Improvement of Power Generation by Recovering Energy from Exhaust Gases of Blast Furnace by Rectifying the Existing Problems

Vinay Kumar D S[1] Dodda Hanumesha[2]
[1]PG Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Government Engineering College, Hassan

Abstract— The Blast Furnaces in steel plant operates at a high top gas pressure. The gases coming out of the furnace are consisting of huge amount of dust particles and also moisture content.. Cleaned gases are used in the steel plant for heating purposes at relatively low pressures. In this process, a large amount of pressure energy is exhausted across the valve. So because of this reason, GET (GAS EXPANSION TURBINE) mechanism which involves recovery of the pressure energy of the gases from the top of a blast furnace is used to drive the turbines in turn to generate the power. In the existing plant JSW Steel Limited, Bellary District, Karnataka (Where this project work is carried out) some problems such as the mechanical obstruction caused by entry of foreign material through gas cleaning plant, decreasing of flow of blast furnace gases, increasing of inlet blast furnace gas pressure from 1.95 bar (Normal) to 2.15 bar, non-opening of guide vanes beyond 75%, nonlinear of guide vane actuators and also non-working of water spray nozzles inside the turbine; are occurred which result the decrease in the power generation from rated 12.2 MW to 10 MW. So, in the present work, certain methods and modifications are used to resolve the above mentioned problems the power generation. Process is recovered which is economically remarkable by the present work.

Key words: BF, Gas Expansion Turbine, Power Generation, Modification Of Bypass Valve DN 1600mm And Dowel Pin

I. INTRODUCTION

A blast furnace is a metallurgical furnace used for smelting to production engineering metal. The chemical reactions occur through the furnace as the material travels downward. The end products are frequently molten metal and slag stages nominated from the bottom and flue gases escaping from the top of the furnace. The downward flow of the ore and flux in interaction with an up flow of hot, carbon monoxide-rich combustion gases is a security present conversation method. The gases from the top of the BF are used to a power generation.

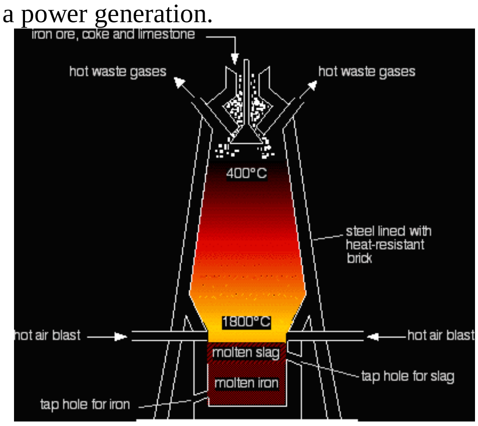


Fig. 1: Blast Furnace

II. GAS CLEANING PLANT

In Gas Cleaning Plant there are two type of gas cleaning system is provided

Primarily dry dust catcher and cyclone separator. In dry dust catcher small amount of a dust is removed. And next cyclone Separator large amount of dust is removed by water spraying through the gases

Demister: moisture content in the gas is removed by demister

III. GAS EXPANSION TURBINE

The GET utilizes the pressure energy of BF gas which is the by-product of the blast furnace. The cleaned gas is fed to Gas expansion turbine. In GET the top gas kinetic energy converted to mechanical energy which is then converted to electric energy to generate power through generator. The outlet pressure from the GET is sent to the gas holder from where it is distributed to the different consumers at constant pressure. If GET not installed, pressure energy of gas goes as waste and we could lose substantial amount of power which can be generated at very low generation cost.

Fig. 2: Gas Expansion Turbine

TECHNICAL SPECIFICATIONS OF GET

BF gas flow rate (wet): Max. Flow rate: 512,000 Nm^3/h

BF top pressure: 2.5 kg/cm^2 gauge (maximum) BF gas pressure at GET inlet: 2.2 kg/cm^2 gauge (maximum) 2 kg/cm^2 gauge (Normal)

BF gas temperature at turbine inlet: 80ºC maximum 50ºC normal

BF gas pressure at GET outlet: 0.125 kg/cm^2 gauge (maximum) 0.08 – 0.1 kg/cm^2 gauge (Normal)

BF gas dust content: 5.0 mg/Nm^3 maximum (Dry)

BF gas chemical composition: CO- 22- 28 %, CO2-18-28%, H2-3-8%, AND N2-40-45%.

