Prediction of Reaction Performance Furnace in Clauss Based Sulphur Recovery Unit by Artificial Neural Network

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***Abstract*—In today's real world there are many problems that are dealing with predictions, uncertainty , and with the help of traditional methods it is difficult to analyze such type of problems therefore scientist have developed an artificial neural network architecture which is trained in a similar fashion as that of human brain. There are many advantages that allows one to develop ANN architecture for different types of problems such as prediction of concentration of different output constituents in oil refinery by different processes. In this paper prediction of reaction performance in clauss based sulphur recovery unit has been described. This paper describes about prediction of output parameter concentration i.e. H2S, So2, furnace temperature and total gas flow using neural network architecture. The conventional approach to computing is based on an explicit set of programmed instructions, and dates from the work of Babbage, Turing, Von Neumann.**

Keywords: SRU, Artificial Neural Network, Matlab, clauss process.

I. Introduction

Sulphur removal facilities are located at the majority of oil and gas processing facilities and Refineries throughout the world. The sulphur recovery unit does not make a profit for the operator but it is an essential processing step to allow the overall facility to operate as the discharge of sulphur compounds to the atmosphere is severely restricted by environmental regulations[1]. Oil and gas producers are attempting to maximize production at minimum cost.

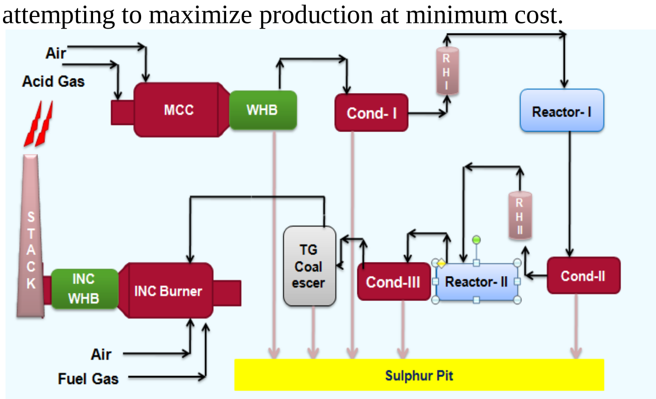

Fig.1 Clauss Process

A. *Process chemistry:*

Claus Section includes Main Combustion Chamber (also called as Reaction Furnace), reactors and heat recovery facilities. A feed i.e., combined stream of acid gas & sour gas is fed to the burner of Main Combustion Chamber [2]. The burner is designed to provide complete mixing of air and feed gas for oxidation of all hydrocarbons, residual sulphur compounds (like mercaptans, if any), ammonia and one third of the total hydrogen sulphide present in feed gas without use of any supplemental fuel gas. The use of a high intensity burner promotes the combustion of ammonia in the feed gas to nitrogen and water. The adiabatic flame temperature for such a case is kept above 1350oC to ensure complete destruction of ammonia. However, the burner design should keep the provision to increase the flame zone temp, if needed for the cases where the feed gas composition gets changed. In the reaction furnace, one third of the hydrogen sulfide in the acid stream is burnt to form sulfur dioxide (SO2) (equation 1). [3]The resulting sulfur dioxide then reacts with the balance of H2S (equation 2) to form elementary sulphur(S) and water in vapor phase. Ammonia (NH3), present in the sour water stripper acid gas , is destroyed during the combustion on process (equation 3).

$$H_2S + 3/2\ O_2 \longrightarrow SO_2 + H_2O + Heat \quad (1)$$

$$2H_2S + SO_2 \longrightarrow 2H_2O + 3/n\ S_n + Heat \quad (2)$$

$$2NH_3 + 3/2\ O_2 \longrightarrow 3H_2O + N_2 \quad (3)$$

The sulfur formed remains in vapor phase and goes in polymeric reaction, which forms polymeric sulfur in vapor phase. The predominate reactions are

$$3S_2 \longrightarrow S_6 + Heat \quad (4)$$

$$4S_2 \longrightarrow S_8 + Heat \quad (5)$$

Some of these combustion reactions also take place in the burner section of the reaction furnace [4]. The list of reactions taken place in the reaction furnace are given below:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2\ H_2O \quad (6)$$

