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Waste Heat Utilization of Coal Based Thermal Power Plant Using

Prashant Singh[1] and O.P. Pandey[2]

[1,2]Birla Institute of Technology, Mesra, Ranchi
E-mail: [1]prashantbbd@gmail.com, [2]oppandey28@yahoo.com

Abstract—*In the world of energy generation, developing country like India, which mostly depend on conventional coal based thermal power plant. This source of energy generation has solely accounted for 76.5% of total energy generated in India till 31st December 2017. Due to rise in prices of coal, high emission and limited coal stock, it is important to restrict the consumption of coal in order to achieve sustainable development. However in a India having a huge population load, the use of coal as the primary source of energy cannot be ignored. In order to achieve sustainable development, the best way is to increase the efficiency of present thermal power plant. In general, loss of energy in thermal power plant is nearly about 45-55% of total energy generated, out of which major losses occurs as thermal loss. Thermal loss that occurs through flue gases accounts to 26.56% of total energy generated by a 210MW plant running at load of 170MW, which is equal to 42.5MW. The aim of this paper is to investigate a method to recover a major portion of this wasted energy, which otherwise goes unused via hot flue gases by the use of Thermoelectric Generator. Another objective of this paper is to suggest a suitable position to install thermoelectric generator inside the thermal power plant. As thermoelectric generator requires a hot junction along with a cold junction, which itself needs energy to maintain its cool temperatures. So the installation of thermoelectric generator has been suggested in this paper at a place inside thermal power plant, as it would be provided with a continuous temperature gradient without use of any extra energy sources to maintain the temperature difference.*

Keywords*: waste-energy recovery, thermoelectric generator, direct energy conversion, seebeck effect.*

1. INTRODUCTION

1.1. Thermal power plant

Regular thermal power plant is a station, which convert heat energy to electricity that can easily be transferred through grid and can be transferred in different type as per requirement. There are so many types of thermal power plant, which is in use or designed and their basic classification is by their types of fuel it is using. We are concentrating on coal fired boiler types thermal power plant. This can also be further classified in many types like subcritical, critical or supercritical. The real time data used in this paper is for subcritical type 210 MW power plant. Here in this type basic process of working is burning coal in boiler and then using that heat, water is heated and that turns into steam which create pressure and when release to turbine blade it get rotated. Generator shaft is coupled with turbine and it gets rotated too and we get electricity. After passing the turbine, steam is condensed in condenser and recycled to where it was heated. This is also known as Rankine cycle.

This is the basic principle of working of thermal power plant.

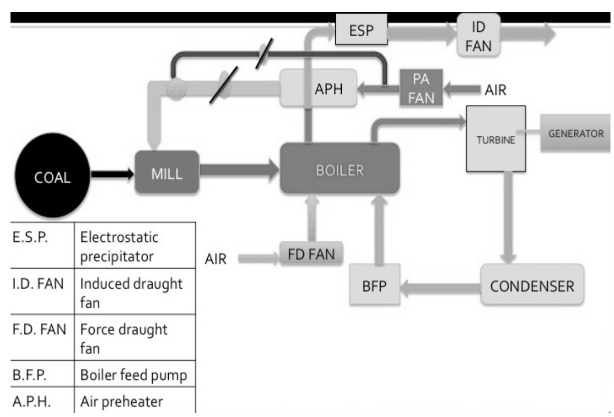

Figure 1 Air/Flue gas and Water/Steam Scheme.

1.2. Thermoelectric generator

Thermoelectric generator converts heat it directly into electricity by seebeck effect. It is of low maintenance and can also be used by low-grade heat of less than 200^{o}C. It is currently designed to work even for 20 years of life.

Basic principle behind thermoelectric generator is **seebeck effect,** which was discovered in 1821 and as stated as: "whenever there is temperature difference between two junctions in a loop, made up of two dissimilar conductors, thermal electromotive force is produced in the loop". Such a loop is known as thermoelectric and shown in the figure below. The effect is more pronounced in thermocouple formed with P type and N type semiconductor materials. In N type material, current flows in the direction of heat flows EMF produced is proportional to temperature gradient between two junction the power produced P is;

$P = Q_h - Q_L = I^2R_L$

Where Q_H =heat flow rate into hot junction

Q_L=dissipated heat flow rate to cold junction.

