ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

An ISO 3297: 2007 Certified Organization *Volume 5, Special Issue 1, March 2016*

National Conference on Recent Trends in Electronics and Instrumentation Engineering (NCRTE 2K16)

1st& 2nd March 2016

Organized by

Department of Electronics &Instrumentation Engineering, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India

Model Based Fault Detection in Plate Heat Exchanger Using Ann

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ABSTRACT: Heat exchanger is a device used to transfer heat between one or more fluids. Fault detection is important problem in the heat exchange process. In order to achieve fault detection mathematical modelling with set of inputs and output must be designed for the process and then residuals need to be determined. Residuals indicates the difference between one step predicted output from model and measured output from validation set. In this paper Sensor faults are detected using Artificial Neural Network (ANN) is proposed and it is trained by Levenberg –Marquardt algorithm.

KEYWORDS: Heat Exchanger, ANN, Levenberg-Marquardt algorithm.

I.INTRODUCTION

Mathematical modelling must be designed for the process to represent the system dynamics in mathematical formulations [1]. Existing methods are grouped into three categories namely qualitative, quantitative and data driven methods [3]. Data driven methods using ANN is proposed in this work [7].The difference between one step predicted output and measured output are called residuals. [4].

A Plate Heat Exchanger (PHE) is a type of heat exchanger that uses metal plates to transfer heat between two fluids. A PHE is a compact heat exchanger where thin plates (0.5mm thick) are stacked in contact with each other and two fluids are made to flow separately along adjacent channels. The plates are made up of stainless steel, copper and titanium. The application of plate heat exchanger is liquid to liquid heat transfer, special plates are designed for phase change applications. When compared to shell and tube heat exchangers, stacked-plate arrangement typically has lower volume and cost. Another difference between the two is that plate heat exchangers typically serve low to medium pressure fluids, compared to medium and high pressures of shell and tube. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical.

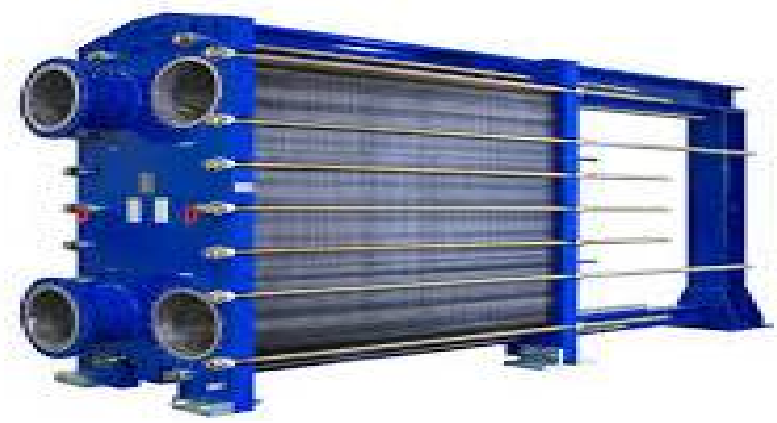

Fig 1 Plate Heat Exchanger

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II.GENERAL STRUCTURE

Faults present in a system may lead to failure of Heat exchanger. To detect faults residuals need to be generated. Residual generator generates residual. If there is no fault residual is zero and in the other case if any fault is present in the system residual is different from zero. The controller which suits this situation is ANN and the network is trained with Levenberg –Marquardt algorithm.

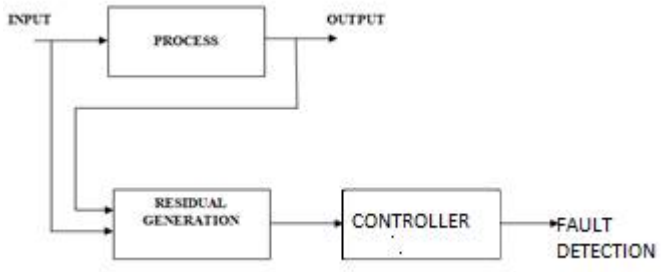

Fig 2 General structure

III.MATHEMATICAL MODELLING

The mathematical model is one which promotes the system dynamics and the mathematical formulations. It requires the calculation of certain parameters according to the type of system employed and the derived knowledge from the nature of the plant. Prior information about the basic outline of the system is necessary for the modelling purpose.

