Adaptive Control Using NARMA-L2 Model and Electric Circuit for Condenser of Thermal Power Plant

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Abstract. Design and implantation electric circuit for enhancement performance of steam power plant and artificial neural networks technique used to control of condenser. Artificial neural network has been applied to control of the important variables of condenser in Al–Dura power plant in Baghdad such as pressure, temperature. In this study, applied Simulink model in Matlab program (v 2014 a) by using artificial neural network toolbox. the model of condenser of neural network by using NARMA to generated data and train network and using back propagation algorithm for training neural network. The method of control by ANN is off line. the electric circuit of pressure sensor and temperature sensor consist of transformer, dc bridge and voltage regulator. Experimental data of actual power plant obtained from al-dura power plant. comparing results of modelling neural network and electric circuit with experimental data of actual power plant. the results shown the maximum deviation between the ANN and electric circuit with experimental data is less than 4%. artificial neural network can be used in many industrial and engineering application.

Keywords: Artificial Neural Network, NARMA, Condenser, Steam Power Plant, Pressure, Temperature

1. Introduction

Condenser (atmospheric) of steam power plant that’s working under the ranking cycle is a simply heat exchanger and the function of a condenser is to convert gaseous form exhaust steam into liquid by cooling mediums such as water/air and then pumped back into the boiler. To operation steam power plant strongly under minimum cost and maximum efficiency the condenser must be operation at optimum condition. The studies and literature review of condenser and artificial neural network as: [1] presented to control of cooling water flow rate, pressure and temperature of the condenser which these variables affected of performance of thermal plant, and thus on energy efficiency and its specific heat rate of the coal fired plant. The study applied when the plant runs at full load. The results suggest some approaches for the active control of backpressure operating the condenser at optimum cooling water mass flow rate to increase energy efficiency. [2] present a model of heat exchanger for analytical of mass transfer and heat in a flue gas condensing. The analytical model used to validate a pilot-scale heat exchanger. The result shows a good agreement of experimental result with analytical model results. [3] present a study of using a ANN for control of changeable-speed air conditioner by developed a dynamic model of a steam condenser. The model is based on the assumptions of constant liquid and vapour volumes and total condensation. The operating condition is taken from the static balance of a power plant. The neural network controller is feed forward network trained with two hidden layer using a model reference technique. Training network by back-propagation algorithm. The results obtained the responses of the model reference is similar with neural network control system and compared the results with using a fixed speed conventional of air conditioner, ANN control system consumed. [4] applied artificial neural network to determine exit water temperature of a condenser at various operation conditions and compared with the water temperature exit by experimental work. Back propagation algorithm used for training and learning neural network. Input of ANN include surface area, inlet temperature, flow...
rate of water, steam temperature, enthalpy difference and steam flow rate. Experimental results and measurements obtained by engineering equation solver used as a set of input. The results shown the deviations of ANN models are less than 0.12 and shows the change of exit water temperature with the change of input parameters. [5] presented investigates task-blind and task-this method is reminiscent of time series prediction, but the network would also utilize information on the current state of the system. The controller design and apply it to the control of an actual air-cooled condenser and compare its performance with the one of the conventional controller. [6] presented PID neural network to get satisfactory control effect for the advantages of PID, capabilities of learning and nonlinear propose a deaerator water level of condenser decoupling control strategy founded on PID ANN which integrates PID and ANN by establishing proportional neuron, integral neuron and derivative neuron corresponding to proportional, integral and derivative, also used a method of choosing initial weights and learning coefficient from experience of PID to enhance the convergence performance of PID ANN. The results of simulation model show that the PID ANN decoupling control strategy can meet the requirements of multivariable system decoupling control. It is more successful in condenser water level and deaerator water level decoupling than PID control strategy.

The aim of this research is to control of variables pressure and temperature of condenser of al-dura power plant in Baghdad which affected of maximum generated power and plant performance.