T_H= Temperature of hot junction

T_C= Temperature of hot junction

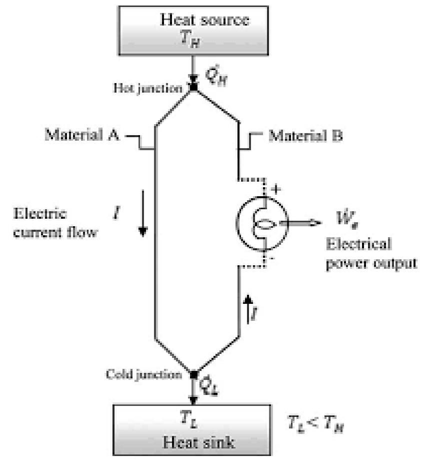

Figure 2: Energy flow diagram of thermoelectric generator.

2. OBJECTIVE

Currently conventional thermal power plant has energy efficiency of 33% to 48% as in all type of heat engine the efficiency is limited and governed by law of thermodynamics. Rest of the heat energy generated gets lost out into environment. Regular heat loss in thermal power plant is in form of condenser losses, frictional losses etc. But the major heat goes directly out from flue gas. In present times, thermal power plant is designed to save some of that by installing air-preheater which takes some of its heat from going out with flue gases and inject it to incoming fresh air from primary air fan duct. For operation of air preheater electrical motor or air motor is required to rotate the desiccant wheel in order to maintain or regulate rate of heat transfer from hot side to cold side.

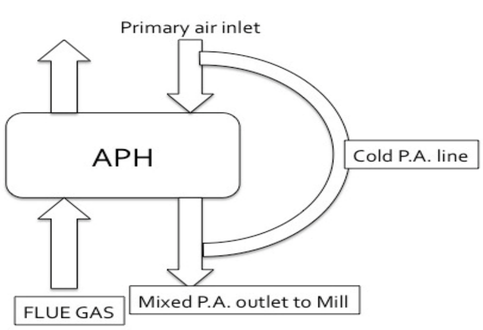

Figure 3 Current arrangement of air-preheater.

Flue gas coming out after that air-preheater is a still headed to a temperature of around 320°C.

Dew Point temperature of flue gas after expected installation of “Flue gas desulphurizer” (F.G.D.) and “selective catalyst reduction” (S.C.R.) as per current scenario of tightening law of emissions day by day. Using A.G. OKKES calculation methods to calculate due point temperature.

$$t_{sld} = 10.8809 + 27.6 \lg P_{H_2O} + 10.83 \lg P_{SO_3} + 1.06(\lg P_{SO_3} + 2.9943)^{2.19}$$

t_{STD}= Flue gas acid dew point temperature

P_{H2O}=Partial pressure of water vapour in flue gas

P_{SO2}=Partial pressure of SO_2 gas in flue gas

Further calculation is done by A.G. OKKES calculation method because future thermal plants are planned to be equipped with “selective catalyst reduction” (S.C.R.) and Flue gas desulphurizer (F.G.D.) which will change the SO_3 and water vapor content of flue gas, which will affect the dew point temperature of flue gas directly

Using A.G. OKKES method of dew point temperature calculation, the calculated temperature is **95.64°C**.

We get your point temperature of 95.64°C. So this means that we can father decrease the temperature of fluids from 320°C to 95.64°C.

This paper proposes to replace the Air-preheater with Thermoelectric generator.

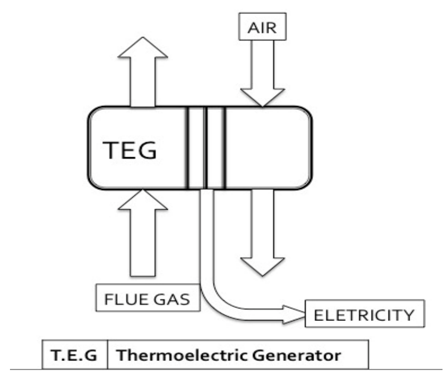

Figure 4: Replacement of Air-preheater by Thermoelectric generator.

Benefit for this will be that we can generate energy while transferring it from hot side to cold side, which is currently not been utilized completely. As we cannot heat primary air about certain level as it may pre-ignite the coal in pulverizer and this situation will be dangerous. In order to over this situation, presently we need to split primary air in 2 parts, 1st passed through a air-preheater which is called “hot primary air duct” and other is called “cold primary air duct” which is mixed to hot primary air duct after it get heated from air preheater. The purpose of this is to continuously monitor the hot primary air temperature and regulating the ratio of hot duct and cold duct in order to get optimize temperature, which in the above mentioned unit is 230^oC. This continuous regulation in gates of hot primary air duct and cold primary air duct gives slow regulation and always maintains a risk of failure of gate, was which in returns demand great maintenance. Air preheater replacement by thermoelectric generator will give easy regulation of output temperature and despite of that we won't need any extra duck of cold primary air. Only one duct will solve the purpose.

