MODELING AND CONTROL OF VENTILATION AND HEATING SYSTEM USING NEURO-FUZZY INFERENCE SYSTEM

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This thesis is dedicated to my parents.

For their endless love, support and encouragement.

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ABSTRACT

Dealing with the nonlinearities and uncertainties in Ventilation and Heating System are the main challenges in developing a reliable model for the system. In this project, artificial neural network (ANN) modeling technique was used as it has demonstrated the capability of handling certain uncertainties. The laboratory scale ventilation and heating system, VVS-400 equipped with RTD temperature sensor and orifice plate as flow sensor is chosen as the case study. The input-output data of the system was collected experimentally in building ANN model for the plant. Large portion of the pre-treated data were used to train the ANN model. The remaining portion were used to test the generalization capabilities of the realized ANN model. The prediction performances of the model were evaluated using root-mean square error (RMSE) and correlation coefficient (R). A neuro-fuzzy controller was designed to control the air temperature of the system. The simulation studies were achieved through the use of MATLAB/Simulink software.

ABSTRAK

Berhubung dengan sistem tidak linear di dalam Sistem Ventilasi dan Pemanasan adalah cabaran utama untuk menghasilkan model untuk sistem tersebut. Dalam projek ini, teknik modeling Rangkaian Neural Buatan (ANN) telah digunakan kerana ia telah mendemontrasi keupayaan untuk mengendalikan ketidaksamaan. Sistem Ventilasi dan Pemanasan, VVS-400 berskala makmal dilengkapi dengan sensor suhu rintangan pengesan thermometer (RTD) dan sensor aliran udara plat orifis telah dipilih menjadi kes pembelajaran. Data input-output sistem tersebut telah dikumpulkan secara eksperimen untuk membina *'ANN'* model untuk sistem tersebut. Sebahagian besar daripada data yg telah diproses telah digunakan untuk melatih model *'ANN'*. Baki sebahagian data telah digunakan untuk menguji kebolehan generalisasi *'ANN'* model tersebut. Ramalan prestasi model tersebut kemudian telah dianalisa menggunakan punca min kuasa dua (RMSE) dan pekali korelasi (R). Sistem kawalan '*Neuro-Fuzzy'* telah direka untuk mengawal suhu sistem tersebut. Simulasi telah dicapai dengan menggunakan perisian MATLAB/Simulink.

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
ANFIS	-	Adaptive Neuro-Fuzzy Inference System
BP	-	Backpropagation
CANFIS	-	Coactive Adaptive Neuro-Fuzzy Inference System
DAQ	-	Data Acquisition
DAFDV	-	Double-level air flow field dynamic vacuum
DX A/C	-	Direct Expansion Air Conditioner
FFNN	-	Feedforward Neural Network
FIS	-	Fuzzy Inference System
FLC	-	Fuzzy Logic Controller
GA	-	Genetic Algorithm
HVAC	-	Heating Ventilation Air Conditioner
I/O	-	Input-Output
LSE	-	Linear Square Error
MIMO	-	Multiple Input Multiple Output
NI	-	National Instrument
PID	-	Proportional Integral Derivative
PMV	-	Predicted Mean Vote
PRBS	-	Pseudo-Random Binary Sequence
PSO	-	Particle Swarm Optimization
R	-	Correlation Cofficient

RMSE	-	Root Mean Square Error
RTWT	-	Real Time Windows Target
RTD	-	Resistance Thermo Detector
SIFLC	-	Single-Input Fuzzy Logic Controller
TRIAC	-	Triode for Alternating Current
TS	-	Takagi-Sugeno

LIST OF SYMBOLS

γ	-	Conjuctive form antecedent
Σ	-	Fuzzy mean operator
Π	-	Antecedent connective
σ	-	Basis Function Parameter
β	-	Degree of fulfillment

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Generally, heaters are appliances which function to generate heat. The heat can be transferred by either convection, conduction or radiation. A heating system is a mechanism for maintaining temperatures at an acceptable level by using thermal energy within a home, office, or other dwelling. Ventilation is the process of changing or replacing air in any space to provide high indoor air quality to control temperature. Furthermore, heating and ventilation elements are combined to form heating and ventilation system which are also widely used in industries to control air temperature and flow of processes taking part in the industry. In industries which involve many processes where high heat is presence, ventilation is needed in order to regulate the temperature. Due to this matter, controlling of air flow and air temperature is very important.

In developing a reliable model for ventilation and heating system the main challenges are dealing with nonlinearities and uncertainties as Multiple Input-Multiple Output (MIMO) systems often show dynamic behavior of processes. In order to solve this matter, a system identification technique based on neuro-fuzzy system which demonstrate efficiency and the capability of enduring uncertainties must be applied in order to design a controller for the system.

1.2 Problem Statement

In developing a reliable model for ventilation and heating system the main challenges are dealing with nonlinearities and uncertainties of the system. For example, MIMO systems often show dynamic behaviour of processes inside the system.

This may include temperature and flow processes. In order to solve this matter, modeling technique which consider the nonlinearities of the system must be applied and a controller which demonstrate efficiency and the capability of enduring nonlinearities and uncertainties must be designed.

1.3 Project Objective

1. To develop ANN model that describes the dynamic behavior of VVS-400 using system identification approach.
2. To design a controller using neuro-fuzzy method
3. To test the performance of the controller design into VVS-400.

1.4 Scope of Work

Initially, the characteristics and dynamics behavior of pilot scale heating and ventilation system, VVS-400 are studied. Then, experimental set-up and data collection from the plant model will be done. The heating and ventilation system will be modeled using system identification technique. In addition, the prediction performances of the model will be evaluated. The neuro-fuzzy controller will be designed based on verified model to control the air temperature and also air flow inside the system.

1.5 Thesis Structure

This thesis is organized in five Chapters. The first chapter gives an overview of the project that gives the introduction of heating and ventilation system, nonlinearities and the modeling and control approach proposed.

Chapter 2 covers literature review on related works, system description, and system identification and controller design.

Chapter 3 the flow of methodology and description of each procedure taken to complete the project.

Chapter 4 mainly discuss about the results of this project. Both results for neural-network and neuro-fuzzy modeling were discussed in this chapter. Furthermore, results for developed neuro-fuzzy controller were also discussed.

Chapter 5 includes the conclusion and summarization of the thesis and recommendation for future works.

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