Performance Improvement of AFBC Boiler through Analysis of Heat Losses

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Abstract— Electricity is essential in the economic development of any nation. Due to rapid growth of economy and industrial development in India, the demand for use of electricity has increased rapidly. Power generation capacity in India is 70 percent thermal, with the remaining being hydro and nuclear. Thermal generation is mainly based on steam generation using a coal-fired boiler. This paper deals with the determination of efficiency of boiler and calculates the heat losses in Suryalakshmi thermal power plant, Nagardhan of 25 MW unit and try to give some suggestions to reduce heat losses. Power Plant play very important role in improving the economic condition, competitive advantage, life style, of people in any country. The understanding of the structure, i.e., system and connectivity between different systems and It is useful for estimating the contribution of different attributes of the performance of the system. Any Production system should be kept failure free under the given operative conditions to achieve the set goals of economical production and long run performance. A highly reliable system tends of increases the efficiency of production. Efficient power generation is expected to make more power available at a lower cost.

Key words: Thermal Power Plant, Coal Fired Boiler, Performance

I. INTRODUCTION

Now days power demand increases is extremely very high compared to the rate at which generation capacity increase. Boiler is a heart of power plant, so its efficiency is directly affected to the all over efficiency of the plant. It is quite obvious that approximately 65% to 70% power generation comes out from Thermal Power Plant uses Coal as fuel available from various parts of India, where transportation is also made easy and timely. Power is one of the basic infrastructures necessary for the Industries and socio economic development in the State. Installed capacity of the State has increased from 315 MW in 1960-61 to 11711 MW in 2009- 2010. Power consumption per capital indicates the industrial and economical growth of the country and thereby represents the living standard of the people of the same. The whole world is in grip of electrical energy crisis and pollution due to the power plants. The overall power scene in India shows heavy shortages in almost all the states. The government of India has advocated “Energy for all” by the year 2012. Even though the Indian power sector is at the forth place of the power production in the world.

Today’s process and heating applications continue to be powered by steam and hot water. The mainstay technology for generating heating or process energy is the packaged water tube boiler. The packaged water tube boiler has proven to be highly efficient and cost effective in generating energy for process and heating applications. Conducting a thorough evaluation of boiler equipment requires review of boiler type, feature and benefit comparison, maintenance requirements and fuel usage requirements. Of these evaluation criteria, a key factor is fuel usage or boiler efficiency. Selection of a boiler with “designed-in” low maintenance costs and high efficiency can really provide savings and maximize boiler investment. Efficiency is only useful if it is repeatable and sustainable over the life of the equipment.

A. Atmospheric Fluidized Bed Combustion (AFBC):

In AFBC, coal is crushed to a size of 1 – 10 mm depending on the rank of coal, type of fuel feed and fed into the combustion chamber. The atmospheric air, which acts as both the fluidization air and combustion air, is delivered at a pressure and flows through the bed after being preheated by the exhaust flue gases. The velocity of fluidising air is in the range of 1.2 to 3.7 m /sec. The rate at which air is blown through the bed determines the amount of fuel that can be reacted.

Almost all AFBC/ bubbling bed boilers use in-bed evaporator tubes in the bed of limestone, sand and fuel for extracting the heat from the bed to maintain the bed temperature. The bed depth is usually 0.9 m to 1.5 m deep and the pressure drop averages about 1 inch of water per inch of bed depth. Very little material leaves the bubbling bed – only about 2 to 4 kg of solids are recycled per ton of fuel burned. The combustion gases pass over the super heater sections of the boiler, flow past the economizer, the dust collectors and the air preheaters before being exhausted to atmosphere.

The main special feature of atmospheric fluidized bed combustion is the constraint imposed by the relatively narrow temperature range within which the bed must be operated. With coal, there is risk of clinker formation in the bed if the temperature exceeds 950 ^{o}C and loss of combustion efficiency if the temperature falls below 800 ^{o}C. For efficient sulphur retention, the temperature should be in the range of 800 ^{o}C to 850 ^{o}C.

