MODELING AND DEVELOPMENT OF PREDICTIVE CONTROLLER FOR TEMPERATURE CONTROL OF HOT AIR BLOWER SYSTEM

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DEDICATION

I wholeheartedly dedicate this thesis to my parents, my best friend, my supervisor, all my lecturers, and above all to our Almighty Allah S.W.T. Their encouragement and guidance have always inspired me along this educational journey.

ABSTRACT

A hot air blower (HAB) system is a process of heating air flowing to a certain temperature level. The crucial part of this system is to control the temperature of flowing air to the desired temperature level. The main problem encountered when using this system is the temperature of airflow inside the blower is very challenging to be controlled, which may cause overheating of the system [1]. This study is proposed for this reason. The scope of this study consists of modeling and controller HAB system. PT326 process trainer is a HAB system employed in this study. System identification technique was used to determine the mathematical model of the system. In this study, the ARX341 was selected as a plant model. Meanwhile, a predictive controller is proposed as a new strategy to control the temperature of airflow. MATLAB Simulink was used for both modeling and controlling processes. In order to evaluate the effectiveness of the proposed controller, the performance of the proposed predictive controller was compared with the Proportional-Integral-Derivative (PID) controller in terms of transient response. Simulation results based on MATLAB Simulink revealed that the proposed predictive controller effectively provides fast, accurate, and stable performances in controlling the temperature of the HAB system compared to other strategies.

ABSTRAK

Sistem penghembus udara panas (HAB) ialah proses pemanasan udara yang mengalir ke tahap suhu dikehendaki. Bahagian penting dari sistem ini adalah untuk mengawal suhu udara yang mengalir ke tahap suhu yang dikehendaki. Masalah utama yang dihadapi semasa menggunakan sistem ini ialah suhu aliran udara di dalam penghembus sangat mencabar untuk dikawal, yang boleh menyebabkan sistem menjadi terlalu panas [1]. Kajian ini dicadangkan atas sebab ini. Skop kajian ini terdiri daripada pemodelan dan kawalan rekabentuk sistem HAB. PT326 ialah sistem HAB yang digunakan dalam kajian ini. Teknik pengenalpastian sistem digunakan untuk menentukan model matematik sistem. Dalam kajian ini, ARX341 telah dipilih sebagai model. Sementara itu, rekabentuk kawalan ramalan dicadangkan sebagai strategi baru untuk mengawal suhu aliran udara. MATLAB Simulink telah digunakan untuk kedua-dua proses pemodelan dan kawalan. Untuk menilai keberkesanan reka bentuk yang dicadangkan, prestasi rekabentuk Kawalan Ramalan telah dibandingkan dengan pengawal Derivative-Berkadar-Integral (PID) dari segi tindak balas sementara. Hasil keputusan simulasi berdasarkan MATLAB Simulink menunjukkan bahawa kawalan ramalan yang dicadangkan berkesan memberikan prestasi yang pantas, tepat dan stabil dalam mengawal suhu sistem HAB berbanding strategi yang lain.

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LIST OF SYMBOLS AND ABREVIATIONS

HAB	:	Hot Air Blower
ARX	:	Auto-Regressive with Exogenous
ARMAX	:	Autoregressive Moving Average with Exogenous
OE	:	Output Error
BJ	:	Block Jenkins
PID	:	Proportional-Integral-Derivative
PFC	:	Predictive Functional Controller
LTV	:	Linear Time-Varying
AWC	:	Anti-Windup Compensator
FPE	:	Final Prediction Error
MSE	:	Mean Square Error
ISE	:	Integral Square Error
IAE	:	Integral Absolute Error
ROC	:	Region of Convergence
PI	:	Proportional Integral
PRBS	:	Pseudo Random Binary Sequence
ZOH	:	Zero-Order Latch
GPC	:	Generalized Predictive Control

RLS	:	Recursive Least Square
PSO	:	Particle Swarm Optimization
HSA	:	Harmony Search Algorithm
RMPC	:	Robust Model Predictive Control
GMV	:	Generalized Minimum Variance
ZN	:	Ziegler-Nichols
MV	:	Manipulating Variable
PC	:	Predictive Controller
DOF	:	Degree of Freedom
GPC	:	Generalized Predictive Controller
MPC	:	Model Predictive Controller

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Temperature is an important control variable, like flow rate and motor velocity in thermal machines. Temperature must be carefully managed in certain industrial applications to ensure equipment safety [2]. The temperature of flowing air is the process to be controlled in this study. In this study, the PT326 air blower system is chosen as a plant which needs to be maintained at a certain level of temperature. The PT326 process trainer is a self-contained process control trainer that includes both plant and control equipment inside one unit. The PT326 air blower used in this study is considered non-linear and had a significant time delay. In this study, the control aims is to maintain the temperature of air flowing inside the blower at the desired value. Several steps must be considered when conducting this study: identify a process, obtain a mathematical model of the system, analyze and estimate the parameters using the system identification approach, design appropriate controllers for controlling the system and simulate their implementation, and finally make an analysis and reasoning depends on the findings.

A mathematical modeling process was crucial in this study since it was employed to define a system, depict the dynamic, and explain the behavior of a physical system. The analytical approach (physics law) and the experimental approach (System Identification) can be both used to determine a mathematical model of a physical system [2]. According to Rahmat et al. (2005) in [3], the fundamental challenge when using a physical law is that if the physical law guiding the system's behaviour is not completely described, it may be impossible to formulate a mathematical model. In contrast, the system identification approach only involves input and output data obtained from experiments for the purpose of modeling the system, without having to fully explain the behavior of the system. As a result, this study used an experimental technique based on system identification.

The measured input and output data set for this study was received from the Real Laboratory Process, gathered via MATLAB demos. The system identification tool in MATLAB is then used to predict the model's parameters based on the selected model structure. Generally, the system identification approach uses parametric and non-parametric methods to describe a mathematical model of a system. In this study, four parametric approach using Auto-Regressive with Exogenous Input (ARX), Autoregressive Moving Average with Exogenous Input (ARMAX), Output Error (OE) and Box Jenkins (BJ) was considered to represent the dynamic characteristics of a PT326 hot air blower (HAB) system. The model validation criterion was used to determine if the models were acceptable or otherwise an appropriate controller must be constructed in order to achieve the maximum performance in temperature control of the air blower system. This study proposed a Predictive Functional Controller (PFC) as a main controller in this study, and Proportional-Integral-Derivative (PID) controller proposed as a controller for comparison. Finally, the simulation of the temperature control system's performance using both PID and PFC were carried out, compared and analyzed.

1.2 Problem Statement

This study is proposed based on these two main issues:

Modeling

- The use of theoretical approach usually complicates the modeling process due to system complexities and unknown variables within the system.
- The use of theoretical approach also causes the time allocated to model a system is quite long.
- Improper modeling will result in inaccurate characteristics and dynamics of the HAB system [4].

Hence, this study proposes an empirical approach or system identification technique for modeling the HAB system.