3. CALCULATION OF MASS FLOW RATE OF FLUE GASES

Burning of coal in presence of air inside boiler forms flue gases.

DATA TAKEN FROM RUNNING POWER PLANT

(a) Loading of mill B = 29.8 T.P.H
(b) Loading of mill C = 32.0 T.P.H
(c) Loading of mill D = 30 T.P.H
(d) Loading of mill E = 29.63 T.P.H
(e) Mass flow rate of P.A.FAN A = 215 T.P.H.
(f) Mass flow rate of P.A.FAN B = 200 T.P.H.

So total mass flow inside the boiler is 29.8+32.0+30.0+29.63+215+200 = **536.43** T.P.H.

So by mass balance equation 536.43 T.P.H. will the mass flow rate of flue gases and fly ash all together.

T.P.H.= TONS PER HOURS

4. CALCULATION OF HEAT TAKEN BY HOT SIDE OF T.E.G. LEG

By heat and mass transfer equation

$Q_H = \{M^* \text{ X } C_{P\ F/G} \text{ X } (T_1 - T_2)\}$

$= \{(536.43\text{T.P.H}) \text{ X } (2.78933 \text{ x } 10^{-4} \text{ KWh/TON/}^OC) \text{ X } (314-95.64)\ ^OC$

Q_H= 32329.21992 kWHrs

= 32.3292199 MWHrs

5. CALCULATION OF HEAT TAKEN BY COLD SIDE OF T.E.G. LEG

By heat and mass transfer equation

$Q_C = \{M^* \text{ X } C_{P\ AIR} \text{ X } (T_4 - T_3)\}$

$= \{(200\text{TPH}_{(PA\ fan\ A)} + 215\text{TPH}_{(PA\ fan\ B)}) \text{ X } (0.0199 \text{ kWhrs/TON/}^OC) \text{ X } ((263-40)\ ^OC)\}$

= 18.434 MWHrs

6. CALCULATION OF ENERGY AVAILABLE FOR T.E.G

$P_{elec} = Q_H - Q_C$=13.89521992MWHrs(available)

13.8952 MWHrs is the energy available for use when plant is at 170MW as load.

This is 8.17% of total load.

7. CONCLUSION

Considering of thermoelectric generator, which can provide that much efficiency at above mentioned temperature difference could help to achieve the target of harvesting 13.8952MW, that is 8.17% of total load.

8. FUTURE WORK

In order to get that efficiency of thermoelectric generator we need to develop the thermoelectric generator material of such figure of merit (ZT)

As $\eta = \eta_{carnot}\,[(\{\sqrt{(1+ZT)}\}-1)/(\{\sqrt{(1+ZT)}\}+\{T_L/T_H\})]$

Here $ZT = (\alpha^2 T/KR)$

$T = (T_H + T_C) / 2$

α=Seebeck coefficient

T_H= Temperature of hot side

T_c= Temperature of cold side

9. ACKNOWLEDGMENT

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REFERENCES

[1] Stecanella, P.A., Faria, M.A., Domingues, E.G., Gomes, P.H., Calixto, W.P. and Alves, A.J., 2015, June. Eletricity generation using thermoelectric generator-TEG. In *Environment and Electrical Engineering (EEEIC), 2015 IEEE 15th International Conference on* (pp. 2104-2108). IEEE.

[2] Champier, D., 2017. Thermoelectric generators: A review of applications. *Energy Conversion and Management*, *140*, pp.167-181.

[3] Peter, A.J.D., Balaji, D. and Gowrishankar, D., 2013. Waste heat energy harvesting using thermo electric generator. *IOSR Journal of Engineering (IOSRJEN) Vol*, *3*, pp.01-04.

[4] Haidar, J.G. and Ghojel, J.I., 2001. Waste heat recovery from the exhaust of low-power diesel engine using thermoelectric generators. In *Thermoelectrics, 2001. Proceedings ICT 2001. XX International Conference on* (pp. 413-418). IEEE.

[5] Fleurial, J.P., 2009. Thermoelectric power generation materials: Technology and application opportunities. *Jom*, *61*(4), pp.79-85.