B. About Rankine Cycle:

A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine, the steam is condenced in a condenser and recycled to where it was heated; this is known as a Rankine cycle.. The greatest variation in the design of thermal power stations is due to the different fossil fuel resources generally used to heat the water. Certain thermal power plants also are designed to produce heat energy for industrial purposes of district heating or desalination of water, in addition to generating electrical power.

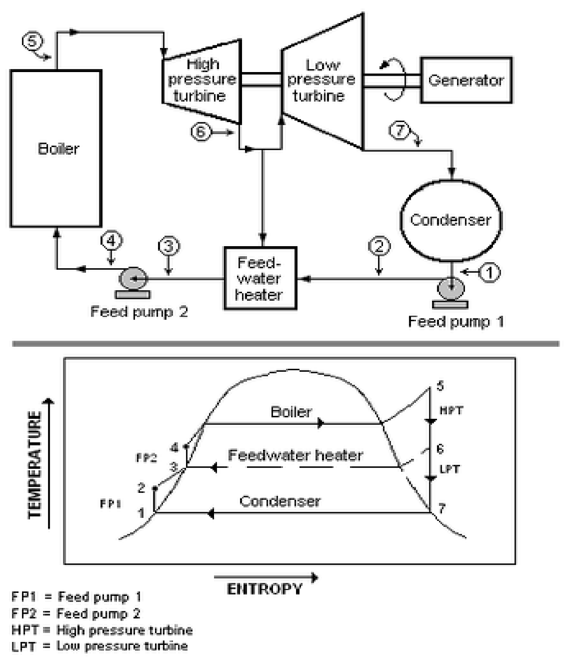

Fig. 1: Line diagram of Thermal power plant

II. Performance of Boiler

Performance of boiler – For calculating the performance of boiler the following Parameter required. This parameter taken from power plant for 12 MW power generation.

1) Steam temperature = 510 ^{0} C
2) Steam pressure = 109 kg/cm^2
3) Steam flow = 62T/hr
4) Fuel firing rate = 16 T/hr
5) Ambient temperature = 30^0 C
6) Temperature of flue gases = 128^0 C
7) Feed water temperature = 123^0 C
8) Humidity in ambient air = 0.0204 kg / kg of air
9) Ratio of bottom ash to fly ash = 35:65
10) GCV of bottom ash = 3517.08 kJ/kg
11) GCV of fly ash = 1934.4 kJ/kg
12) GCV of coal = 13398.4 kJ/kg
13) % CO2 in flue gas = 14 %
14) % CO in flue gas = 0.5 %

Analysis of coal

- Carbon = 44.37 %
- Hydrogen = 2.80 %
- Nitrogen = 1.20 %
- Oxygen = 9.82 %
- Sulphur = 0.51 %
- Ash = 36.81 %
- Moisture = 4.49 %

Basically boiler efficiency can be tested by the following methods:-

A. The Direct Method:

This is also known as input-output method, where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.

Boiler efficiency by direct method calculated as,

$$\eta = \frac{Q\,(h - h_f) \times 100}{q \times GCV}$$

Where, Q= quantity of steam generated

h = enthalpy of superheated steam

h_f = enthalpy of feed water

q = quantity of fuel used

$$\eta = \frac{62\,(3362.2 - 517.5) \times 100}{16 \times 13398.4}$$

= 82.29 %

B. The Indirect Method:

By indirect method efficiency is the difference between the losses and the energy input. Indirect method is also called as heat loss method. A detailed procedure for calculating boiler efficiency by indirect method is given below.

