International Journal of Advance Engineering and Research Development (IJAERD)
Volume 1,Issue 5,May 2014, e-ISSN: 2348 - 4470 , print-ISSN:2348-6406

CYCLE EFFICIENCY AND HEAT RATE OF THERMAL POWER PLANT

Prof. N R Sheth [1], Prof. Dhaval P Patel[2], Brijesh Patel[3]

[1] *Mechanical Engineering Department, Government Engineering College, Valsad, Email id*
[2] *Mechanical Engineering Department, Gandhinagar Institute of Technology, dhaval.patel@git.org.in*
[3] *P G Student, Mechanical Engineering Department, Government Engineering College, Valsad, Email*

Abstract— The first law analysis of the coal fired thermal power station namely Gandhinagar Thermal Power Station (GTPS).In research paper, a detailed energy study is shown for 210MW, of coal fired thermal power plant at Gandhinagar Thermal Power Station (GTPS) to evaluate the plant and subsystem [feed water heaters (high pressure and low pressure)],etc. efficiencies. Cycle efficiency and heat rate are calculated using thermodynamic relation after estimating the various heat losses in the boilers, turbine and generator. Researcher gives suggestion for reduced heat losses in different components of power plant by applying Transport Membrane Condenser (TMC) in between boiler and condenser. Using TMC system which gives collect energy of flue gases and heated water directly bled in boiler which increase boiler efficiency.

Keywords- Power generating plant, boiler, steam turbine, first law analysis, Transport Membrane Condenser.

I. INTRODUCTION

In a coal based power plan coal is transported from coal mines to the power plant by railway in wagons or in a merry-go-round system. Coal is unloaded from the wagons to a moving underground conveyor belt. This coal from the mines is of no uniform size. So it is taken to the Crusher house and crushed to a size of 20mm. From the crusher house the coal is either stored in dead storage (generally 40 days coal supply) which serves as coal supply in case of coal supply bottle neck or to the live storage (8hours coal supply) in the raw coal bunker in the boiler house. Raw coal from the raw coal bunker is supplied to the Coal Mills by a Raw Coal Feeder. The Coal Mills or pulverizer pulverizes the coal to 200 mesh size. The powdered coal from the coal mills is carried to the boiler in coal pipes by high pressure hot air. The pulverized coal air mixture is burnt in the boiler in the combustion zone [10].

Generally in modern boilers tangential firing system is used i.e. the coal nozzles/guns form tangent to a circle. The temperature in fire wall is of the order of 1300deg.C. The boiler is a water tube boiler hanging from the top. Water is converted to steam in the boiler and steam is separated from water in the boiler Drum. The saturated steam from the boiler drum is taken to the Low Temperature Super heater, Platen Super heater and Final Super heater respectively for super heating. The super-heated steam from the final super heater is taken to the High Pressure Steam Turbine (HPT). In the HPT the steam pressure is utilized to rotate the turbine and the resultant is rotational energy. From the HPT the out coming steam is taken to the Reheater in the boiler to increase its temperature as the steam becomes wet at the HPT outlet. After reheating this steam is taken to the Intermediate Pressure Turbine (IPT) and then to the Low Pressure Turbine (LPT).The outlet of the LPT is sent to the condenser for condensing back to water by a cooling water system. This condensed water is collected in the hot well and is again sent to the boiler in a closed cycle. The rotational energy imparted to the turbine by high pressure steam is converted to electrical energy in generator [10].

