal price at Rs-3500 / ton.
Then it comes 1 Kcal = 25 Lakhs.
So if we can save 60 Kcal of any of the unit then it will impact 15 Cr in a year. This will reduce the cost of generation.

IV. Conclusion

The efficiency of the thermal power plant (TPP) decreases at increase age, A good performance program will be able to identify these losses of the degradation of the heat rate.A more accurate knowledge of thermal power plant heat rates & maintaining all performance parameter near to design can improve economic dispatching costs and In fact, the performance parameters measure how well the TPP produces Electricity efficiently. The improvement should not necessarily to be done only in thermodynamic Efficiency, but rather to improve TPPs overall efficiency. In this paper, we presented an analysis of the daily performance parameter monitoring to improve the TPP heat rate. Here in this paper we have calculated how by improving the temperature of working fluid we can improve the thermal efficiency of thermodynamic cycle. From table II, we observe that by improving the Main stream temperature & Re heater temperature by 10 °C we can reduce the Heat Rate upto 2 Kcal/Kwh. The objective is to determine the possible causes generating losses and provoking the degradation of the TPP heat rate while using a parameter analysis method

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