Boiler Efficiency by indirect method calculated by

η = 100 – (L1 + L2 + L3 + L4 + L5 + L6 + L7 +L8)

Where,

L1- Loss of heat due to dry flue gas (Sensible heat)

L2- Loss due to hydrogen in fuel (H2)

L3- Loss of heat due to moisture in fuel (H2O)

L4- Loss of heat due to moisture in air (H2O)

L5- Loss of heat due to carbon monoxide (CO)

L6- Loss of heat due to radiation and Convection

L7- Un-burnt losses in fly ash (Carbon)

L8- Un-burnt losses in bottom ash (Carbon)

1) Theoretical Air required for Combustion:

= [(11.6 × C) + {34.8 × (H_2 – O2/8)} + (4.35 × S)] / 100

= [(11.6 × 44.37) + {34.8 × (2.80– 9.82/8)} + (4.35 × 0.51)] / 100

= 5.72 kg/kg of fuel

2) Theoretical CO_2 %:

$$\text{Theoretical } CO_2\,\% = \frac{\text{Mole of C}}{\text{Mole of C} + \text{Mole of } N_2}$$

Where,

$$\text{Moles of } N_2 = \frac{5.72 \times 77/100 + 0.012/28}{28}$$

= 0.1577

Moles of C = 0.4437/12 = 0.03697

$$\text{Theoretical } CO_2\,\% = \frac{0.03697}{0.03697+0.1577}$$

= 18.99 %

3) % Excess air supplied (EA):

$$EA = \frac{7900\,[(CO_2)t - (CO_2)a]}{(CO_2)\,a \times [100 - (CO_2)t\,]}$$

$$= \frac{7900\,[18.99-14]}{14[100-18.99]}$$

= 34.76 %

4) Actual mass of air supplied / kg of fuel (AAS):

AAS = {1 + EA / 100} × theoretical air

= {1 + 34.76 / 100} × 5.72

= 7.71 kg/kg of fuel

5) Actual mass of dry flue gas:

Actual mass of dry flue gas = Mass of CO_2 + Mass of N_2 in fuel + Mass of N_2 in Combustion air supplied + Mass of O_2 in flue gas

= [(0.4437× 44)/12] + 0.012 + [(7.71 × 77) / 100] + (7.71-5.72) × [23/100]

= 8.033 kg/ kg of fuel

a) Heat loss due to dry flue gas (L1):

$$L1 = \frac{m \times Cp \times (T_f - T_a) \times 100}{\text{GCV of coal}}$$

$$= \frac{8.033 \times 0.963 \times (128 - 30) \times 100}{13398.4}$$

= 5.66 %

b) Heat loss due to evaporation of water formed d due to H2 in fuel (L2):

$$L2 = \frac{9H_2\,[\,584 + Cp \times (\,T_f - T_a\,)\,] \times 100}{GCV\ of\ coal}$$

$$= \frac{9 \times 0.028\,[\,2445.2 + 1.884\,(128-30\,)\,] \times 100}{13398.4}$$

= 4.94 %

c) Heat loss due to moisture in fuel (L3):

$$L3 = \frac{M \times [\,584 + Cp \times (\,T_f - T_a\,)\,] \times 100}{GCV\ of\ coal}$$

$$= \frac{0.0449 \times [\,2445.2 + 1.884\,(128-30\,)\,] \times 100}{13398.4}$$

= 0.881 %

d) Heat loss due to moisture present in air (L4):

$$L4 = \frac{ASS \times humidity \times Cp \times (\,T_f - T_a\,) \times 100}{GCV\ of\ coal}$$

$$= \frac{7.71 \times 0.0204 \times 1.884 \times (128 - 30\,) \times 100}{13398.4}$$

= 0.216 %

e) Heat loss due to incomplete combustion (L5):

$$L5 = \frac{\%\ of\ CO \times (\%\ of\ C/100)}{\%\ of\ CO + \%\ of\ CO_2} \times \frac{24050.12}{GCV}$$

$$= \frac{0.5 \times 0.4437}{0.5 + 14} \times \frac{24050.12}{13398.4}$$

= 2.75 %

f) Heat loss due to radiation and convection (L6):

For small capacity of power generation, the radiation and Convection losses should be taken as 1 to 2 % (Reference: Bureau of energy efficiency) so we consider as;