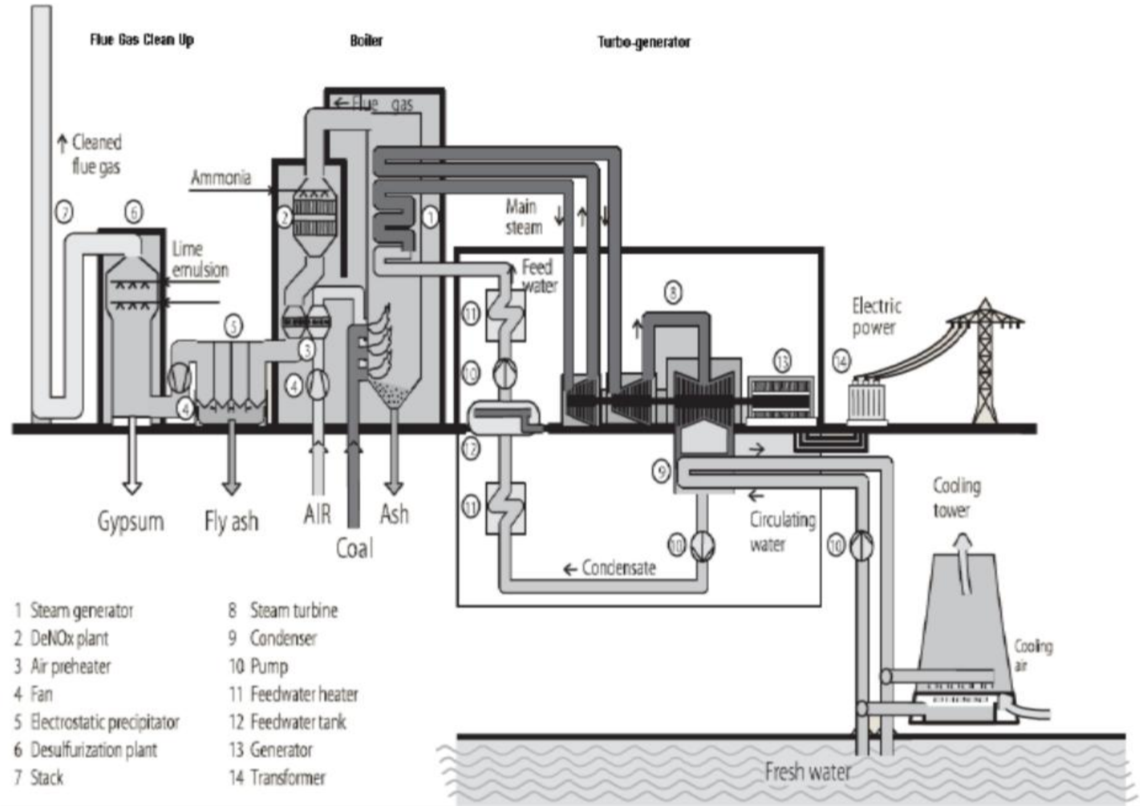

Figure 1. Diagram of a Typical Coal-fired Thermal Power Station

II. CYCLE EFFICIENCY

CARNOT EFFICIENCY

$$\eta_{carnot} = 1 - \frac{T_{min}}{T_{max}}$$

Here, It is found that maximum temperature at high pressure in a cycle is at superheated inlet condition, T_{max} = 535°C Minimum temperature in a cycle is feed water temperature at high pressure condition T_{min}=241°C [3].

$$\eta_{carnot} = 1 - \frac{241}{535}$$

$$\eta_{carnot} = 54.954\ \%$$

THERMAL EFFICIENCY

$$\eta_{thermal} = \frac{Shaft\ output}{Fuel\ input}$$

$$\eta_{thermal} = \frac{Wnet}{mf * CV}$$

Where, W_{net}= W_T-W_P
Here, Turbine work W_T =210 MW (100%NCR)
Pump Work W_P = 10MW (100%NCR)
Coal mass flow rate,
m_f = 125T/ hr = 34.72Kg/s CV of coal = 4097Kcal/Kg = 17141.84817KJ/Kg

$$\eta_{thermal} = \frac{(210 - 10) * 1000}{34.72 * 1741.84817}$$

$$\eta_{thermal} = 33.60\ \%$$

OVERALL CYCLE EFFICIENCY

Generator efficiency is taken as 98% so, the overall efficiency [3]

$$\eta_{overall} = (boiler\ efficiency * turbine\ efficiency * generator\ efficiency)$$

$$\eta_{overall} = (0.8511\ X\ 0.435\ X\ 0.98)$$

$$\eta_{overall} = 36.28\%$$

Due to the turbine efficiency and boiler efficiency, we get overall efficiency is 36.28% i.e. is very low. The efficiency of the turbine is determined estimating the net heat input to turbine and electrical power plant from the generator in terms of heat values. Thus turbine efficiency obtained is 44.11%. The above results are shown in the table shown below:

Table 1 Result Summary: Cycle Efficiency

CYCLE	**EFFICIENCY (%)**
CARNOTEFFICIENCY	54.95
THERMAL EFFICIENCY	33.60
OVERALL CYCLE EFFICIENCY	36.28

Table 2 Result Summary: Components

COMPONENT	EFFICIENCY (%)
BOILER	85.11
TURBINE	44.11
GENERATOR	98
OVERALLCYCLE	36.28

III. HEAT RATE

TURBINE HEAT RATE[9][10]

