IMPLEMENTATION OF GENERALIZED PREDICTIVE CONTROL (GPC) FOR A REAL-TIME PROCESS CONTROL USING LABVIEW

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Specially dedicated to

my beloved wife for her support and caring,

my family for their encouragement and blessings,

and my new born baby..ahna safiy

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ABSTRACT

Real-time control is an approach to evaluate process system with real-time parameters by controlling selected variables to accomplish the control objectives. Real-time issues such as rapid testing, nonlinearity and computational problem have led researchers in recent years to do intensive work on development methodologies to enhance control in real-time. Selection of control approaches has also been reviewed to adapt with these real-time issues apart from other strategies. In this research, a predictive algorithm namely Generalized Predictive Control will be evaluated in real-time by applying LabVIEW software as tools for algorithm implementation. LabVIEW is chosen because of its block diagram implementation with simple graphical user interface approach to execute algorithm in real-time faster. Hence, it is essential for complex algorithm to control real-time process system. Coupled-tanks have been identified as process models that are inherently nonlinear and hard to control due to unavailability of the exact models' descriptions. As for this, real time control will be applied to the coupled tank as the test bed for level control process. Experimental evaluation and comparison of the predictive algorithm performance will be benchmarked against PID control. PC and analogue input output card will be used as the controller and also for data acquisition and real-time data display.

ABSTRAK

Kawalan dalam masa nyata adalah kaedah yang digunakan untuk mengawal proses sesuatu sistem menggunakan penilaian masa nyata dengan mengawal sesuatu pembolehubah bagi mencapai objektif kawalan. Isu-isu yang berkaitan dengan kawalan masa nyata seperti pengujian yang kerap, sistem tidak lelurus dan isu yang berkaitan dengan komputer telah menyebabkan ramai pengkaji masakini mengkaji metod baru dan cara –cara bagi menyelesai dan memperbaharui kawalan dalam masa nyata. Bukan itu sahaja malahan pendekatan mengkaji kawalan pengaturcaraan juga giat dilaksanakan untuk membolehkan penyesuaian dengan kawalan masa nyata selain daripada kajian-kajian yang lain. Dalam kajian ini, kawalan pengaturcaraan menggunakan *Generalized Predictive Control* akan dikaji untuk kawalan masa nyata dengan menggunakan perisian LabVIEW. Perisian LabVIEW dipilih kerana pengoperasian pengaturcaraannya menggunakan gambarajah blok dan perisian ini mesra pengguna. Dengan perisian ini, aturcara dapat dilaksanakan dengan lebih cepat kawalan masa nyata sesuatu proses dan membantu dalam pengalikasian sesuatu aturcara yang rumit. Tangki berkembar telah dikenalpasti sebagai model proses yang tidak lelurus dan sukar dikawal disebabkan ketiadaan maklumat yang tepat tentang modelnya. Oleh itu tangki berkembar ini telah dipilih untuk melaksanakan kawalan masa nyata dengan mengawal paras air di dalamnya. Beberapa eksperimen akan dijalankan dan hasilnya akan dinilai dan dibandingkan dengan *PID*. Komputer dan kad input output akan digunakan sebagai pengawal dan juga sebagai bacaan data dalam sistem masa nyata.

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LIST OF ABBREVIATIONS

CARIMA	-	Controlled Autoregressive Integrated Moving Average
DAQ	-	Data Acquisition
DC	-	Direct Current
DLL	-	Data Link Library
DMC	-	Dynamic Matrix Control
EH	-	Extended Horizon
FOPDT	-	First Order Model Plus Dead Time
GA	-	Genetic Algorithm
GMV	-	Generalized Minimum Variance
GPC	-	Generalized Predictive Control
GUI	-	Graphical User Interface
LabVIEW	-	Laboratory Virtual Instrument Engineering Workbench
LVDT	-	Linear-Variable Differential Transformer
MPC	-	Model Predictive Control
MPC	-	Model Predictive Control
NFCGA	-	Neuro-fuzzy controller by Genetic Algorithm
NI	-	National Instrument
NIDAQ	-	National Instrument Data Acquisition
PID	-	Proportional plus Integral plus Derivative
PP	-	Pole Placement
PWM	-	Pulse Width Modulation
RLS	-	Recursive Least Square
SCADA	-	Supervisory Control Data Acquisition
VI	-	Virtual Instrument

CHAPTER 1

INTRODUCTION

1.1 Overview

Over the past 40 years, digital control of industrial processes has changed from being the exception to the commonplace. Each succeeding year sees an increase in the range of applications and each advance in hardware design widens the potential application areas. Computers now form an integral part of most real-time control systems; such computers are generally referred to as *embedded real-time computers* and an understanding of how to design and build systems containing embedded computers is an essential requirement for a systems engineer.