L6 = 1.5 %

g) Heat loss due to un-burnt in fly ash (L7) :-

$$L7 = \frac{Total\ ash\ collected/kg\ of\ fuel\ burn \times GCV\ of\ fly\ ash \times 100}{GCV\ of\ coal}$$

$$= \frac{0.65 \times 0.3681 \times 1934.4 \times 100}{13398.4}$$

= 3.4543 %

h) Heat loss due to un-burnt in bottom ash (L8):-

$$L8 = \frac{Total\ ash\ collected/kg\ of\ fuel\ burn \times GCV\ of\ bottom\ ash \times 100}{GCV\ of\ coal}$$

$$= \frac{0.35 \times 0.3681 \times 3517.4 \times 100}{13398.4}$$

= 3.38197 %

Boiler Efficiency by indirect method is

η = 100 – (L1 + L2 + L3 + L4 + L5 + L6 + L7 +L8)

= 100 – (5.66 + 4.94 + 0.881 + 0.216 + 2.75 + 1.5 + 3.3454 + 3.3819)

= 77.2168 %

% loss by indirect method-

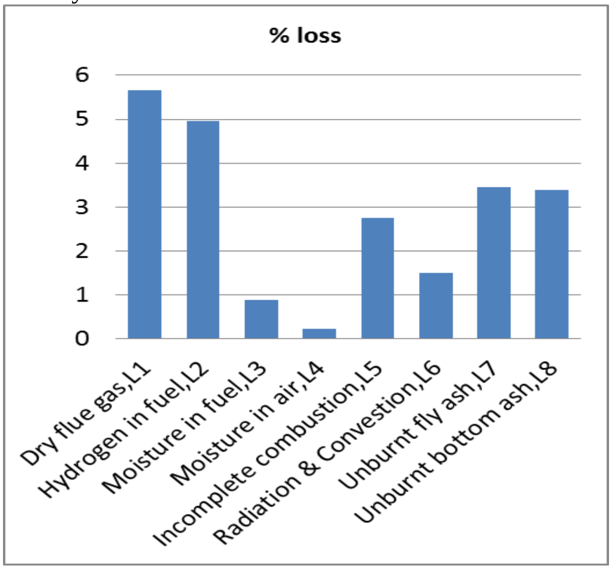

Fig. 2: Graph - Percentage losses in boiler

6) Causes of various heat losses and Suggestions to reduce heat losses:

a) Dry Flue Gas Losses:

– Boiler casing air in leakage.
– Air preheater leakage.
– Incorrect fuel to air ratio.
– Improper burner damper settings.

Suggestions-

– O2 reading should be taken at several stage.
– Condition monitoring of inlet and outlet temperature of gases.
– Continuous check burners setting.

b) Loss due to H2 in fuel:

– Fuel having higher the hydrogen content, the more water vapour is formed during combustion. The result is energy loss as the vapour absorbs energy in the boiler and lowers the efficiency of the equipment.

Suggestions-

– Good quality of coal should be used.

c) Incomplete combustion loss:

– Incorrect fuel to air ratio.
– Improper burner damper setting.
– Quality of coal.

Suggestions-

– Bed temperature should be in controlled condition.
– Bed charging should be done regularly.

d) Un-burnt bottom and fly ash loss:

– Larger size of bottom ash increases the bed height and affects the fluidization.
– Maximum pressure drop occur across the bed.
– It affects the efficiency of boiler.

Suggestions-

– Bed height should be maintained to minimize that loss.

- Bed ash overflow arrangement should be provided. i.e. idle compartment so that excess bed ash overflows to separate compartment where it is cooled and drained out.