$CO_2 + H_2S \longrightarrow COS + H_2O$ (7)
$COS + H_2S \longrightarrow CS_2 + H_2O$ (8)

$2H_2S \longrightarrow 2H_2 + S_2$ (9)

$COS + H_2O \longrightarrow H2S + CO_2$ (10)

Generally, the Claus reaction (equation 2) starts in the combustion chamber (mixing chamber) of the furnace. The hot gas is cooled in a Waste Heat Boiler (WHB) and subsequently, sulfur is removed as liquid sulphur from the sulfur condensers.

The major part of the heat generated in the furnace is recovered by producing MP steam (19 kg/cm2g) in the Waste Heat Boiler (WHB) [5]. The gas leaving the waste heat boiler is further cooled to 188.8oC in the first condenser to remove sulphur as liquid sulphur from the gaseous stream. The gas from the first condenser is reheated to 290 oC and fed to Claus converter. Additional conversion of H2S and SO2 to sulphur takes place in the Claus converter. The exit gas from the first converter is cooled to 161.4 oC in the second condenser. The gas from the second condenser is reheated to 200 oC and fed to the second Claus converter. The exit gas from the second converter is cooled to 131.7 oC in the third condenser [6]. The gas from the third condenser is sent to TGTU and the liquid sulphur from WHB and all the three condensers are sent to the liquid sulfur pit.

B. *Main Reaction :*

$H_2S + 1/2\ O_2 \longrightarrow SO_2 + H_2O + Heat$ (1)

$2H_2S + SO_2 \longrightarrow 3S + 2H_2O + Heat$ (2)

II. PARAMETER SELECTION

Depending on the working of reaction furnace, 6 selected input parameters and 4 output parameters [7].
The input and output parameter are as follows.

A. *Input parameters:-*

H2S(Kmol/hr):exists mainly as an undesirable by-product of gas processing. The air to the acid gas ratio is controlled such that in total 1/3 of all hydrogen sulfide (H2S) is converted to SO2
C2H6(Kmol/hr): Hydrocarbon is utilized in the thermal steps for making carbon disulfide
H2O(Kmol/hr): chemical processes taking place in the thermal step for the formation of hydrogen gas
Input flow(Kmol/hr): The flow of air is used to controlled to produce desired amount of SO2
Temp(˚C): Recommended temperature for the first catalytic stage is 315-330 C. The high temp in the first stage also helps in the hydrolyze COS & CS2 whereas the operating temperatures of the subsequent catalytic stages are typically 240 °C for the second stage and 200 °C for the third stage.
Air Temp.(˚C): The temperature of air is used to controlled to produce desired amount of SO2

B. *Output Parameters:-*

- **H2S(Kmol/hr):** Gives us the amount of input H2S remain unconverted into SO2.
- **SO2(Kmol/hr):** In the reaction furnace, one third of the hydrogen sulfide in the acid stream is burnt to form sulfur dioxide (SO2). This gives us a view about the conversion rate of H2S into SO2 [8].
- **Furnace temp(˚C):** Provide us with the value of temperature at which maximum of H2S gets converted into SO2.
- **Total Gas Flow(Kmol/hr):** It is the flow of generated SO2 in Kmol/hr

III. MODELLING OF ARTIFICIAL NEURAL NETWROKS

Artificial neural network (ANN) technology is employed for prediction of reaction performance of Claus furnace in clauss process for Oil Refinery. The implementation is done on several neural network models using back propagation algorithm based on collection of real-time data of the plant.
In this paper we have trained the data in different ways. The selection parameters for the artificial neural networks in as follows:-

A. *Training functions:-*

The data is tested with many training functions which are present in neural networks. The training functions which have been used in this paper are:-

- TRAINCGP
- TRAINBR
- TRAINSCG
- TRAINGDA

The above mentioned training function has been given satisfactory results, but the network has been trained with all training functions.

