UNIVERSITI TEKNOLOGI MARA

NEURAL NETWORK BASED ADAPTIVE PID CONTROLLER FOR SHELL-AND-TUBE HEAT EXCHANGER

MOHAMAD HAKIMI BIN OTHMAN

Dissertation submitted in partial fulfilment of
requirements for the award of
Bachelor of Engineering (Hons) Chemical

Faculty of Chemical Engineering

July 2019

ABSTRACT

This research presents the design and simulation of nonlinear adaptive control system on the heating process of shell-and-tube heat exchanger model BDT921. Shell-and-tube heat exchanger is a nonlinear process due to the factor of friction, temperature dependent properties, and unmeasured disturbance. As the heating process is nonlinear in nature and conventional PID is a linear controller, change in process dynamics cause instability of the controller parameters i.e proportional gain, integral time and derivative time. Thus, these controller parameters need to be repeatedly retuned. In this circumstance, auto tuning of the controller parameters is incredibly important. In this study, neural network approach was introduced to auto-tune the controller parameters. The dynamic data from the BDT921 plant was collected to formulate the mathematical model of the process using MATLAB System Identification Toolbox. The dynamic behavior of the process is accurately modeled using nonlinear ARX model with 96.17% of validation accuracy and 97.5% of fit to estimation accuracy. Dynamic time series neural network model was used together with Levenberg-Marquardt algorithm as the training method. Single hidden layer feed forward neural networks with 20 neurons in hidden layer was selected. The neural network model consists of 4 input variables and 4 output variables. Simulation and development of the controller was done in the Simulink environment meanwhile the effectiveness of the controller was evaluated based on the set point tracking and disturbance rejection. Simulation result proved that the adaptive PID controller was more effective in tracking the set point with faster settling time and lower or no overshoot respond compared to conventional PID controller. However, there is no significant improvement in controller performance when disturbance is introduced to the controller.

ACKNOWLEDGEMENT

I am grateful to the God for the good health and well being that were necessary to complete this research. I wish to express my sincere thanks to Madam Zalizawati Abdullah, my supervisor while doing my project research. I am extremely thankful and indebted to her for sharing expertise, and sincere and valuable guidance and encouragement extended to me. I take this opportunity to express gratitude to all other either directly or indirectly help me to complete this paper. I also thank my parents for the unceasing encouragement, support and attention.

TABLE OF CONTENTS

AUTHOR'S DECLARATION **I**

ABSTRACT **V**

ACKNOWLEDGEMENT **VI**

TABLE OF CONTENTS **VII**

LIST OF TABLES **X**

LIST OF FIGURES **XI**

LIST OF PLATES **XIII**

LIST OF SYMBOLS **XIV**

LIST OF NOMENCLATURES **XVI**

CHAPTER ONE: INTRODUCTION **1**

1.1 Summary 1

1.2 Research Background 1

1.3 Problem Statement 3

1.4 Objective 4

1.5 Scope of Research 4

CHAPTER ONE
INTRODUCTION

1.1 Summary

Shell-and-tube heat exchanger is a nonlinear system and complex in nature. These complex phenomena cause uncertainties on the heat exchanger. Conventional PID controller is not effective to control the shell and tube heat exchanger in order to achieve the desired output when disturbance happen or set point are change. The artificial neural network is introduced to be combined with the PID controller to increase the effectiveness of the controller by auto tune the controller parameter. In this research, dynamic times series artificial neural network (NN) with Levenberg-Marquard training method was used. The PID control loop that has been chosen for this research is a feedback control system which is the manipulated variable is adjusted by recognizing the error in control variable or process output. The manipulated variable is the inlet hot water flow rate of heat exchanger and the control variable is the temperature of heated stream from the heat exchanger. Dynamic input and output of the shell-and-tube heat exchanger model BDT921 was recorded to study the nonlinearity of the process and to develop the mathematical model to represent the process in simulation environment. The comparison of effective of proposed controller with conventional feedback PID controller is based on the ability to eliminate the overshoot condition and faster settling time.

1.2 Research Background

Heat exchanger is commonly used in industries for heating or cooling a fluid. Heat exchanger is an equipment that controls the temperature of a fluid by apply heat transfer principles were hot fluid is cold down or vice versa without physical mixing (Cengel & Ghajar, 2015). There are several types of heat exchanger in industries such