III. RESULTS AND DISCUSSION

- The boiler efficiency is obtained by direct method, indirect method as 82.29 %, 77.2168 % respectively.
- The losses of AFBC boiler are obtained and studied in detailed to find out energy saving opportunity. The heat losses in boiler are found to are as follows:

1) Loss of heat due to dry flue gas (L1) = 5.66 %
2) Loss due to hydrogen in fuel (L2) = 4.94 %
3) Loss of heat due to moisture in fuel (L3) = 0.881 %
4) Loss of heat due to moisture in air (L4) = 0.216 %
5) Loss of heat due to carbon monoxide (L5) = 2.75 %
6) Loss of heat due to radiation and convection (L6) = 1.5 %
7) Un-burnt losses in fly ash (L7) = 3.4543 %
8) Un-burnt losses in bottom ash (L8) = 3.3819 %

- Major heat losses are found to be in

1) Loss of heat due to dry flue gas (L1) = 5.66 %
2) Loss due to hydrogen in fuel (L2) = 4.94 %
3) Loss of heat due to carbon monoxide (L5) = 2.75 %
4) Un-burnt losses in fly ash (L7) = 3.4543 %
5) Un-burnt losses in bottom ash (L8) = 3.3819 %

IV. CONCLUSION

With the growing need of the coal, which is an nonrenewable source of energy and depleting with a very fast pace, it is desirable to have such optimal techniques (better quality of coal) which can reduce the energy losses in the coal fired boiler and improves its performance these create impact on production and optimizations uses of energy sources. In addition this study shows the better quality of coal giving the high performance of plant and even though the consumption of coal is been reduced that creates economic condition for overall plant.

The coal type affects efficiency of the system considerably. It has been also analyzed that a part of energy loss occurs through flue gases. The carbon content in the coal has to be proper. The presence of moisture has a detrimental effect on overall efficiency. If we use the heat recovery system to recover the heat losses through flue gases then it will be more useful for us.

REFERENCES

[1] Mehta, A.V., and Patel, M., 2010. Thermodynamic analysis of Gandhinagar thermal power station. International Journal of Advanced Engineering Technology, 1(3), 1-12.
[2] Kakkar, M. M., Kumar, R. and Gupta, M., 2012. Performance based comparative analysis of thermal power plant: A Review. Proceedings of the National conference on Trends and Advances in Mechanical Engineering, 174-179.
[3] Mehta, N.S., 2012. A case study-Ukai thermal power station. *Scientific Research*, 2, 1-108.
[4] Murehwa, G., Zimwara, D., Tumbudzuku, W., and Mhlanga, S., 2012. Energy efficiency improvement in thermal power plants. International Journal of Innovative Technology and Exploring Engineering, 2(1), 20-25.
[5] Nagar, V., Dr. Soni, V. K., and Dr. Khare, V. K., 2013. Boiler Efficiency improvement through analysis of losses. International Journal for Scientific Research and Development, 1(3), 801-805.
[6] Hada, P. S., and Shah, I. H., 2012. First law and second law analysis of a lignite fired boiler used in a 30 MW thermal power plant. International Journal of Engineering and Innovative Technology and Exploring, 1(6), 84-88.
[7] Kurkiya, R., and Choudhary, S., 2012. Energy analysis of thermal power plant. International Journal of Science and Engineering Research, 3(7), 1-7.
[8] Shanmugam, K .R, and Kulshreshtha, P., 2005. Efficiency analysis of coal-based thermal power generation in India during post-reform era. International Journal of Global Energy, 23(1), 15-28.
[9] Mohan, M., Gandhi, O.P., and Agrawal, V.P., 2003. Systems modeling of a coal based steam power plant proceeding of the Institution of Mechanical Engineers, Part A. Journal of Power and Energy, 217, 259-277.
[10] Nag, B., 2006. Estimation of carbon baseline for power generation in India: the supply side approach. Energy policy, 34(12), 1399-1410.
[11] Bureau of Energy Efficiency, Energy performance assessment of boilers, 1-22.
[12] Bureau of Energy Efficiency, Energy efficiency in thermal utilities, 35.
[13] Nag, P. K., 2008. *Power Plant Engineering*. 6th Edition, Tata McGraw Hill, New Delhi, 317- 428.
[14] Rajput, R. K., 2008. An Introduction to Power Plant Engineering. 6th Edition, Laxmi Publication ltd., 225-256.