$$T_{co}(t) = \frac{W_c}{\rho_c V_c (T_{ci}(t) - T_{co}(t))} + \frac{U_c A_c}{\rho_c V_c C_{pc} (T_{ho}(t) - T_{co}(t))} \quad (1)$$

$$T_{ho}(t) = \frac{W_h}{\rho_h V_h (T_{hi}(t) - T_{ho}(t))} + \frac{U_h A_h}{\rho_h V_h C_{ph} (T_{co}(t) - T_{ho}(t))} \quad (2)$$

Where, T_{ci}, T_{co}, T_{hi} and T_{ho} are inlet and outlet cold and hot fluid temperature respectively (ºC), W_c and W_h are mass flow rate of cold and hot fluid respectively (kg/sec), C_{pc} and C_{ph} are the heat capacity of cold and hot fluid respectively (J/kg.ºC), V_c and V_h are volume of cold and hot fluid respectively (cm^3), A_c and A_h are heat transfer surface area of cold and hot fluid respectively (cm^2), U_c and U_h are the heat transfer coefficient of cold and hot fluid respectively (W/cm^2 ºC). ρ_c and ρ_h are the density of cold and hot fluid respectively (kg/ cm^3).

IV.FAULT DETECTION

Fault can be defined as the change that occurs in the output response of the system. So fault detection can be defined as the detection or finding faults which occurred in the system. There are three types of model based approaches. They are quantitative method, qualitative method and data driven method. In this work data driven method using ANN is employed. The input and target values are given to ANN and the network is trained. Residual is the difference between the measured and estimated process output. Residual is generated for the detection of faults. If there is no fault present then the residual will be equal to zero and different from zero when a fault is present. It indicates the state of the system.

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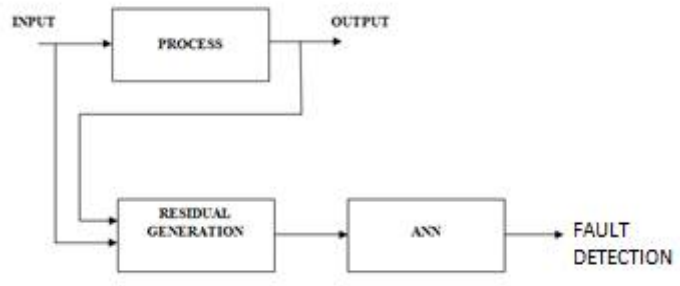

Fig 3. Fault Detection using ANN.

V.NETWORK CONFIGURATION

ANN consists of number of interconnected units. The output of any unit in determined by input characteristic, and its interconnection with other units. ANN consists of Input layer , Output layer and hidden layer with a number of nodes in it. Each connection between two nodes with a real value is called weight. Input layer has no input weights and activation function. Output layer presents output response for a given input. Hidden layer has no connection with outside world. Training methods of the ANN are Back propagation, Nonlinear Autoregressive (NAR),Nonlinear Autoregressive with External Input(NARX), multilayer feed forward network, Multi layer perceptron. The training of neural network can be either online or offline .To train the network, input and output data are fed to the network, then the residual is generated by neural network.Here Nonlinear Autoregressive with External Input(NARX) is used which shows more accurate results since it predict past values of y(t) and x(t).

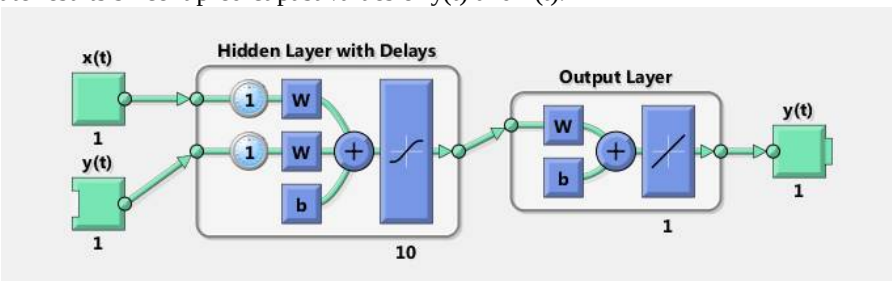

Fig.4 Neural network structure(NARX)

VI.NETWORK TRAINING

The neural network toolbox is used in order to train the network. Levenberg-Marquardt (LM) training function have fast convergence ability so it is used. In the process of training, first load the input and target data in neural network toolbox. Nonlinear Autoregressive with external input is used to define the network structure. Then using Levenberg-Marquardt algorithm method the network is trained. Training is the process in which the input data is usually checked with the target data. Validation to check whether the input data is trained to fit to the target data. In validation process some of the data cannot be trained. Finally in testing process all the input data's are trained to the target data.