2. Neural Network Control System

ANN applied to simulate their biological counterparts. The first simple model of a neuron knows by Mcculloch and Pitts at 1943. [7]. ANN are applied in many fields of science and technology. They provide an alternative approach to the simulation of complex systems [8, 9, 10, 11]. Neural networks have been applied in many engineering applications because they are ability and easy to learn and cost effective. Neural network is applied to fit curves through given data without being provide a predetermined function [12-16]. ANN is a flexible for developing environment and capable to take decision and learned the proper function of control shown in Figure 1, the single artificial neuron consists of input layer, output layer, weighted connection between neurons and activation function as a single model shown in Figure 2.

![Figure 1. Schematic of an Artificial Neural Network](image)

![Figure 2. Basic Element of Artificial Neural Network](image)

3. Experimental Devices

Experimental devices of temperature and pressure sensor. The equivalent circuit this pressure signal is processed to be transfer to the interface unit. In interface unit the signals are processed to enter into the computer after which to take control of an application that has been designed with the system requirements, and consequently offers a message to the operator for you to make the right selection. Pressure sensor consist of electric transformer which capable of increasing or decreasing the voltage and current levels of their supply, DC bridge which it uses to convert signal to continuous voltage signal to obtain logic value of the signal represented by way of one and zero, where in the one represents five volts and zero represents zero volts. the continuous voltage signal is inserted to the voltage regulator type 7805 (5 volts or zero volts). Its purpose is to supply a stable voltage and used as stabilizer may be restricted to ensure that the output as definite limits. The analog signal converted to a digital signal when sensor pressure read high. Figure 3 shown the diagram of sensing pressure circuit and Figure 4 show the photograph of sensing pressure circuit.
Temperature sensor which consists of a comparative voltage, after changing the temperature signal to voltage it's far in comparison with the threshold value (80°C) which has been almost set. The temperature increases more than 80°C or decrease less than 80 °C, signal may be sent to the control system through the equivalent circuit to make the right decision. This limit of temperature makes a condenser in steam power plant have been working in steady state. Figure 5 shown the diagram of temperature sensor circuit and Figure 6 shows the photograph of temperature sensors circuit.

4. Condenser Model Using Neural Network

The kind of controller of neural network used in this study is the nonlinear autoregressive moving average (NARMA) [11] are designed and employed to control of pressure and temperature of condenser of steam power plant. NARMA implemented in the ANN tool-box of simulation of Matlab. In system identification of ANN model of the plant is developed. Controller block of NARMA show in Figure 7.
The building block diagram of plant identification for the NARMA of condenser model working by adjusted parameters for generating data by insert minimum and maximum values for the plant input and output, minimum and maximum interval values as 0.1 and 1 seconds. The size of the hidden layer the number of delayed plant inputs and outputs, the sampling interval and finally the training function is Trainlm. The training network then selected by the response of the resulting plant model was displayed. Separate plots for validation data training data and testing data that’s shown in Figures 8-12.

**Figure 8.** Generate Data of Plant Identification of NARMA  
**Figure 9.** Accept Data of Input Output Data

**Figure 10.** Validation Data of Neural Network  
**Figure 11.** Training Data of Neural Network
5. Results and Discussion

Figure 13 shows the model developed in Simulink \ Matlab to control of pressure and temperature of condenser at optimum value to enhancement of plant efficiency. Figure 14 shows the output of pressure and temperature of condenser of power plant and compared these results with output of experimental device. The experimental results of an electrical device shown in Figure 15, this figure explains the practical pressure signal that measured from electric circuit that allowed to work the condenser under the normal condition, and shown the temperature signal measured practically, represent the perfect temperature to work condenser. The results obtained good agreement between NARMA result and experiment device.
Figure 14. Optimum Value of Temperature and Pressure

Figure 15. Experimental Signals of Temperature and Pressure

6. Conclusion
This paper applied artificial neural network technique to control of condenser for improvement the performance and design electric circuit for this purpose. This study shows the inputs of pressure and temperature of condenser. The trained NN model can approach desired values with height accuracy. And reach for normal condition of working steam plant by increase expansion ratio of steam and thus increase efficiency. The ANN model can advance desired values with height accuracy. When compared the results were used in Matlab program built with experimental circuit that’s designed for control. Show a good agreement of signals pressure and temperature between them. This model gives high accuracy and these rough models are usually used in adaptive control of nonlinear systems.

