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Design of ANN for prediction of operating performance Gas Sweetening Process used in Natural Gas Purification

Roohi Sille[1], Gaurav Kumar Rajput[2], Shailendra Sharma[3]
[1](*Deptt of CIT, University of Petroleum and Energy Studies, Dehradun)*
[2](*Deptt of CIT, University of Petroleum and Energy Studies, Dehradun)*
[3](*Deptt of CIT, University of Petroleum and Energy Studies, Dehradun)*

Abstract: *Gas sweetening unit is an essential industrial processthat exhibits significant non-linear behavior. It comprises of absorption and regeneration towers.Conventional linear control schemes based on rigorous mathematical models, implemented in sweetening units, show poor performance and lead to off-specification products. A feed forward back-propagationneural networkmodelwith an efficiency of 95% has been developed for the Gas Sweetening Process used in Natural gas purification process, as per the data extracted from the GSU specifics.*
Keywords: *Artificial Neural Network, Gas Sweetening Unit, Natural Gas, Feed-forward neural network.*

I. INTRODUCTION

Sour gas sweetening is often achieved by absorption of acid gases in aqueous solution of amines [1].Gas sweetening unit is the fundamental process in natural gas purification. In gas sweetening units, acid gases (H_2S and CO_2) are chemically absorbed from a gas using aqueous alkanolamine solutions, to product a sweet gas. Alkanolamines (such as DEA or MDEA) are usually used for efficient separation of carbon dioxide from various industrial gases[2]. The solvent is regenerated in a desorption column and the purified solvent is recycled to the absorption column. Gas sweetening units can be controlled if all of operation data for example sweet gas, lean amine and rich amine flow rates, concentration and temperatures existed.Due to increasing need of Natural gas in the energy supply of the world, its production has also to be increased.

Crude (sour) natural gas contains, in addition to CH_4 and higher hydrocarbons, various amounts of H_2S, CO_2 and N_2, as well as small amounts of gases such as He, O_2, Ar, H_2 and H_2O vapor. The high concentration of $H_2S$and CO_2 is harmful, so it is needed to remove it from natural gas. The process of removing H_2S and CO_2 from natural gas is known as gas sweetening process. This process occurs in the Gas Sweetening Unit of refineries.

A theoretical model was presented for describing the absorption of carbon dioxide from nitrogen using MEA and MDEA solutions in a packed column under various operating conditions [3]. A model has also been presented to investigate the effect of various operational parameters on the performance of a regeneration packed column [4]. A non-equilibrium heat and mass transfer model to describe the chemical absorption of ammonia, carbon dioxide and hydrogen sulfide in an aqueous solution containing sodium hydroxide, MEA and MDEA [5]. A back-propagation neural network was employed to investigate the fault diagnosis in an ammonia-water packed distillation column. The network was reported to perform satisfactorily on detection of the designated faults. The simulation results indicates that “bottoms temperature, overhead composition and overhead temperature are not much affected by the disturbance in feed rate, feed composition and vapor rate in given range” [6].

Conventional linear control schemes based on rigorous mathematical models, implemented in sweetening units, show poor performance and lead to off-specification products. To overcome the limitations of the previous control schemes, artificial neural network model are used. An artificial neural network provides higher level of accuracy and performance rather than other statistical models.

In this paper, we developed afeed forward back propagation neural network model for the prediction of operating performance of gas sweetening process used in natural gas purification. The model is trained with training function TrainCGD (Conjugate Gradient Descent Training function). The performance of the neural network model is measured by Mean Squared Error. The developed model gives 95% efficiency.

II.PROCESS DESCRIPTION

Gas sweetening unit in refineries is used for the purpose of natural gas purification.The feed gas (sour gas) containsH2S and/or CO2is entered in the Gas Sweetening Unit of the plant through an Inlet Separator(or feed gas knock-out drum) to remove free liquids and/or entrained solids.The gas from this separator enters the bottom of the Absorber and flows upward through the column in intimate counter-current contact with the aqueous amine solution (lean solution). In the GSU column, the chemical reaction between the amine and the acid gas occurs and the amine solution absorbs the acid gas. The chemical reaction (due to the heat of reaction between the amine and the acid gas) is exothermic. It will raise the temperature of the gas. Treated gas (lean gas or sweet gas) leaves the top of the column and the amine solution loaded with acid gas (rich solution) leaves the bottom of the column.