B. *Selection of hidden layer and neurons*

- Here neural network with 2 layers in it has been used. The first layer consists of hidden layer and second layer consist of output layer. The first layer consists of hidden layer, all the neural are presented in this layer only and having a transfer function of LOGSIG[11]. The second layer consists of output layer, and having a transfer function of TRANSIG.
- The number of neuron has been varied in each training event. The numbers of neurons that has been taken in 1st layer of neural network is:-
- Training with 3 neurons is hidden layer
- Training with 4 neurons is hidden layer
- Training with 5 neurons is hidden layer
- Training with 6neurons is hidden layer
- Each training function described above is trained with different number of neurons in hidden layer.

C. Prediction range:-

The neural network should predict the output parameter with a accuracy of above 95%. Prediction means that the network is fully trained by optimized value and it should give the predefined value. As per the furnace output the predicted value of the furnace should lies between the following range:-

PARAMETER	OUTPUT RANGE
H2S	3.05-3.24(Kmol/hr)
SO2	1.51-1.64(Kmol/hr)
Furnace Temerature	1213-1319(˚C)
Total gas flow	53.09-70.59(Kmol/hr)

Table 1:-Ouput parameter range values

IV. RESULTS

The neural network has been trained different number of neurons and with different training function. The predicted output using different number of neurons and having transfer function of TRAINGDA.

Table2:-The table above shows that neural network with 6 neurons in the hidden layer yields better output for the parameters.

Thus the regression graph for the network with 6 neurons and having training function of TRAINGDA is given below that yielded better performance:-

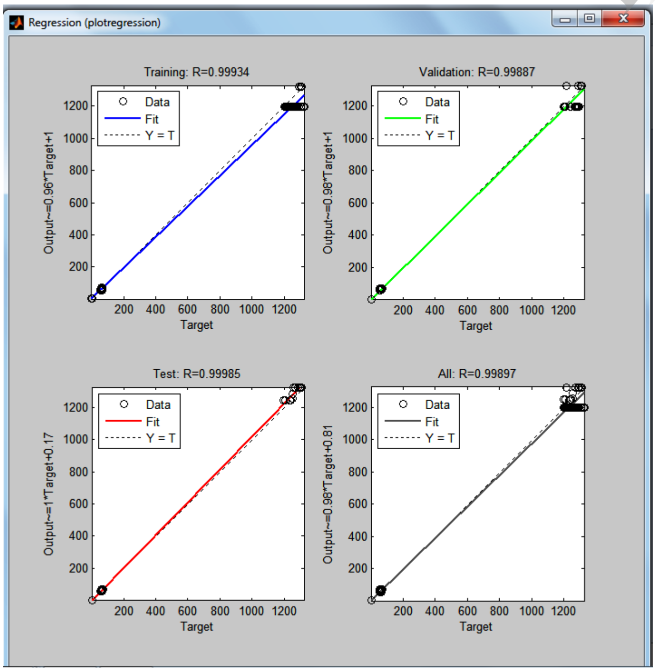

Figure 2:- Regression Graph of 6 neurons with TRAINGDA function

The regression graph and output parameter table shows that network with 6 neurons has given more accuracy. And also the comparison result of network with different training function is also given below:-

