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Prediction of Excess Air Requirement Using ANN for the Improvement of Boiler Efficiency

Arun. S. Gopinath[#1], N. Sreenivasa Babu[*2]

Engineering Department, Shinas College of Technology
Sultanate of Oman

arun@shct.edu.om
babu@shct.edu.om

***Abstract*—An improvement in the efficiency on converting fuel energy to useful thermal energy could result in significant fuel saving for industrial Sector. In this paper artificial intelligence concept using Artificial Neural Network (ANN) is used to predict the optimized excess air requirement using real time and calculated data. This work determines the excess air requirement for complete combustion corresponding to theoretical CO_2 in flue gases and real-time values obtained from remote measurements of CO_2 (actual) in flue gases.**

***Keywords*— ANN, Flue gas Analysis, Excess Air Control, Boiler Efficiency, Losses**

I. Introduction

The operating efficiency of industrial boilers is one of the critical concerns in National Energy Consumption.The improvement in boiler efficiency will increase the steam input to the turbine and hence the alternator output power as well. Improvement in boiler efficiency can be done by optimizing the combustion with excess air control. Moreover Optimized combustion directly minimizes the emission of hazardous pollutants into the atmosphere like CO, Oxides of Sulphur and Nitrogen etc. which will minimize air pollution.

II. Fuels, Combustion & Formulation

Coal is one among the prominent fuel using in the power generation industry. For the Complete combustion of Coal as fuel, air is required. Normally Oxygen (O_2) is required for the combustion. It is obtained from the air which is supplied to the furnace. The amount of air required to supply sufficient Oxygen for the complete combustion of fuel is the Theoretical air. Excess Air is the amount of air required in addition to the stoichiometric air to make sureof complete oxidation during burning of fuel.

Among the types of fuels ,Natural gas requires less and coal requires the maximum amount of excess air for the complete combustion[1].A typical 210 MW natural circulation , dry Bottom , tangentially fired , balanced draft and radiant Reheat type with direct fired pulverized coal system boiler is considered for this analysis. Data from the Proximate and Ultimate analysis of Coal used in the boiler is as shown in Table1&2. In situ Measurements from 210MW Boiler is shown in Table 3 & 4.

TABLE I
SAMPLE OF PROXIMITY ANALYSIS RESULT OF COAL

	Content	Percentage
1	Ash	38
2	Volatile Matter	20
3	Moisture	7.1
4	Fixed Carbon	34.6
GCV of Coal : 4210 K Cal/kg		

TABLE-2
SAMPLE OF ULTIMATE ANALYSIS OF COAL FROM PROXIMITY ANALYSIS

Sl. No	Content	Percentage
1	Carbon	45.957
2	Hydrogen	2.835
3	Nitrogen	0.935
4	Sulphur	0.3
5	Oxygen	4.873

TABLE-3
PERFORMANCE DATA FROM 210MW BOILER

Sl. No	Parameter	Unit	Test value

1	Load	MW	210
2	PA In Temp.to APH A	^0C	42
3	PA In Temp.to APH B	^0C	42
4	SEC. AIR TEMP.TO APH A	^0C	42
5	SEC. AIR TEMP.TO APH B	^0C	42
6	Flue Gas TEMP APH A INLET	^0C	147.7
7	Flue Gas TEMP APH B INLET	^0C	159.0
8	Flue Gas TEMP. APH A OUTLET	^0C	333
9	Flue Gas TEMP. APH B OUTLET	^0C	331
10	SEC.AIR TEMP. APH A OUTLET	^0C	262.5
11	SEC.AIR TEMP.APH B OUTLET	^0C	280
12	PA OUTLET TEMP.APH A	^0C	292
13	PA OUTLET TEMP.APH B	^0C	282
14	TOTAL SEC. AIR FLOW	T/Hr.	405
15	TOTAL PA FLOW	T/Hr.	340
16	TOTAL AIR FLOW	T/Hr.	705

TABLE IV
IN SITE MEASUREMENTS

Sl. No	Parameters	Quantity in %
1	O_2 INLET	3.585
2	O_2 OUTLET	5.115
3	CO_2 INLET	15.715
4	CO_2 OUTLET	14.185
5	CO OUTLET	0.005

An Indirect Method is followed in this analysis for evaluating boiler efficiency. In Indirect method the following losses are considered [2];

- Percentage heat loss due to dry flue gas, L1
- Percentage heat loss due to evaporation of water formed, L2
- Percentage heat loss due to moisture present in fuel,L3
- Percentage heat loss due to moisture present in air, L4
- Percentage heat loss due to Partial Conversion of C to CO , L5
- Percentage heat loss due to Radiation & Convection, L6
- Percentage heat loss due to Un burnt carbon in Fly ash, L7
- Percentage heat loss due to Unburnt carbon in Bottom Ash, L8

Boiler Efficiency =

[100 – (L1+ L2+ L3+ L4+ L5+ L6+ L7+ L8)]

III. ALGORITHM & RESULT ANALYSIS

The Excess air required for the complete combustion is calculated by comparing the actual CO_2measured from insitu and the theoretical CO_2 value derived from the theoretical air required for complete combustion [6].