References
[1] V. Haldkara, A. Sharmaa, R. Ranjana And V.K. Bajpaib."An Energy Analysis of Condenser",International Journal of Thermal Technologies01, Vol.3, No.4. December 2013

[2] K. Jeong, M. Kessen, H.Bilirgen, E. Levy. "Analytical Modeling of Water Condensation In Condensing Heat Exchanger",ELSEVIER International Journal of Heat And Mass Transfer (53) 2361-2368. 2010
[3] W. Thambanchacheep and S. Kuntanapreed. "A Model Reference Neural Network Control for A Variable-Speed Air Conditioner" Research And Development Center For Intelligent Systems Faculty Of Engineering King., Bangkok, THAILAND 10800

[4] H. Jasim, H. Jaffa, "Effect Of Operation Conditions On Exit Water Temperature Of Condenser (Atmospheric) By Using Neural Network ". Journal of Engineering and Development, Vol. 15, No. 3, ISSN 1813-7822. September 2011

[5] G. Henze, R. Hindman. "Control of Air-Cooled Chiller Condenser Fans Using Clustering Neural Networks". ASHRAE. TRANSACTIONS- AMERICAN SOCIETY OF HEATING REFRIGERATING AND AIR CONDITIONING ENGINEERS. 2002.

[6] Wang Peng, Meng Hao, Dong Peng And Dai Ri-Hui " Decoupling Control Based On Pid Neural Network For Deaerator And Condenser Water Level Control System" IEEE . ISSN: 1934-1768. 14 September 2015

[7] Roland S. Burns, "Advance Control Engineering", Butterworth-Heinemann, Published Oxford. 2001.

[8] D. Pallares, F. Johnsson, (2006) Macroscopic Modelling of Fluid Dynamics in Large-Scale Circulating Fluidized Beds, Progress In Energy And Combustion Science 32 (5) 539–569.

[9] C. Zhao, L. Dun, W. Zhou, X. Chen, D. Zeng, T. Flynn, D. Kraft, " Coal Combustion Characteristics On an Oxy-Cfb Combustor with Warm Flue Gas Recycle, In: Proceedings Of The 21st International Conference On Fluidized Bed Combustion, 2012. Pp. 3–6.

[10] U. Kesgin, "Genetic Algorithm and Artificial Neural Network for Engine Optimization of Efficiency and Nox Emission, Fuel 83 (7), 2004, 885–895.

[11] Resat Celikel And Omur Aydogmusnamra-L2 Controller For Single Link Manipulator. IEEE Published In: 2018 International Conference On Artificial Intelligence And Data Processing (IDAP) 24 January 2019.

[12] A.G. Shempelev, V.M. Sushchikh, P.V. Iglin, "On The Results of Comparison of the Calculated and Normative Characteristics of Condensers Steam Turbines in A Wide Range of Steam Loads", Energetic, 2015 Pp. 60-64.

[13] Xiao Fan; Zhou Youbin; Ruan Lin; Zhou Kunpeng; Wang Tao; Cao Kan; Rao Yuzestudy "On Transient Reactive Power Characteristics Of New-Generation Large Synchronous Condenser .IEEE 2018 China International Conference On Electricity Distribution (CICED) 31 December 2018.

[14] Zekun Yang; Xiaoping Shiresearch "On Vacuum Control For Condenser With Double Compensation Loops: IEEE 2017 IEEE International Conference On Information And Automation (ICIA) Date Of Conference: 18-20 23 October 2017

[15] A. Shempelev; P. Iglin; N. Tatarinovacondenser Mathematical Model Method Introduction Into Steam Turbine Unit Mathematical Model. IEEE 2017 International Conference On Industrial Engineering, Applications And Manufacturing (ICIEAM) Date Of Conference: 16-19 May 2017.
[16] Shempelev; P. Iglin. "On Mathematical Model Of Condenser Equipped With Water-Jet Ejector. IEEE 2018 International Conference On Industrial Engineering, Applications And Manufacturing (ICIEAM) Date Of Conference. 06 June 2019