IV. METHODOLOGY

The gases coming out of the blast furnace are carbon monoxide (CO), carbon dioxide (CO2), hydrogen (H2) and nitrogen (N2). These gases carry huge amount of dust particles and also moisture content. These dust particles are removed in gas cleaning plant. In gas cleaning plant there are two types of gas cleaning system. In first type i.e. dry dust catcher, small amount of dust particles are removed and in second cyclone separator, the large amount of dust particles are removed by water spraying to the gases and moisture is removed by demister. Along the side by following certain methods and modifications, such as cleaning of turbine stator and rotor blades by NDT testing, replacement of new seal and piston ring with spare supplied OEM and modification of GET bypass valve DN 1600mm and dowel pin (junction plate securing pin), the existing problems mentioned in the problem definition have been resolved to carry out the proper operation of the plant to enhance the power generation.

V. RESULT OF PROBLEMS WITH THE GAS EXPANSION TURBINE

Power generation of Gas Expansion Turbine (GET) found gradually decreased from rated 12.2 MW to 10MWdue to the following existing problems.

VI. EXISTING PROBLEMS

Blast Furnace gas flow found gradually decreased, Inlet Blast Furnace gas pressure found gradually increased from 1.95 bar(Normal) to 2.15 bar, Guide vanes are not opening beyond 75% and guide vane actuators found nonlinear, Blast Furnace gas leakage observed through the seals of guide vane actuators, and Water spray nozzles might have not working inside the turbine.

VII. RECTIFICATION OF EXISTING PROBLEMS

Turbine Stator & rotor blades are thoroughly cleaned by using soft buffing wheel and zero emery paper. All stator and rotor blades checked for any minor cracks by using NDT test (Non-Destructive Test) found ok. Clearances between stator blades to turbine rotor and rotating blades to turbine casing checked by using lead wire and feeler gauge and found within the limit. Replacement of new seals and Piston rings.

Fig. 3: NDT Testing of Rotor

Fig. 4: NDT Testing Of Stator

Fig. 5: cleaned turbine Rotor

Power generation of Gas Expansion Turbine is decreased. Because failure of seals of guide vane actuating mechanism, worn out of connecting rod and burrs on sliding surface of connecting rod due to foreign particles, blast Furnace gas leakages are observed through the seals of guide vane actuators.

Fig. 5: Replacement of New Seals and Piston Rings

All Water Spray Nozzles Were Removed & Cleaned With Water & Compressed Air & Fixed Back. Because of the problem of choking of spray nozzles by deposition of dirt on the rotating and

Stator blades of the turbine, the water spray nozzles had not been working inside the turbine.

Fig. 6: Cleaned Water Spray Nozzle

VIII. MODIFICATION OF DOWEL PIN OR JUNCTION PLATE SECURING PIN

The failure of guide vane connecting mechanism inside the turbine and looseness of connecting fasteners and connecting pins at junction plates, guide vanes are not opening beyond 75% and guide vane actuators found nonlinear.

Fig. 6: Junction Plate Securing Pin

Design of Pins at Junction Plates or dowel pin

Material selected is EN 8 series Specification Chemical Composition: - Copper-0.36-0.44%, Silicon-0.10-0.40%, Manganese0.60-1.00%, Phosphor0.050Max, Sulphur0.050Max.

