SYSTEM IDENTIFICATION, ESTIMATION AND CONTROLLER DESIGN OF A HOT AIR BLOWER SYSTEM

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To my beloved husband, mother, father and families.

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ABSTRACT

This project presents an importance task of System Identification, parameter estimation and model validation to develop a mathematical model that describes the dynamics of a hot air blower system. A PT326 process trainer is a hot air blower system used in this project. The scope of work for this project consists of modeling and controller design of a PT326 process trainer. A heating ventilation model is the system to be modeled and is perturbed by a Pseudo Random Binary Sequences (PRBS) signal. Parametric approach using Auto Regressive with Exogenous Input (ARX) model structure is used to estimate the mathematical model of PT326 process trainer. The System Identification Toolbox GUI in MATLAB environment is used to estimate this approximated plant model. Once the estimated plant model is validated using Model Validity Criterion method, the behavior of the system without applied any controller have been analyzed using MATLAB Simulink and result shows that the output responds does not corresponds to its input; the output temperature of air flowing is not maintained at a desired level. Several controllers such as Pole-Assignment Servo-Regulator controller, Proportional-Integral-Derivative (PID) controller, and Generalized Minimum Variance (GMV) controller were designed using the approximated plant model obtained and the performance of each controller was compared and justified by running a simulation. Simulation results demonstrated that in most cases, a Self-Tuning Pole Assignment Servo-Regulator controller with a small value of pole provide relatively high ability in controlling the system and a GMV controller using PSO tuning method obviously has improved the performance of the Self-Tuning GMV controller in term of rise time *(T_r)* and settling time *(T_s)*.

ABSTRAK

Projek ini memaparkan kepentingan pengenalpastian sistem, pentaksiran parameter dan pengesahan model yang bertujuan untuk mendapatkan model matematik yang berupaya menghuraikan dinamik pada sistem penghembus udara panas. Alat latihan proses PT326 adalah sistem penghembus udara panas yang digunakan di dalam projek ini. Skop kerja merangkumi proses pemodelan dan rekabentuk pengawal untuk alat latihan proses PT326. Pendekatan parametrik menggunakan struktur model *"Auto Regressive with Exogenous Input (ARX)"* digunakan bagi mentaksir model alat latihan proses PT326. Setelah model matematik yang ditaksirkan disahkan menggunakan kaedah Kriteria Kesahihan Model, ciri-ciri yang terdapat pada sistem yang dikaji tanpa menggunakan sebarang pengawal dianalisis menggunakan MATLAB Simulink. Keputusan menunjukkan respon keluaran tidak selari dengan masukan. Menerusi projek ini, pengawal *"Pole-Assignment Servo-Regulator"*, *"Proportional-Integral-Derivative (PID)"*, dan *"Generalized Minimum Variance (GMV)"* direka dengan menggunakan model matematik yang telah dianggarkan. Pelaksanaan setiap pengawal dibandingkan dan dibuktikan dengan menggunakan kaedah simulasi. Hasil simulasi menunjukkan bahawa pengawal *"Self-Tuning Pole Assignment Servo-Regulator"* dengan nilai kutub yang kecil mempunyai keupayaan yang tinggi bagi mengawal sistem yang dikaji, manakala pengawal GMV menggunakan kaedah talaan PSO telah berjaya memperbaiki pelaksanaan yang terdapat pada pengawal GMV menggunakan kaedah talaan sendiri dari aspek masa naik (T_r) dan masa berhenti (T_s).

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligent
ANFIS	-	Adaptive Neuro-Fuzzy Inference Systems
ARMAX	-	AutoRegressive Moving Average with Exogenous input
ARX	-	AutoRegressive with Exogenous input
BJ	-	Box Jenkins
FPE	-	Final Prediction Error
GMV	-	Generalized Minimum Variance
MRAC	-	Model Reference Adaptive Control
MVC	-	Minimum Variance Control
OE	-	Output Error
PB	-	Proportional Band
PID	-	Proportional-Integral-Derivative
PRBS	-	Pseudo Random Binary Sequences
PSO	-	Particle Swarm Optimization
RBFNN	-	Radial Basis Function Neural Network
STC	-	Self-Tuning Control
ZN	-	Ziegler Nichols

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In control system engineering, the ability to accurately control the system that involves the temperature of flowing air is vital to numerous design efforts [1]. This project was conducted due to this problem. The process to be controlled in this project is the temperature of a flowing air. The PT326 process trainer is a hot air blower system employed in this project. PT326 process trainer is a self-contained process control trainer and it incorporates a plant and control equipment in a single unit. The system to be controlled in this project also was a non-linear and has a significant time delay. In this project, the control objective is to maintain the process temperature at a desired value. There are several steps to be considered while doing this project; identify a process, obtain the mathematical model of the system, analyze and estimate the parameters using System Identification approach, design appropriate controllers for controlling the system and implement it to the system by simulation, and lastly make analysis and justification based on the results obtained.