The absorber column operates at the feed gas pressure. A minimum pressure of 4.5b.a is required to make the process feasible and operable. There is no limitation on high pressure as far as the process is concerned. The only limitation relates to the thickness of the steel plates to form the body of the column (anticipated construction problems for thickness above 150 mm). Feed gas temperature must be positive (high freezing point of the amine solutions). However, high temperatures will affect the performance of the unit. An inlet cooler (using air or water) or a gas/gas exchangerwill be provided. This equipment will be installed upstream of the inlet separator. The top of the absorber can be equipped with additional trays (2 to 4) to accommodate a water wash section. The injected water will remove the amine carried over with the treated gas. It is injected at the top tray and completely withdrawn at last tray of the water wash section. The treated gas is then handled by a separator to collect entrained liquid before being routed to the downstream facilities.

The rich solution from the Absorber is then let down and generally routed to the Amine Flash Drum. This drum (which operating pressure is between 7 and 15b.a) allows removing a portion of acid gas which evolves from the solution by the pressure let-down effect. The acid gas stream from the Amine Flash Drum is routed either to the fuel gas pool of the facilities or to the acid gas disposal system.

The rich solution from the Amine Flash Drum then passes through an Amine/Amine Heat Exchanger. This heat exchanger serves as a heat conservation device and lowers the total heat requirements for the process. The rich solution is heated by the regenerated solution (lean solution) coming from the regenerator.

Then the rich solution is let down to the operating pressure of the Regenerator (generally between 1.2 and 2 b.a) also called stripper is a fractionation column (with trays or packing) with a condenser (using water or air as cooling medium) and a reboiler.

Regeneration Section

The stream of the rich amine solution is recovered under level control valve from the bottom of the absorber and piped to the rich amine flash drum. The flashed sour gas from flash drum is brought into contact with a small lean MDEA flow in an absorption tower placed on the top of the rich amine flash drum in order to meet the fuel gas specifications.The rich amine solution flows from the flash drum to the rich/lean amine exchanger. The rich amine flash drum level control valve is located downstream of exchanger in order to minimize the solution degassing by the exchanger plates. MDEA solution stripping is accomplished in the regenerator by the vapor generated from the reboiler. The lean amine collected at the bottom of the regenerator is pumped &routed through rich/lean amine exchanger to air cooler followed by water cooler before sending it to lean amine storage tank. MDEA is very sensitive to oxygen whose contact produces acidic elements. In order to avoid direct contact with air, the storage tank is equipped with a gas blanket. Inert gas is normally used as a blanketing gas.From the storage tank lean amine is pumped back to the absorbers by the main lean amine charge pump. The discharged amine stream is split into two parts through flow rate control valves: a main stream flow to the high pressure absorber and a smaller one to the fuel gas absorber. The hot acid gas mixture from the overhead of the regenerator is cooled in an air cooler followed by a water condenser where water vapor condenses. This condensed vapour is separated in the reflux drum and pumped back to the top section of the regenerator as reflux liquid. Acid gas is sent to Sulphur Recovery Unit (SRU) through an acid gas header under pressure control provided on top of the reflux drum.

