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Controlling and modeling phases of distillation column using artificial neural networks

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ABSTRACT

In this paper is described the choice of the control system design for a binary distillation column. The column has been formed dynamically. Using artificial neural networks (ANN) in system control design, the effects of disturbance on the column has been rejected to modeling ANN. These networks are used to model complex and non-linear processes and have the potential to solve some types of complex problems, where traditional methods won't answer properly. Using dynamic simulation, the proper educational, testing and validation data for designing neural network is yielded. Modeling the system is done by multi layer perceptrons Levenberg-Marquardt algorithm. Finally, according to the error result values, acceptable errors for neural network are presented.

KEYWORDS

Artificial neural network;
Distillation;
Control;
Simulation;
Design.

INTRODUCTION

During the past two decades, due to simplicity of application and high efficiency in various areas including process control, troubleshooting, analyzing processes and also modeling the behavior of non-linear processes, Artificial neural networks have been used by researchers.

Venkatasubramanian et. al, investigated the applications of artificial neural networks in chemical engineering. They also worked on ANN's capability which could play an important role in Chemical Engineering calculations[1]. Montague et al used dynamics of neural networks to control the behavior of distillation towers. In this context they used these networks in modeling nonlinear processes based on control model[2]. Nazario D.Ramirez and et investigated study and application of neural networks to chemical engineering process control. They used ANN an control the pH of the erythromycin acetate salt. Experiments were mainly conducted to determine the time delay of chemical reaction[3].

Today, using artificial neural networks (ANN) has vast applications in chemical engineering and oil and gas industries. Neural networks have the ability to generalize and they are strong against disturbance. There have been so important reasons in using ANN such as being complex structure, highly nonlinear and flexible and also because the structure does not have to be pre specified[4]. These kinds of abilities make ANNs proper for solving problems in the petroleum industry[5]. No need of chemical reactions and process details as well as its practical simplicity, precise ability, and access to the input and output data, in this method, the behavior of system shall be obtained more properly. One of the applications of neural networks is to control and process modeling based on the experimental data obtained from the system. The explosive progress of the computer science and their applications in calculating has resulted in advanced control methods' software. This method needs a very detailed model of process and due to lack of a more accurate model and also applying to the approximations, considerably large errors occur in the system. In this paper, firstly the binary distillation control system design, on neural network will be discussed; the simulation of the system for producing of data is explained. The structure of control system is the next. Methodology of ANN comes after data acquisition, and eventually the results and discussion will be presented.

METHOD

In this paper a process of controlling and modeling has been studied, two-component Distillation column water-isobutanol that includes one outlet product from top and one output product from bottom. The simulated column has 10 stages, the feed steam is fed above stage 6. Properties feed and output flow were given in TABLE 1.

TABLE 1 : Properties feed and output flow

	Feed	Top Product	Bottom Product
Flow (kg mol/hr)	45.35	19.14	26.21
Concentration (Isobutene)	0.70	0.29	0.997

Control system designs with the simultaneous use of Aspen Dynamic and Simulink software according to the communication capabilities of two software have been done. In figure 1 is shown the Schematics of control system design of distillation column. In this work, concurrent with the aid of two Apsen plus and Simulink

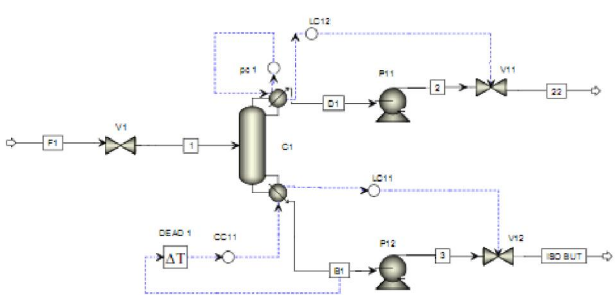

Figure 1 : Schematics of control system design

software, the binary distillation control system design has been discussed product.

In the control system design, a PI controller has been used to design controlling system due to the its simplicity and the ability to reject the effects of disturbances. And select a suitable product that can be controlled up and down products of the column with the amount of boiling hot liquid back and binding. In Figure 2 a Schematics of controls design of distillation column in Simulink environment is shown.

