

BF GAS UTILIZATION AND POWER GENERATION IN STEEL PLANT USING TRT

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Abstract- This paper describes power generation simulation results using MATLAB. The output power depends on various parameters such as turbine inlet pressure, turbine outlet pressure, temperature and flow rate of BF gas. The results are compared and optimal value for which the turbine has to be operated are determined.

Index Terms- TRT (Top gas pressure recovery turbine), BF gas, MATLAB/Simulink, software.

I. INTRODUCTION

The increasing price of fossil fuels, the increasing need for the power supply reliability and increasing demand for energy-efficient technologies are tending to favor the application of small power generation solutions. Cogeneration produces a given amount of electricity and heat. In iron and steel works, byproduct gas – blast furnace gas (BFG) is widely flared and vented to the atmosphere without utilization. On account of this, it is an important task for the iron and steel works to sufficiently and effectively utilize BFG so as to reduce waste gases emissions and save energy. On the other hand, the power generated through combusting waste gases will replace the major quantity of electricity that could have been generated by greenhouse gases (GHG) intensive fossil fuel power plant, thus GHG emission reductions could be achieved. Aside from exploring renewable energy alternatives, available energy resources must be utilized to their maximum potential.

Blast Furnace gas :

BF gas leaves the furnace at a temp of 150 - 250°C and at a pressure equal to the top gas pressure of the furnace. BF gas also has a huge dust content which needs to be removed before it can be put to use. The primary cleaning system at all blast furnaces is a dry system where about 75% of the dust is removed. This is typically a dust catcher. This dust is called Flue Dust and is typically recycled through sinter plants or rotary hearth furnace BF gas also has calorific value of about 700 – 800 Kcal/ Nm³. This calorific value is quite low compared to coke oven gas CV of 1850 Kcal/Nm³. Due to low CV; BF gas does not have self supporting flame. However in view of its quantity and the fact that it is available at high pressure, BF gas is the ideal fuel for reheating furnaces and power houses in BF. It is also necessarily used for heating the stoves which heat the cold blast for the BF. The hot blast of air entering the furnace through the tuyeres burns the coke carbon to

CO₂. The intense heat produced gives a flame temperature of 1800 2000°C, depending upon the blast temperature. Since CO₂ is unstable in the presence of carbon above 1000°C, CO is produced according to CO₂+C=2CO. The tuyere gas therefore, consists only CO and nitrogen, their contents being about 25 and 40 percent respectively when dry blast is used. This hot reducing gas rises through the active coke bed to the bosh, belly and shaft and iron oxides. Composition of BF gas is CO(22- 28 %), CO₂(18-28%), H₂(3-8%), N₂(40-45%)

TRT (Top gas pressure recovery turbine):

Blast furnace top gas pressure recovery turbine unit is an energy recovery machine train, and its function is to guide gas into turbine by residual pressure of blast furnace top gas, then gas works due to expanding and the generator is driven to generate power. The TRT-unit can recover 25-30% energy of the blast furnace requirement. At the same time, when it is running normally, it can act as pressure reducing valve unit. The TRT can control blast furnace top pressure sensitively and the scope of fluctuation is small. So it plays an active role that can make blast furnace running normally and increasing production.

The TRT utilizes the pressure energy of BF gas which is the by-product of the blast furnace. The cleaned gas is fed to top gas recovery turbine. In TRT 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 TRT is sent to the gas holder from where it is distributed to the different consumers at constant pressure. If TRT 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. There are two types of TRT Wet and Dry type .The dry type TRT can generate more power than wet type TRT.



Fig.1. TRT (Top gas recovery turbine)

II. POWER RECOVERED BY TRT:

Twenty five to fifty percent (25~30%) of the power consumed by the blast furnace blower can be recovered, which is economically remarkable. The power required to produce 1 Tonne of Hot Metal (THM) is 150 KWhr. The daily average production is 8000THM.