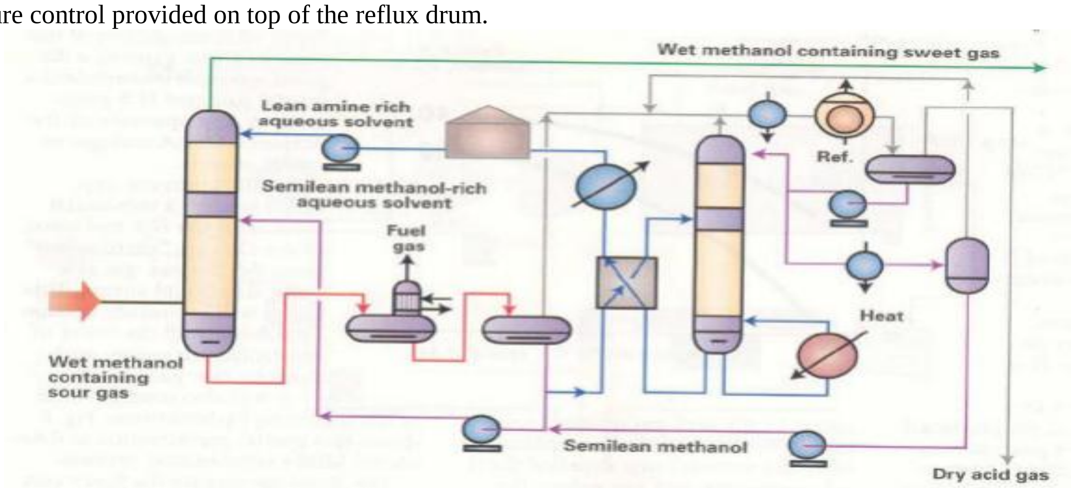

Fig:- GSU block diagram

DATASET USED:The data generated by ASPEN_11.1 simulator for 180 datasets. The inlet and outlet parameters used are as follows:-
INLETS :- Temperature(‘C),Pressure(kg/cm2g), percentage of Methyl Di-Ethanol Amine in Lean Amine (MDEA), Loading (percentage of equilibrium acid gas) , Concentration of Hydrogen Sulphide (in %) , Concentration of Carbon Dioxide (in %) .
OUTLETS: - Hydrogen Sulphide (<100 PPM), Carbon Dioxide (5 – 6 %).

III.PROCESS CHEMISTRY

For a good understanding of a process, a brief recall of reaction mechanism of carbon dioxide and Hydrogen Sulfide with ethanolamine is necessary.
First the case of a primary or secondary amine (monoethanolamineor diethanolamine) whose reactions with the acid components H_2S , CO_2 are similar, is investigated.
H_2S reacts to give amine hydrosulfide:
$H_2S + R_2NH \leftrightarrow HS^-, R_2NH_2^+$ (1)
CO_2 can react directly with amine to form an amine carbonate:
$CO_2 + 2R_2NH \leftrightarrow R_2NCOO^-, R_2NH_2^+$ (2)
But CO_2can also react with water or hydroxyl ions to form carbonic acid or bicarbonate ions :
$CO_2 + H_2O \leftrightarrow H_2CO_3$ (3)
$CO_2 + HO^- \leftrightarrow H_2CO_3^-$ (4)

These acids then react with the amine to form amine bicarbonate (HCO_3^- , RNH_2^+) and amine carbonate (CO_2^{--} ,$(R_2NH_2^+)_2$).
As regards kinetics, 3 types of reactions can be distinguished:

- Reaction (1) whose rate is infinite ,
- Reaction (2) whose rate is moderate, depending on amine.
- Reaction(3) known to be slow.
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It is known that using MEA or DEA, the absorption rate of CO_2 in the absorber may be lower than the absorption rate of H_2S, however CO_2 removing is regarded as complete.
The case of tertiary amine is different. As a matter of fact, the molecular structure of the tertiary amine prevents the direct reaction of CO_2 with carbonate formation (reaction 2).

III.RESULTS & DISCUSSION

The feed forward back propagation neural network was trained on different training functions like trainlm and traincgd. Some adaptation characteristics were applied on the neural network such as keeping the temperature fixed and changing the pressure or keeping the pressure fixedand hanging the temperature.
Based on the “ ADAPTATION CHARACTERISTICS “ and “ ERROR HISTOGRAM “ of the modeled Artificial Neural Network for GSU , the Adaptation characteristics (Level 1 to 4) shows no variations i.e. after training of the neural network with the generated 180 datasets (Aspen 11.1) when adaptation is applied the neural network doesn’t show any significance change in the training details as well as there is no modification in the error-values , hence the network is trained and optimized till the upper-limits of training criterion. The neural network trained with traincgd (conjugate gradient descent)gives the accuracy of 95%.
Hence, the Feed Forward Back-propagation Neural Network is developed, satisfying the optimal efficiency criterion of Gas Sweetening Unit, keeping in mind the volumes of inlets (input parameters) and outlets (output parameter) in the neural network. The developed neural network gives the 95% accuracy.