The steps followed for the calculation is as follows:

Step 1: Fuel Parameters after Proximity Analysis and Ultimate Analysis should be given as input
Step 2: Boiler parameters & Ambient parameters from the In site measurements to be given as input
Step 3: Calculate the Theoretical Air required for the Combustion of Fuel
Step 4: Calculate the Theoretical CO_2 Required for the complete Combustion of fuel
Step 5: Actual CO_2 from the Flue gas is taken from in site measurements
Step 6: Excess Air required for the complete combustion was calculated by comparing the theoretical CO_2 and Actual CO_2
Step 7: After calculating the Excess Air Required for different combinations of theoretical CO_2 and Actual $CO_2$for different grades of coal, a neural network was trained to predict the values of excess air required.

A. ANN for Prediction of Excess Air Requirement

A feed forward neural network trained with back propagation is used for this prediction.

The steps followed for creating the Artificial Neural Network is as follows:

Step 1: Theoretical CO_2 from different grades of coal and their Measured Actual CO_2 where given as Input vectors.
Step 2: Corresponding Excess air Requirement calculated were assigned as the target values for their input vectors.
Step 3: The 2 layer feed forward Neural Network was created with 3 neurons in each hidden layer.
Step 4: TheNetwork was trained and created with the Data samples
Step 5: Weight values and the biasing is adjusted iteratively to improve the network performance function.
Step 6: Mean square error between the network outputs and the target outputs is the performance function
Step 7: Trained network can be applied to simulate output corresponding to any new set of input data

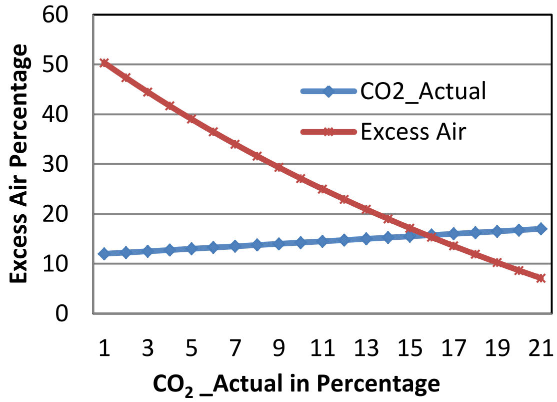

Fig. 1 Excess Air Requirement for Different CO2 actual measurements of coal using indirect method

Neural Network Training data is shown in Table 5. The CO_2 actual is taken from in site measurements for different grades of pulverized coal with different compositions. The training algorithm used in neural network is Levenberg -Marquardt algorithm which works better on function fitting problems with small networks [3]. CO_2theoretical is derived from the details of ultimate analysis of the coal [4-5]. The performance function for the feed forward network is its mean square error between the network output and targets.

The resulting graph with test data, validation data and training is shown in Fig 2.

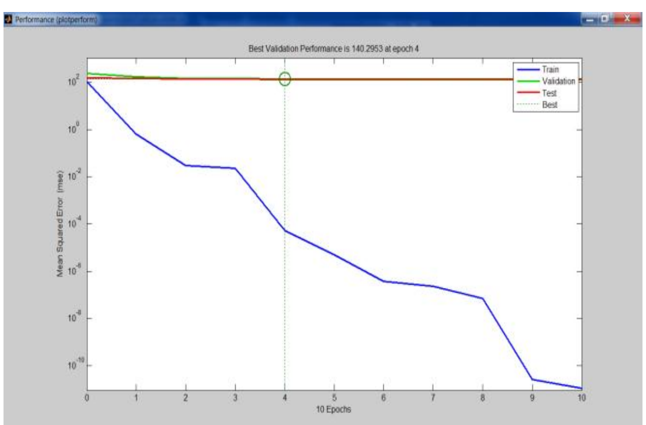

Fig 2 Training plot showing Mean Square Error (MSE) of the network

TABLE V
RESULTS OF INDIRECT METHOD USED FOR TRAINING NETWORK IN ANN

CO_2Theoretical %	CO_2 Actual %	Excess air % by Indirect method
22.32	15.6	43.81
21.5	15.83	36.04
20.67	14	47.44
18.25	15.76	15.27
15.5	10	51.42

TABLE VI
RESULTS OF SIMULATION FROM ANN

CO_2Theore-tical %	CO_2 Actual %	Excess Air % from ANN	Excess air % by Indirect method	Error %
20.5	15.2	39.68	34.69	14.38
21	14.8	44.55	41.89	6.3
22	13.6	71.53	62.55	14.3
22.5	15.8	42.2	43.23	2.5
23	16	42.38	44.88	5.5

IV. CONCLUSIONS

The Excess air requirement predicted by the ANN is in good understanding with the values using indirect method. As the CO_2 actual from the flue gas reduces, the excess air Requirement is increasing. The Errors can be minimized in this prediction if more training data's are added for training. This Prediction method can be incorporated with the control mechanism of primary and secondary induced/Forced draft fans to give excessair control in boilers which in turn will increase the combustion efficiency as well as the boiler efficiency.

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