A mathematical modeling process was provided a very useful method in this project since it was used in identifying a process, representing the dynamic, and describing the behavior of a physical system. A mathematical model of a physical system can be obtained using two approaches; analytical approach (physics law) and experimental approach (System Identification) [2]. Study on [3] found that the main problem of applying a physical law is, if a physical law that governing the behavior of the system is not completely defined, then formulating a mathematical model may be impossible. Thus, an experimental approach using System Identification was considered in this work. In this project, a mathematical model of the temperature response for the system is developed based on the measured input and output data set obtained from Real Laboratory Process which can be obtained from MATLAB demos. System Identification Toolbox which is available in MATLAB is then used to estimate the parameters and approximate the system models according to the mathematical models obtained. Basically, System Identification approach offers two techniques in describing a mathematical model, which are parametric and non-parametric method. In this project, parametric approach using AutoRegressive with Exogenous input (ARX) model structure is chosen to estimate and validate the approximated system model. In order to ensure the validity of the ARX model, Model Validation Criterion was used to decide whether the ARX model obtained should be accepted or rejected. Once the model have been identified and validated, appropriate controllers were designed to improve the output performance of the system. Three types of controllers were proposed in this work; Self-Tuning Pole Assignment controller, Proportional-Integral-Derivative (PID) controller, and Generalized Minimum Variance (GMV) controller. The tracking performances of the system by simulation using different type of controllers designed in order to maintain the process temperature at a given value were carried out, analyzed, and justified.

1.2 Problem Statements

The development of this project is based on these problems:

- Unknown plant model or mathematical model of the PT326 process trainer.
- Unknown suitable parametric approach or model structure to be used to estimate the mathematical model of a particular system.
- Undesired output response of the system.

1.3 Project Objectives

The objectives of this project comprises of the following:

- To determine the mathematical model of the PT326 process trainer using System Identification approach based on Real Laboratory Process Data [16].
- To estimate and validate the parameters of the PT326 mathematical model using ARX model structure.
- To design several controllers for controlling the PT326 process trainer, make comparison and justification based on the result obtained from a simulation.

1.4 Scope and Project Background

The scope of work for this project consists of identification, estimation and controller design of a hot air blower system (PT326 process trainer). A PT326 process trainer is the system to be modeled and was perturbed by a PRBS signal. Parametric approach using ARX model structure is used to estimate the mathematical model or approximated plant model. The approximated plant model is estimated using System Identification approach. Several controllers are then designed to improve the output performance of the system and the comparison study and justification is made based on the performance of each controller.

1.4.1 System identification

System Identification is used to determine the transfer function or equivalent mathematical description that describes the behavior of the PT326 process trainer using the data obtained from a Real Laboratory Process.

1.4.2 Parameter estimation

The parameters of PT326 process trainer were estimated using MATLAB System Identification Toolbox and linear parametric approach using AutoRegressive with Exogenous Input (ARX) model structure is chosen.

1.4.3 Model validation

A Model Validation Criterion is used in order to decide whether to accept or reject the ARX model obtained.

1.4.4 Controller design

Appropriate controllers were design based on the ARX model obtained. The controllers designed must meet the requirements of this project.

1.4.5 Comparison and justification

A comparative study based on simulation is analyzed and discussed in order to identify which controller deliver better performance in terms of the system's tracking performances.

1.5 Thesis Outline

This thesis is organized in six chapters accordingly. Chapter One gives a general overview of the project, describes the main purposes of the development of the project, and states clearly the scopes and limitations that is covered during the implementation of the project.

Chapter Two is more than a literature review on how previous work being described that relates to the project proposed and how related work is organized during the implementation of the project. The importance of related topics and its opportunities are also identified in this chapter.

Chapter Three contains procedures, definition and explanations of techniques used to collect, store, analyze and present any information that related to the project.

Chapter Four presents the results from study and a discussion of the results. The comparison and justification based on the results obtained from each controller are also discussed through this chapter.

Chapter Five states the problem, research design, and the findings of the project. The conclusions and recommendations that are made based on the findings and conclusion of the study is also stated in this chapter.

Chapter Six listed all of the author's suggestions and recommendations that might be can be used to improve the performance of the systems to be controlled for future works.

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