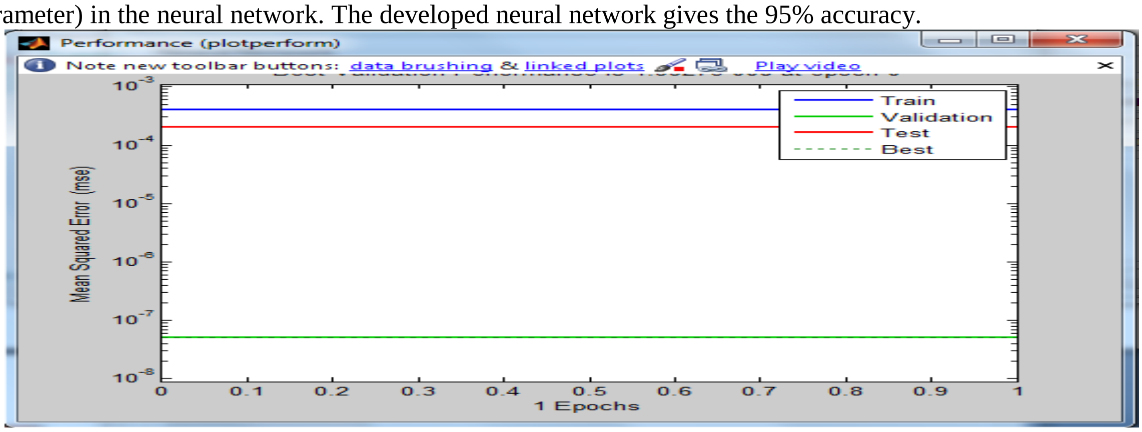

Fig:- Performance plot of trained ANN model

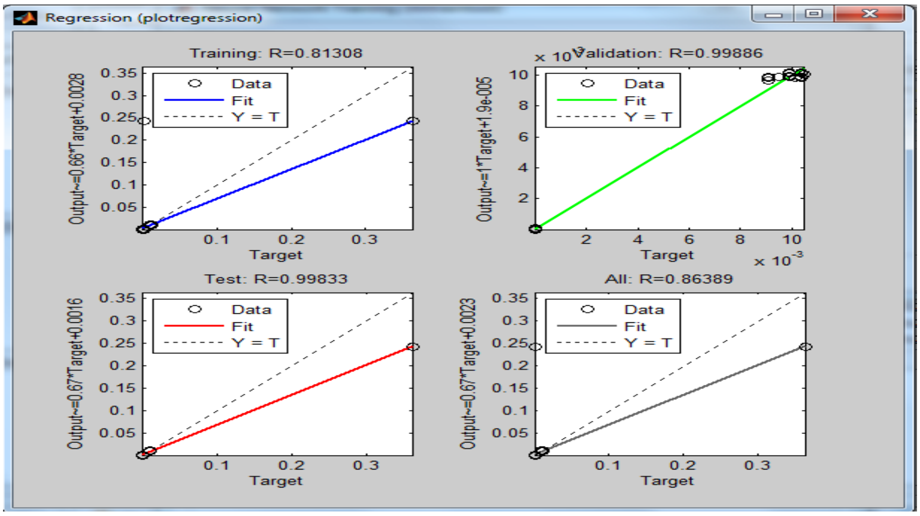

Fig:- Regression Plot of trained ANN model

IV.CONCLUSION

The computing world has lot to gain from neural networks. Their ability to learn and adapt makes them very flexible and powerful. Furthermore there is no need to devise an algorithm in order to perform a specific task; i.e. there is no need to understand the internal mechanisms of that task. They are also very well suited for real time systems because of their fast response and time of computation.The artificial neural networks are more adaptive to the non-linear and non-stationary data. These are also fault-tolerant. Research is going on the side to make the artificial neural networks more adaptive towards the world.

As far as the GSU unit is concerned , the neural network model developed shows the +95% success rate i.e. efficiency and -5 % value variations , which is optimal state of the network as per the simulated data used as INLETS , and the specifics of GSU .

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