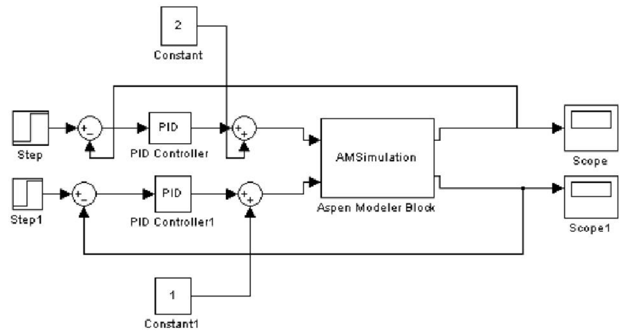

Figure 2 : Schematics of controls design of distillation column

MODELLING USING ARTIFICIAL NEURAL NETWORKS (ANNs)

Artificial neural networks (ANNs) are one of the general branches of artificial intelligence[6].

They have very un complication neuron-like processing elements connected to each other by weighting. The weights on each connection can be dynamically adjusted until the desired output is generated for a given input. An artificial neuron model consists of a linear combination followed by an activation function. Different types of activation functions can be employed for the network; in any event the common ones, which are adequate for most applications, are the sigmoidal and hyperbolic tangent functions[7].

Multiple layers arrangement of a typical intercon-

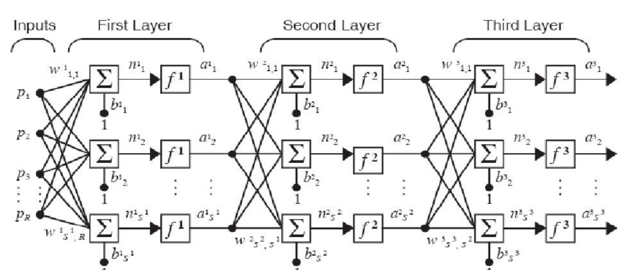

Figure 3 : General structure of an MLPNN.

nected neural network is shown in Figure 3. It includes an input layer, an output layer, and one hidden layer with different roles[8].

To model the system of Multi-Layer Neural Networks (MLPNN), the perceptrons Levenberg-Marquardt's algorithm is used. Artificial neural networks are trained by adjusting these input weights (connection weights), so that the calculated outputs may be approximated by the desired values. The output from a given neuron is calculated by applying a transfer function to a weighted summation of its input to give an output, which can serve as input to other neurons, as follows[9]. Equations related to different layers of the network output is as follows:

$$a^1 = f^1(W^1 p + b^1) \quad (1)$$

$$a^2 = f^2(W^2 a^1 + b^2) \quad (2)$$

$$a^3 = f^3(W^3 a^2 + b^3) \quad (3)$$

$$a^3 = f^3(W^3 f^2(W^2 f^1(W^1 p + b^1) + b^2) + b^3) \quad (4)$$

Each layer has its own weight matrix w, its own bias vector b, a net input vector n and an output vector a[10]. For more details of various activation functions see.

The training process needs a proper set of data i.e. input (e_i) and target output (t_i). During training the weights and biases of the network are iteratively arranged to minimize the network performance function[11].

The unique performance function that is used for training feed forward neural networks is the network Mean Squares Errors (MSE) Eq. 5.

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(e_i)^2 = \frac{1}{N}\sum_{i=1}^{N}(t_i - a_i)^2 \quad (5)$$

The process details flowchart to find the optimal model is shown in Figure 4[8].

This network consists of two input parameters and two output parameters and according to the number of neurons in the hidden layer which has been calculated using the experimental error for different network is obtained. In figure 5 numbers of neurons obtain with minimum error. So network with arrangement: 2:4:2, that there are four hidden layer of neurons. Hidden layer of the functional derivative sigmoid function is achieved and therefore the appropriate solutions are simple to use. Also in the output layer of linear function, to increase neurotic cell were used. Measures to improve the learning process, learning the target system model does. Learning law is that process the weight matrices and bias vectors of neural network can be set by that. Neural network during training, after iteration, the algorithm learning environment, working conditions and purpose are notified. The type of learning is determined by a process under which the network parameters are set to be. After the network arrangement using data obtained from the simulation process 60% Dynamic data is considered as training data and 20% as data Accredited and 20% as the experimental data.