Mechanical Properties of a material: - Max Stress-700-850N/mm, 2 Elongation-16%, Impact KCV-28joules Min, Hardness-201-225 Brinell,

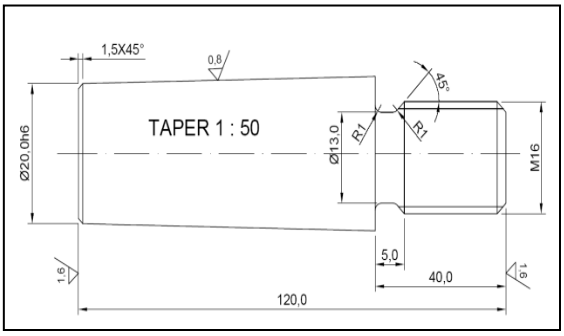


Fig. 7: Drawing of Junction Plate Pin

Total load on the blade carrier drum is 2010KN (Design data as per OEM) Total no of pins 2+2 (two each on left and right side of the blade carrier drum) so the load on each pin is 2010/4= 502.5 KN to find the Dia of the pin Since the tensile load P tends to shear of the pin at two sections i.e. AB and CD therefore the pin is subjected to double shear.

Resisting area A = 2 × (3.14× D^2)/4 = 1.57D^2 Permissible stress in the pin =800N/MM2 (Mechanical properties for material EN 8) So we know Ft = P/A Where Ft = permissible shear stress N/mm P = Load on the pin in N A = Resisting area in mm^2 By Appling the above equation and available data We can write Ft = P/800= 502.5/1.571 D^2 So D = 19.99 MM Die of the pin D= 20mm (Taper 1:50 maintained for better secured fitting as shown in the drawing)

A. *Modification of Get Bypass Valve DN 1600mm:*

During normal operation of GET, Bypass valve DN 1600 & DN800 are in closed position ,Quick shut off valve ,Inlet Goggle valve & Out let Goggle valve will be in open condition, but whenever TRT trips due any reason Quick shut off valve closes in 3 sec & Bypass valve DN 1600 opens in 3 seconds to avoid shoot up of BF top pressure & DN800 should open in such a way that BF top pressure (2.5 bar) is maintained & it should not be affected, Presently when the TRT trips, Quick shut off valve closes, Bypass valve DN 800 valve also opens but Bypass valve DN 1600 does not open until the BF gas pressure drops to 0.6 bar, which is undesirable & affects BF operation and loss of hot metal production & ultimately the hampers the production.

Bypass valve closes by hydraulic pressure and has to open by the spring action. GET by-pass valves DN 1600 hydraulically operated and is originally supplied by M/s Kromback Germany.

Bypass valve DN 1600 valve found not operating beyond the inlet BF gas pressure of 0.6 Bar, hence before stopping the turbine inlet pressure has to be reduced to 0.6 bar in order to avoid the disturbances in Blast furnace operation and production loss.

A modification proposed to operate the valve by applying back pressure through hydraulic accumulator which provides additional force along with the spring force required to operate the valve in 3sec.The proposal is safe and by Precharging the accumulator no additional piping is required as well as it can take care of any emergency opening without disturbing the blast furnace operation schematics as given below.

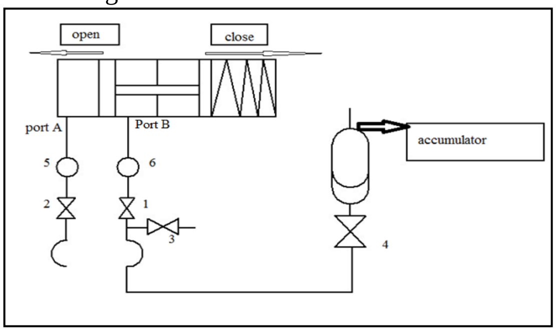


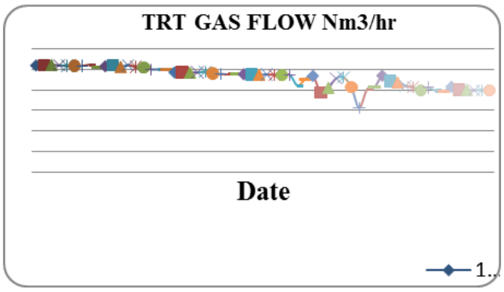
Fig. 8: TRT Bypass Valve Modification

1, 2, 3 & 4 is Ball valve 5 & 6 pressure gauge Port A inlet and Port B outlet.