Table 3 Turbine Steam-Water Data

Sr. No.	**Tag No.**	**Description**	**Value**	**Unit**
1.1	FMST	Main steam flow turbine	692	T/hr
1.2	MWG	Megawatt Generated	206	MW
1.3	PMST	Main Steam Pr. At turbine inlet	132.2	Kg/cm^2
1.4	TMST	Main Steam Temp. At turbine inlet	528	°C
1.5	PFW	Feed water Pr. At Eco. Inlet	154	kg/cm^2
1.6	TFW	Feed water Pr. At Eco. Inlet	238.5	°C
1.7	PHRH	HRH Pr.	33.7	Kg/cm^2
1.8	THRH	HRH Temp.	360	°C
1.9	PCRH	CRH Pr.	37.07	
1.10	TCRH	CRH Temp.	360	°C
1.11	FRHS	Re heater Spray flow(L+R)	8	T/hr
1.12	FFW	Feed flow at Eco. Inlet	625	T/hr
1.13	PEH6	Extraction Pr. Q THPH6 inlet	37.07	Kg/cm^2
1.14	TEH6	Extraction Temp. Q THPH6 inlet	360	°C
1.15	TDH6	Drain Temp. at HPH6	206.5	°C
1.16	TFWHO6	Feed water Temp. at HPH6 outlet	239.2	°C
1.17	TFWHI6	Feed water Temp. at HPH6 inlet	196.2	°C
1.18	PBFD	BFP HDR Pr.	171	Kg/cm^2

Note:-The pressure unit in Instrument is in Kg while in Steam table it is in bar. Hence conversion factor is 1 Kafka/cm^2 = 0.98 bar similarly in steam table enthalpy unit is KJ/Kg while we need enthalpy unit in Kcal/Kg. hence conversion factor is KJ= 1/4.86 Kcal

Table 4 Turbine: Enthaply from Steam table

Sr. No.	Tag No.	Description	Equation	Result (kcal/kg)
2.1	HMST	ENTH MSTOTURB	F(PMST,TMST)#ST	816.85
2.2	HFW	ENTH FWTOECONINLET	F(PFW,TFW)#ST	246.13
2.3	HHRH	ENTH HRHSTM	F(PHRH,THRH) #ST	840.70
2.4	HCRH	ENTH CRHSTM	F(PCRH,TCRH) #ST	752.36
2.5	HEH6	ENTH EXTSTMTOHPH6	F(PEH6,TEH6) #ST	752.36
2.6	HDH6	ENTH HPH6DRN	F(PEH6,TDH6) #ST	210.63
2.7	HFWHO6	ENTH FWHPH6OUT	F(PBFD,TFWHO6) #ST	247.12
2.8	HFWHI6	ENTH FWHPH6IN	F(TPBD,TFWHI6) #ST	199.52

CALCULATION OF HEAT RATE[3][4]

FEH6 = Flow of Extraction steam to HPH6

FEH 6=FFW*(HFWHO6-HFWHI6)/ (HEH6-HDH6)

$$= \frac{Feed\ flow\ toeco.inlet * (Enthalpy\ of\ FW\ of\ HPH6\ outlet - Enthalpy\ of\ FW\ of\ HPH6\ inlet)}{(Enthalpy\ of\ Extraction\ Steam\ of\ HPH6 - Enthalpy\ of\ Drain\ water\ of\ HPH6)}$$

$$= \frac{625 * (247.12 - 199.52)}{(752.36 - 210.63)}$$

$$= \frac{625 * 47.6}{541.73}$$

FEH6 = 54.91 T/hr

FHRH =HRH Flow

= FHRH=FMS-FEH6+FRHS

= (Total Main Steam flow-flow of extract .steam to HPH6) + (Total reheater spray flow)

= (692-54.91) + 8

FHRH=645.09 T/hr

QT = Heat input to Turbine Cycle

= FMST (HMST-HFW) * 1000 + FHRH (HHRH-HCRH) *1000

=Hot Reheat flow *(Enthalpy of HRH steam-Enthalpy of HCRH Steam)*1000

=692*(816.85-246.13)*1000+645.09(840.70-752.36)*1000

=692*570.72*1000+645.09*88.34*1000

=451925490 Kcal/ hr

QT= 451925.49*1000 Kcal/ hr

Turbine Heat Rate=QT/1000*MWG

Where, MWG=MW generated=206MW

=451925.49*1000/206*1000

=2193.81 Kcal/KWh

Hence, Turbine Heat Rate = 2193.81 Kcal/KWh

STATION HEAT RATE

Station heat rate is to be calculated by following formula,

$$Station\ heat\ rate = \frac{Turbine\ cycle\ heat\ rate}{Boiler\ efficiency\%} * 100$$
$$= \frac{2193.81\ Kcal/KWh}{0:8511}$$