The knowledge required covers both hardware and software design and construction, and of the two the software engineering is the most difficult and least understood. The difficulties of specifying, designing and building real-time software and also programming the algorithm needs significant effort from engineers and control practitioners to try and find simple way to solve the problems. Other issues in real-time such as rapid testing, nonlinearity and computational problem have led researchers in recent years to do intensive work on development methodologies to enhance control in real-time. Therefore softwares such as LabVIEW, MATLAB, G2 and other simulation software would reduce the effort for implementation especially in algorithm to imply.

1.2 Problem statements

As real-time control involves algorithms to control a certain processes, two different algorithms will be chosen; a complex and a simple algorithm. In order to study its performance in terms of implementation in real-time and each control features, control of level of a coupled tank is chosen. This application is widely used in the process industry especially in chemical industries. In this project, controlling liquid level process will be done in real-time by applying Generalized Predictive Control (GPC) as a complex algorithm and Proportional-Integral-Derivative (PID) for a simple algorithm.

A common control problem in process industries is the control of fluids level in storage tanks, chemical blending and reaction vessels (Grega and Maciejczyk, 1994). The flow of liquid into and out of the tank must be regulated as to achieve a constant desired liquid level as fluid to be supply at a constant rate. Many control algorithms have been implemented using various techniques to compensate with the control requirement. Each of them has its own advantage and disadvantage. Engin *et al* (2004) have used adaptive network based fuzzy inference system (ANFIS) while Grega (1994) used cascade PID control, minimum time and state feedback control for the coupled tanks. There are wide arrays of other control techniques that have been applied to meet the control objective of the system. Various factors are considered in designing the controllers such as set point tracking and load disturbance, reducing the effects of adverse conditions and uncertainty, behaviors in terms of time response (e.g., stability, a certain rise-time, overshoot, and steady state tracking error) and lastly engineering goals such as cost and reliability which is vital in industrial perspective.

Most of previous works have been performed through simulation and several been tested with the real-time experimental test for validation. There are several data acquisition cards for input output that can be used such as from National Instrument, Advantech and others. Several researchers have reported performance comparison of various controllers for control of the coupled tank. Normally comparisons are being made with PID for benchmarking as the controller might not capable to satisfy the control objectives or requirement at all times as it need to be regularly tuned due to the varying system dynamics.

The system have occurrence of nonlinearity in the system dynamics thus the empirical model of the test-bed is constructed. The main interest in this research is to implement a real-time predictive control algorithm to a coupled tank for level control process using GPC and its control performance will be benchmarked against PID. Moreover, the controllers will also be reviewed in terms of real-time implementation.

1.3 Objectives

The objectives of the project are as followings:

- To evaluate the application of graphical environment using Laboratory Virtual Instrument Engineering Workbench (LabVIEW) language for real-time control software implementation

- To evaluate a predictive control algorithm, GPC and PID control for real-time control of Coupled Tank process

- Verification and benchmarking of GPC with standard PID controller

1.4 Scope of the project

i. Real-time Implementation of GPC with fix plant parameters and PID using LabVIEW software

    - To study the dynamic characteristics of the plant for the nonparametric model.

    - To study LabVIEW, a graphical programming language for software implementation

    - To study the implementation of GPC and PID in LabVIEW using C programming

ii. Experimental evaluation of performance, GPC and PID controller on Coupled Tank CTS 001

    - To gather experimental data and compare control performance and its implementation for GPC and PID

1.5 Summary

This section introduces the overall project and explains the objectives as well as the scope of the project in order to give an insight and the sense of direction of the project. The next chapter will review previous research that is related to the current work which concerns to real-time, GPC and liquid level control of coupled tank system. There are various strategies presented by researchers demonstrating their controllers on certain process control and comparison with others as benchmarking.

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