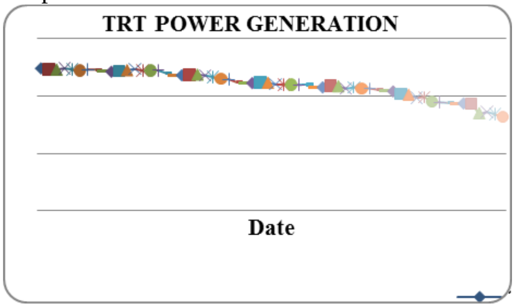
IX. COMPARISON STATEMENT BEFORE AND AFTER RECTIFICATION

A. *Analysis of Data before Rectification:*

These are all data taken from plant before rectification because of improving the power generation reduces the problem associated in gas expansion turbine.



Graph 1: Gas flow v/s Date before Rectification



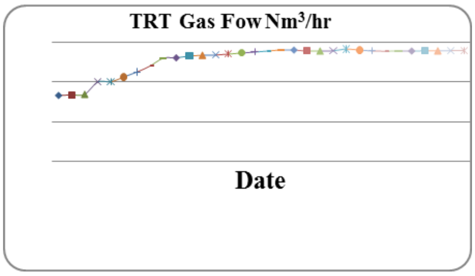
Graph 2: Power generation v/s date Before Rectification

It is evident from the initial data and related trends that main reason for poor power generation is mainly due to chokage gas flow path of the turbine, dirt built up on the blades of the turbine and partially due improper functioning of guide vane actuating mechanism. So decision has been taken to shut down turbine on 17.01.15, dismantle and inspection of the turbine internals to find out the root cause for the problems and their rectification. Turbine was dismantled from 18.01.15 to 25.01.15.

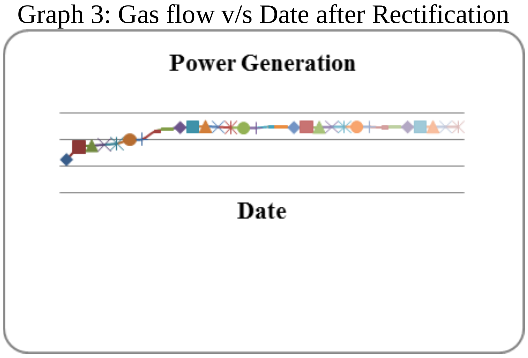
B. *Analysis of Data after Rectification*

These are all data taken from plant after rectification and modifications done through a improvement of power generation.

From Date 17.02.15 to Date 22.02.15 Turbine trial run and testing of turbine carried out. Load gradually increased from 23.02.15 onwards.



Graph 3: Gas flow v/s Date after Rectification



Graph 4: Power generation v/s date after Rectification

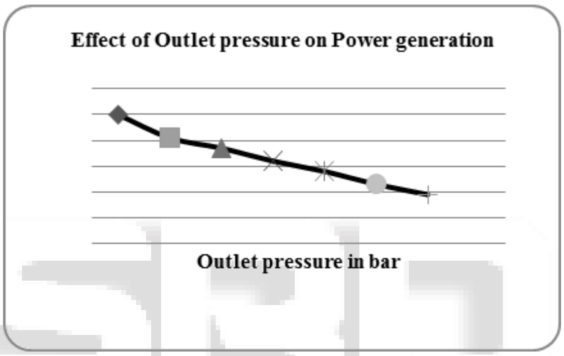
X. EFFECT OF INCREASE OF TRT EXHAUST PRESSURE

The TRT is designed for the constant maximum outlet pressure of 0.125 bar, but the present TRT outlet pressure is higher than designed varying between 0.137 bar-g to 0.14 bar-g due to higher gas network pressure. The increase in TRT outlet pressure reduces the power generation as given below.