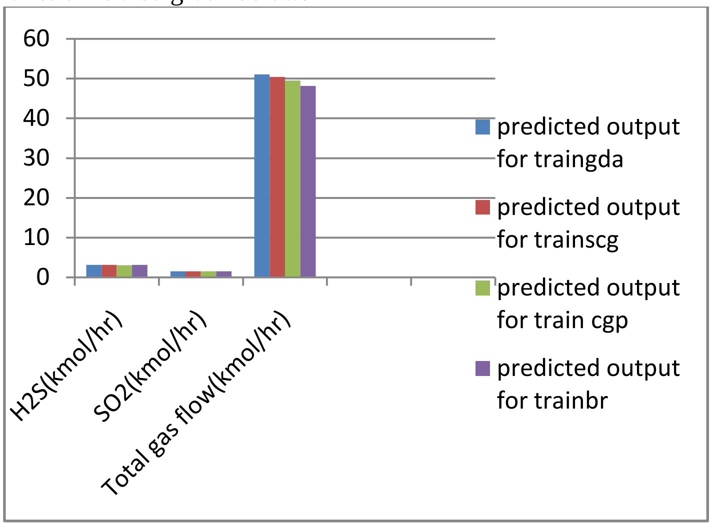

Figure 3:-comparison graph for 3 output parameters

Here first three parameters were compared with different training function. The parameters compared were H2S,SO2, total gas flow.

Looking at the graph it can be see that four different training functions has been used, and out of that predicted

Numbers Of neurons	Output Parameters			
	H2S (Kmol/hr)	SO2 (Kmol/hr)	Furnace Temp.(°C)	Total Gas Flow (Kmol/ hr
3	3.0306	1.496	1212.235	51.023
4	2.95	1.501	1206.321	50.23
5	3.0001	1.510	1232.93	52.03
6	3.1359	1.5652	1238.86	57.0365

output for TRAINGDA is much more promising than other three training functions. The other training function produces much error in different parameters. As per the predicted output TRAINGDA has used 6 neurons in hidden layer and gives output of less error i.e. Error of less the 5%,

Now above given graph consist of three parameters only, the last and most important parameter is furnace temperature, maximum error occurs in this parameter only because temperature fluctuates with different concentration of components. The comparison graph for different training algorithm is shown below:-

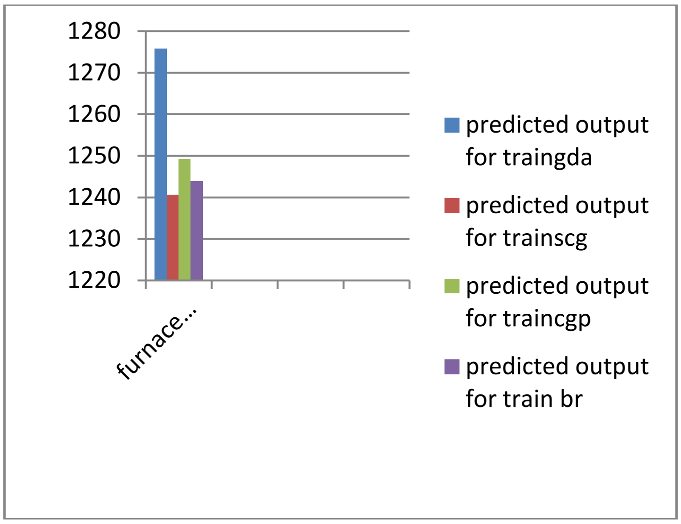

Figure 4:- comparison graph for output parameter i.e. furnace temperature

As shown above the bar for TRAINGDA is much more higher than other three training function, which shows that TRAINGDA gives much more precise output for the temperature of the furnace. It is now shown that TRAINGDA with 6 neurons in a hidden layer gives predictable and precise output for the Claus process.

V. CONCLUSION

The trained neural network for the reaction furnace of the Claus process can be very helpful in refinery, as furnace is one the important equipment of the unit and testing the furnace is not possible. By using the neural network one can give the input parameter to the trained network and it will give desired output for the input and the output can be used for improvement of the plant operation [9]. Through there is no neural network is present in refinery for prediction furnace behaviors of the Claus unit thus use of this tool will be a great help of the operator. Future prospective for the network is that, the network is only for Claus furnace for which network has been simulated, later it can be implemented in different process of the refinery i.e. extraction etc [10]. and with the help of neural network it is possible to predict the non-linear behavior of the process units. Also the proposed neural network architectures can accurately predict various properties associated with crude oil production.

VI. REFERENCES

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