Hence power consumed in daily production is given as: $8000 \text{ THM/day} = 150 \times 8000$

$$= 1200000 \text{ KWhr}$$

$$= 1200 \text{ MWhr}$$

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

TRT capacity = 12.4 MW

$$= 12.4 \times 24 \text{ MWhr}$$

$$= 297.6 \text{ MWhr of power can be produced}$$

using TRT.

Therefore, the energy recovered through TRT = $\frac{297.6}{1200} \times 100 = 24.8 \approx 25\%$

$$1200$$

III. RESULTS

OUTPUT POWER CALCULATION OF TRT:

Parameters considered for estimating the TRT power output:

- BF Gas volume flow
- BF Gas pressure at the furnace top
- Pressure drop across the GCP
- Temperature of BF Gas after the GCP
- BF Gas pressure as desired after the TRT
- Efficiency of top recovery expansion turbine
- Efficiency of Generator

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

Where:

Q = Flow rate in Nm^3/sec ;

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

C_p = Specific heat at constant pressure in $\text{kJ}/\text{kg K}$;

T_1 = TRT Inlet temperature in K;

- p_1 = TRT inlet pressure in bar;
- p_2 = TRT outlet pressure in bar;
- n = Exponent of adiabatic expansion;
- η_T = Efficiency of turbine (85%);
- η_G = Efficiency of generator (97%).

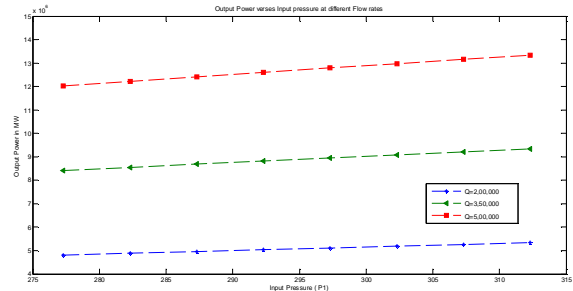


Fig.2. Inlet pressure versus output power at different flow rates

Power increases with increase in inlet power. As pressure increases in steps of 5Kpa power increases by 0.08 MW at $Q=2,00,000 \text{ Nm}^3/\text{hr}$, 0.14 MW at $Q=3,50,000 \text{ Nm}^3/\text{hr}$ and 0.2MW at $5,00,000 \text{ Nm}^3/\text{hr}$. At same inlet pressure power increases by 3.6 MW when flow rate is increased by $1,50,000 \text{ Nm}^3/\text{hr}$.

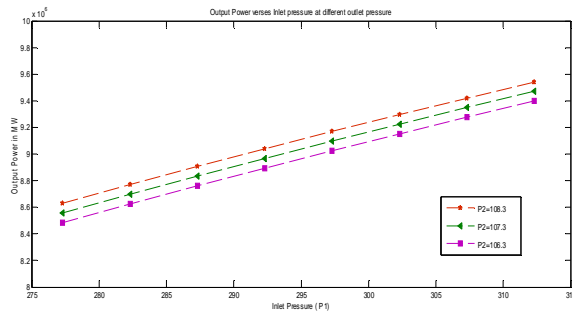


Fig.3. Inlet pressure versus output power at different outlet pressure

Power increases with increase in inlet power. As pressure increases in steps of 5Kpa power increases by 0.13 MW. when outlet pressure is increased by 1 Kpa power decreases by 0.08 MW.

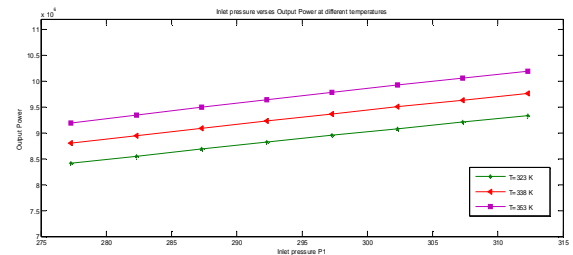


Fig.4. Inlet pressure versus output power at different temperature

Power increases with increase in inlet power. As pressure increases in steps of 5Kpa power increases by 0.13 MW at $T=323$, 0.14 MW at $T=338$, and 0.15 MW at $T=353$. At same inlet pressure power increases by 0.39 MW when Temperature is increased by 15K.