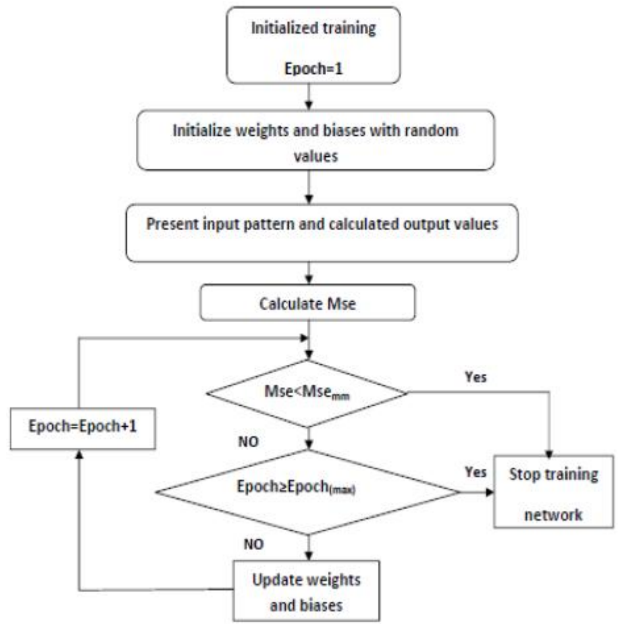

Figure 4 : A training process flowchart

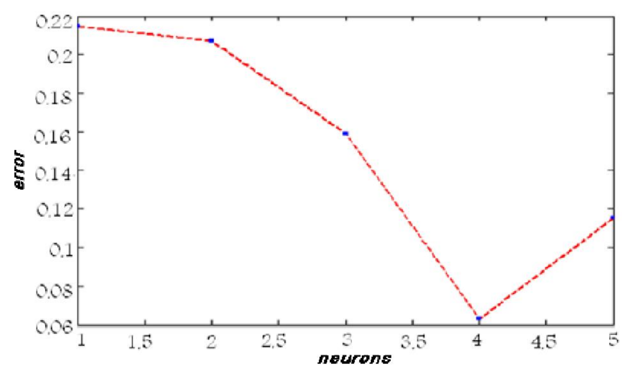

Figure 5 : Number of neuron

RESULTS AND DISCUSSION

Distillation simulations with possible maximum separation have been executed. Distillation simulation with a maximum separation may have been done. Control Design in Simulink environment and applying a stimulus to the system with a controller input has been good.

Due to careful control design the effects of disturbances on the system can be removed and the systems will the desirable state. Figure 6 and 7 the graphs of concentration versus time in the desirable state were shown.

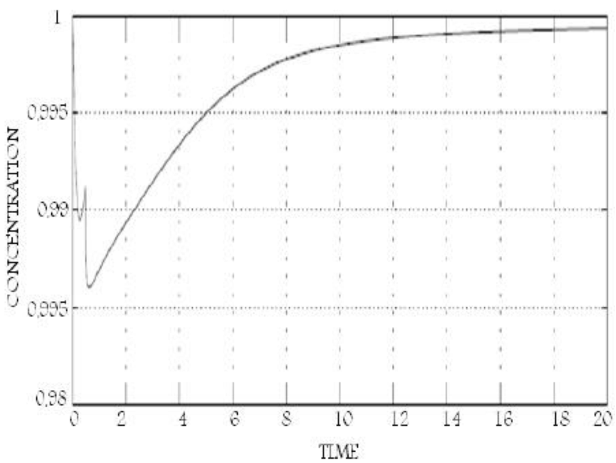

Figure 6 : Response system on controller (Bottom product)

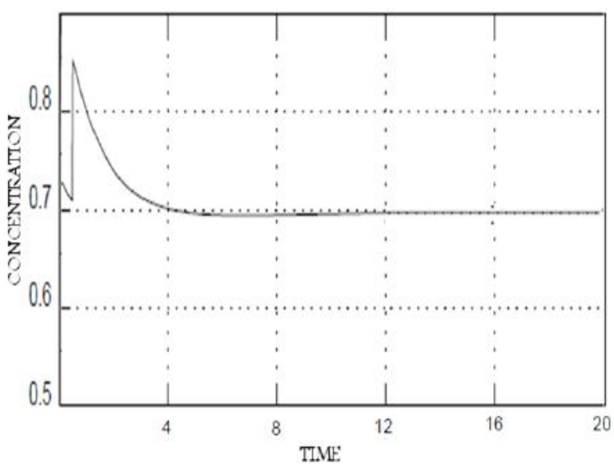

Figure 7 : Response system on controller (Top product)