VII. SIMULATION RESULTS

The best training method is decided by number of hidden layers used during the process of training. By using Neural Network Toolbox the network was trained in MATLAB. The training function used in LM method is trainlm. In order to train the network first load the input and output data in the neural network toolbox and define the structure as Nonlinear Autoregressive with External Input (NARX) and train the network with train data.

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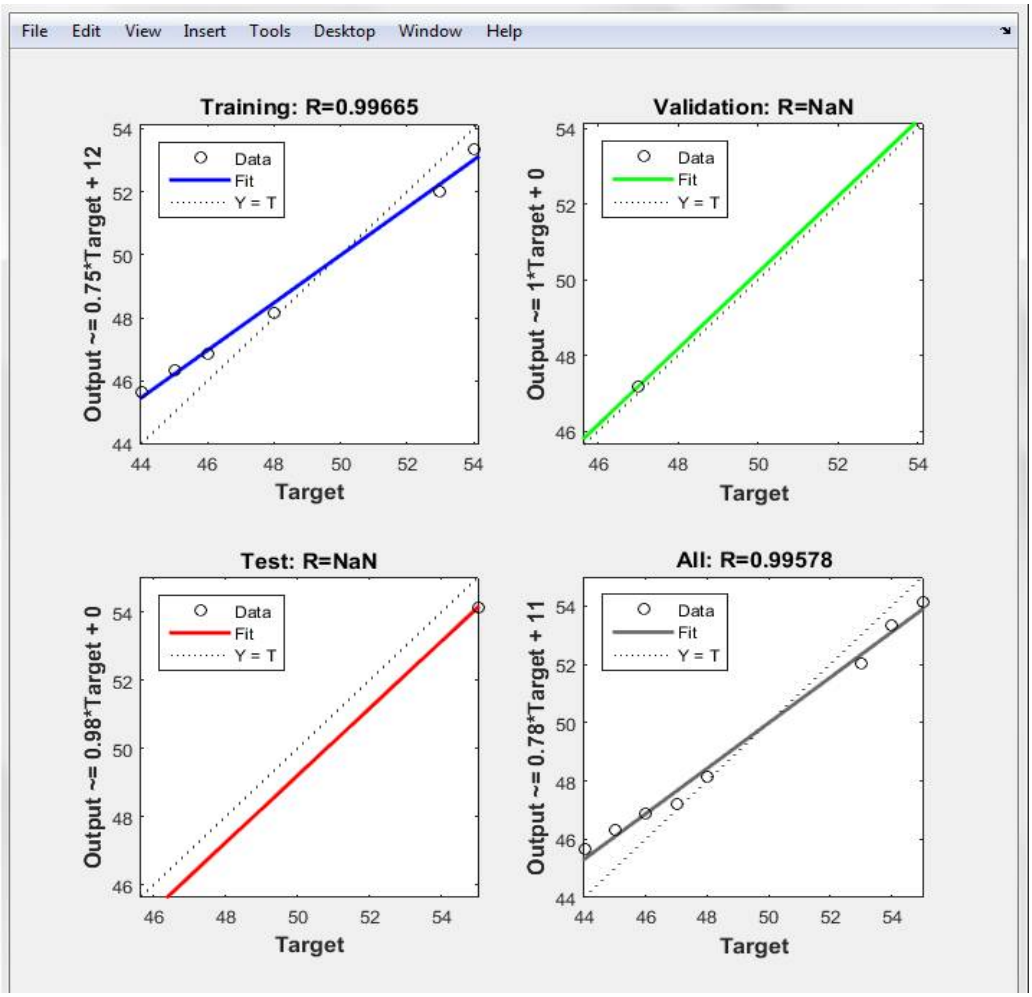

Fig 5 Simulation Results

Results of training algorithm

Parameters	Levenberg-Marquardt
Number of hidden neuron	10
Delay	1
Training Function	trainlm
Training Mean Square Error	3.0228
Testing Mean Square Error	1.578
Epoch	23

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VIII.CONCLUSION

Mathematical modelling for Plate heat exchanger is performed through system Identification and a method to detect Sensor fault using ANN is proposed . Levenberg-Marquardt algorithm is used as it reduces computational overhead and provides accurate results during training. The various parameters of network such as (MSE) Mean Square Error, number of Hidden layer, and number of Epochs has been obtained.

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