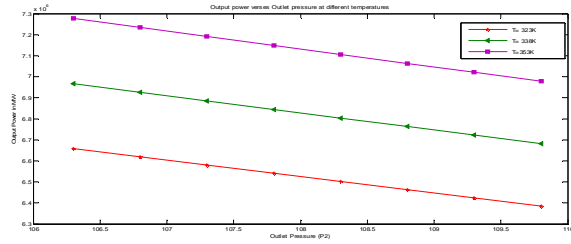


Fig.5.Outlet pressure versus output power at different temperature

Power decreases with increase in outlet pressure. As outlet pressure increases in steps of 0.5Kpa power decreases by 0.04 MW. Power increases by 0.31 MW for increase in temperature by 15K.

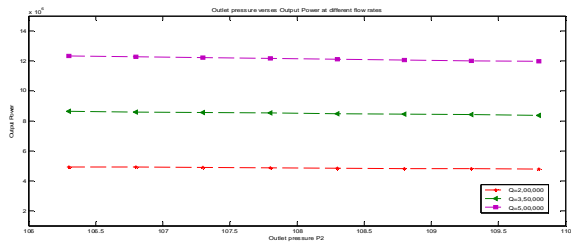


Fig.6.Outlet pressure versus output power at different flow rates

Power decreases with increase in outlet pressure. As pressure increases in steps of 0.5 Kpa power output decreases by 0.02 MW at $Q=2,00,000 \text{ Nm}^3/\text{hr}$, 0.04 MW at $Q=3,50,000 \text{ Nm}^3/\text{hr}$ and 0.05MW at $5,00,000 \text{ Nm}^3/\text{hr}$.The power increases by 3.7 MW as flow rate is increased by $1,50,000 \text{ Nm}^3/\text{hr}$.

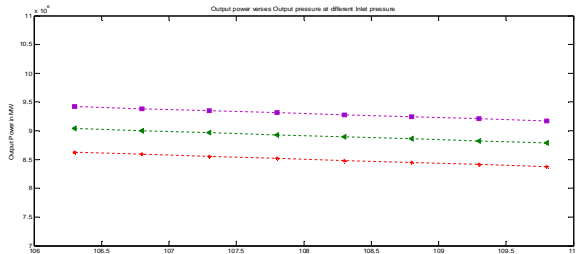


Fig.7.Outlet pressure versus output power at different inlet pressures

Power decreases with increase in outlet pressure. power increases by 0.04 MW as outlet pressure increases in steps of 0.5 Kpa.

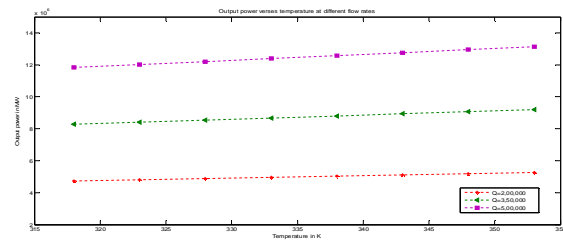


Fig.8. Temperature versus output power at different flow rates

Power increases with increases in temperature. As temperature increases by 5K power increases by 0.07MW at $Q=2, 00,000 \text{ Nm}^3/\text{hr}$, 0.13 MW at $Q=3, 50,000 \text{ Nm}^3/\text{hr}$ and 0.2MW at $5, 00,000 \text{ Nm}^3/\text{hr}$. At same temperature power increases by 3.6 MW when flow rate is increased by $1, 50,000 \text{ Nm}^3/\text{hr}$.