Outlet pressure in bar	Output power in MW
0.11	12.4
0.115	12.31
0.12	12.27
0.125	12.22
0.13	12.18
0.135	12.13
0.14	12.09

Table 1: Effect of Increase of TRT Exhaust Pressure

XI. THE EFFECT OF OUTLET PRESSURE OF TRT V/S POWER GENERATION IS SHOWN IN THE GRAPH BELOW



Graph 5: The Effect of Outlet Pressure of TRT V/S Power Generation

In the above chart the pressure varies from 0.11 bar to 0.14 bar and the power output decreases as the TRT outlet pressure increases. The output power is calculated by the formula in which all the parameters other than the outlet pressure p2 are taken as per design parameters.

XII. RECOVERY OF POWER GENERATION AFTER RECTIFICATION

It has been noticed from the above graph that, there is significant increase in the inlet gas flow and GET power generation as shown above

$P = Q \times D \times Cp \times T_1 \times \{1 - (p_2/p_1)^{(n-1/n)}\} \times \eta_T \times \eta_G$ ---- (1)

$Q = 5120000\ Nm^3/hr$ = Flow rate in Nm^3/sec;

$D = 1.33\ kg/m^3$ = Density of BF Gas in kg/m^3;

Cp = 1.03KJ/kgK = Specific heat at constant pressure in kJ/kgK;

T_1=50˚C= GET Inlet temperature in K;

p_1 = 2.2 bar = GET inlet pressure in bar;

p_2= GET outlet pressure in bar;

n = Exponent of adiabatic expansion;

η_T= 85%= Efficiency of turbine (85%);

η_G= 97%= Efficiency of generator (97%).

Note: Cp = 1.03 kJ/kg K

D = 1.33 kg/m^3

n = 1.384

(Above data are taken from the chemical properties of BF gas)

Twenty five to Thirty percent (25~30%) of the power consumed by the blast furnace blower can be recovered, which is economically remarkable.

For example, in JSW the power required to produce 1 Tonne of Hot Metal (THM) is 150 KWhr approx. The daily average production is 8000THM.

Hence power consumed in daily production is given as:

8000 THM/day = 150 x 8000
= 1200000 KWhr
= 1200 MWhr

By installing the GET unit, the power consumed thus can be recovered about 25-30%.It is shown as follows:

GET capacity = 12.4 MW
= 12.4 x 24 MWhr
= 297.6 MWhr of power can be produced using GET.

Therefore, the energy recovered through GET = 297.6 x 100
= 24.8 25 %

1200

XIII. Conclusion

1) Gas flow found increased from 390000Nm3/hr to 550000Nm3/hr.
2) Blast furnace gas leakages arrested by replacing actuator seals andGuide vanesfound operating smoothly from 0-100%.
3) Water spray nozzels found working normaland DN 1600 Bypass valve operating normally especially during tripping of GET.
4) No Mechanical obstruction or foreign material entry in to the turbine, suction pipe inspected and found ok and no sign of erosion of stator and rotating blades found and turbine blades are found in good condition.
5) Seals of guide vane actuating mechanism found worn out, Connecting rod inspected and found ok and no burrs on sliding surface of connecting rod observed.

Because of the above results obtained after rectification of the previously existing problems by the present work, the power generation increased from 10 MW to 12.2 MW.

Reference

[1] Ali Mousafarash , Mohammad Ameri Mechanical & Energy Engineering Department Power and Water University of Technology (PWUT), 16765-1719, Tehran, Iran
[2] D.M. Todd, GE combined cycle experience. 33rd GD Turbine State-of-the-Art Tech Seminar, Paper No.GER-3585A, 1989.
[3] V.B. Agarwal, A.M. Hardes, Combined steam and gas turbine cycle of 30 MW capacity for low-cost power generation, Energy Management, New Delhi 9 (1985) 295±300.
[4] Zainul Huda1*, Tuan Zaharinie2 and Hany A Al-Ansary3
[5] Hu Junfeng,A,B Gabe Kwok,C Wang Xuan,D James H. Williams,C Fredrich KahrlC*.