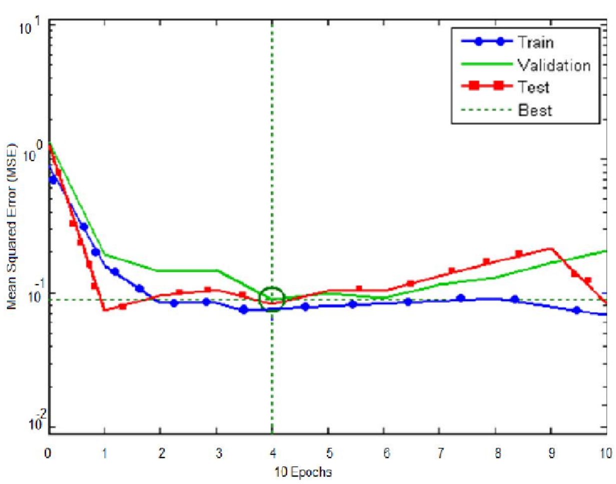

Figure 8 : Approximate errors for isobutanol-water system

Very good model was proposed with minimum possible errors using artificial neural network has been the error graph. Accredited training and testing and using the software content are shown in Figure 8.

Obtained error for train 6.69%, validation 8.55% and tested error 8.84%. To compare values and modeling by neural network for upper and bottom concentration of the column Figures 9 and 10 were drawn.

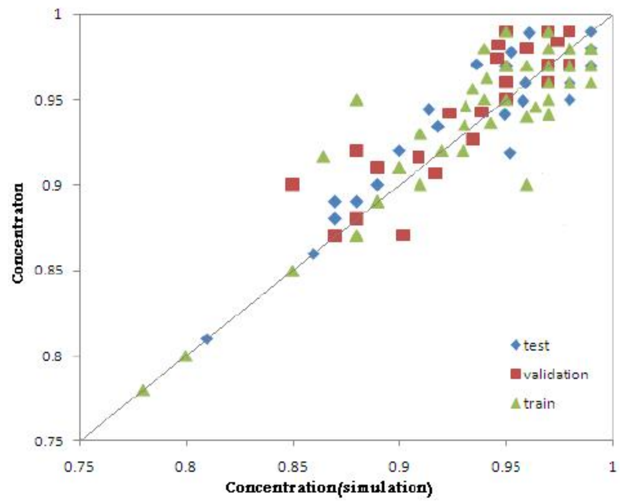

Figure 9 : Comparison of values train, validation and test with modeling for bottom concentration

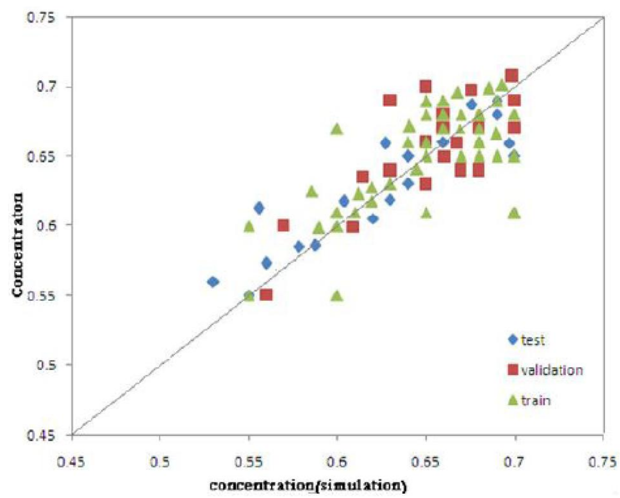

Figure 10 : Comparison of values train, validation and test with modeling for upper concentration

CONCULUSION

In such control design, the parameters can be changed during the operation and simultaneous mutual influence can be witnessed; also by suitable design the riots can be rejected and the base state can be achieved too. Next, using the simulation results, a model of artificial neural networks can be provided with minimal possible range of errors. For this to be resulted, by choosing a suitable network, system conditions, and also the optimal number of neurons, acceptable values error for neural networks that include training errors, validation and testing are determined.

NOMENCLATURE

w : Weight matrix
b : Bias vector
n : Net input vector
a : Output vector
e_i : Input
t_i : Target output

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