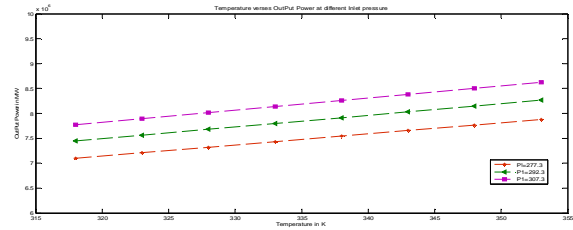


Fig.9. Temperature versus output power at different inlet pressure

Power increases with increases in temperature. As temperature increases by 5K power increases by 0.12 MW. power increases by 0.35 MW for 15 Kpa increase in inlet pressure.

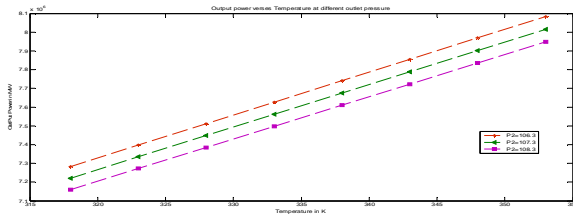


Fig.10. Temperature versus output power at different inlet pressure

Power increases with increases in temperature. As temperature increases by 5K power increases by 0.11 MW

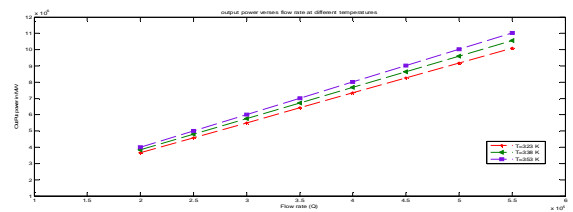


Fig.11.Flow rate versus output power at different temperatures

Power increases with increases in Flow rate. As Flow rate increases by $50,000 \text{ Nm}^3/\text{hr}$ power increases by 0.9MW. Power increases with increases in Flow rate. As Flow rate increases by $50,000 \text{ Nm}^3/\text{hr}$ power increases by 0.9MW.

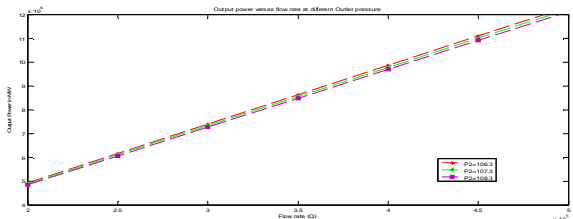


Fig.12.Flow rate versus output power at different outlet pressure

Power increases with increases in Flow rate. As Flow rate increases by 50,000 Nm³/hr power increases by 1.23MW

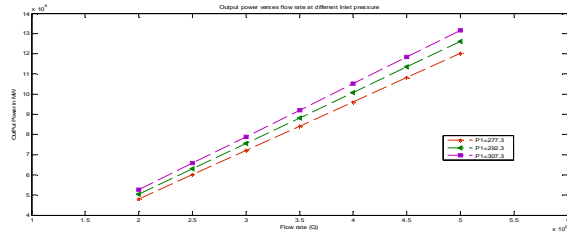


Fig.13.Flow rate verses output power at different inlet pressure

Power increases with increases in Flow rate. As Flow rate increases by 50,000 Nm³/hr power increases by 1.2MW.

CONCLUSION

A consistent and constant TRT inlet BF gas pressure of 2.2 bar is to be maintained to achieve maximum power output of 12.4MW. Fluctuation of BF gas inlet pressure adversely effects the power generation. Therefore to achieve 100% PLF, the inlet BF gas pressure of the

TRT has to be constant to obtain maximum power generation .The furnace top pressure fluctuation is the main reason for variation of TRT inlet pressure. So the fine tuning and trouble free operation of Blast Furnace is required to generate constant BF top pressure.As per design a constant TRT outlet pressure of 0.125 bar max, is also necessary to achieve maximum power output of 12.4MW from the TRT. Flow rate of BF gas should be maintained at 5,00,000 Nm³/hr.

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