Station heat rate = 2577.6172 Kcal/KWh

NET-HEAT RATE

Net-Heat rate i.e. plant heat rate can be calculated as follows,

$$Net\ heatrate = \frac{Fuelflow\,(kg/hr) * Fuelheatingvalue\,(Kcal/Kg)}{Net\ Power\ Output\ (KW)}$$
$$= \frac{125000 * 4097}{210000}$$

Net heat rate=2438.6904 Kcal/KWh

IV. RESULTS

Heat rate	Result (Kcal/KWh)
Turbine Heat rate	2193.81
Station Heat rate	2577.61
Net Heat rate	2438.69

V. TWO-STAGE TMC INTEGRATION WITH A POWER PLANT

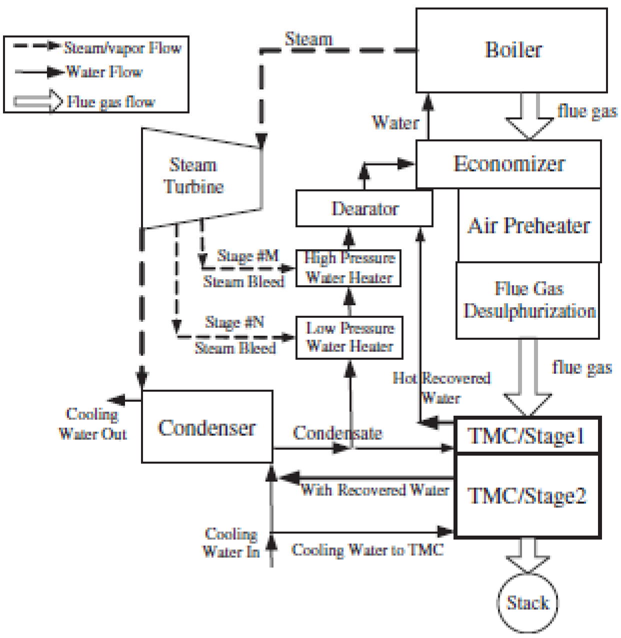

Figure 2 Two-stage TMC integration with a power plant

Fig. 2 shows a schematic for integrating the TMC water recovery unit in a typical power generation boiler and steam turbine loop. For the two-stage TMC unit to maximize its function for recovering both water and heat, two separate cooling water streams are used. On the water side, the first-stage TMC inlet water will be obtained from steam condensate from the condenser, and its outlet water with recovered water vapor and associated latent heat from flue gas will go to the deaerator for boiler water makeup. The second stage TMC inlet water will be part of the condenser cooling water stream. The outlet water from this TMC stage will then be routed to go back to the cooling water stream with extra recovered water from the flue gas. On the flue gas side, the TMC is situated between the FGD unit and the stack.[15]

VI. CONCLUSION

From the energy analysis made for the unit-4,210MW of the GTPS – the following conclusion are drawn:

- From the thermodynamic analysis using first law of thermo dynamics, we can conclude that, energy analysis evaluates the plant quantitatively. The power plant overall efficiency is 36.28%.
- Lower the heat rate, higher the cycle efficiency. Here, net heat rate at full load is to be 2438.69 Kcal/KWh.
- If TMC system implement in thermal power plant it will increase boiler efficiency then effect of TMC reduced heat losses in plant so overall thermal efficiency plant will increase.

REFERENCES

[1] BHEL Boiler Operations Manual
[2] Natural Circulation in Boilers by K.K.Parthibhan, 2002
[3] Thermal Engineering by R.K. Rajput
[4] Heat and Mass Transfer by R.K.Rajput
[5] Bereau of Energy Efficiency Course Book,Ch-4.1Boilers
[6] Heat Exchangers: Selection, Rating, and Thermal Design by Sadik Kakac
[7] Industrial boilers, Longman Scientific Technical1999
[8] International Journal of Advanced Engineering Technology, thermodynamic analysis of thermal power station By Prof. Alpesh V. Mehta
[9] International journal of energy research, Exergy analysis of a coal-based 210MW thermal power plant, S.Sengupta
[10] In-Plant training report, GTPS by jainish jain, sashank thakkar, SVNIT
[11] Perry's Chemical Engineers Handbook (Page: 12-17)
[12] http://www.indiaboiler.co.in/
[13] http://thermalpowerplant.wordpress.com/
[14] http://www4.eere.energy.gov/manufacturing/tech_deployment/amo_steam_tool/equipTurbine
[15] Dexin Wang., Ainan Bao, Walter Kunc, William Liss," Coal power plant flue gas waste heat and water recovery", Applied Energy 91 (2012) 341–348.