UNIVERSITI PUTRA MALAYSIA

COMPARATIVE PERFORMANCE OF ON-OFF, PID AND FUZZY LOGIC CONTROLLERS FOR pH PROCESS IN BOILER APPLICATION

BALBIR SHAH @ MOHD FADDULLAH

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By

BALBIR SHAH @ MOHD FADDULLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the degree of Master of Science

June 2013

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DEDICATION

In the name of ALLAH, The Most Generous and The Most Merciful

This thesis is dedicated to my beloved family, loving wife and my son, Muhammad Shah EL Arasy for their continuous support, patience and understanding. May Almighty Allah bless and reward them for their generosity.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfillment of the requirement for the degree of Master of Science

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June 2013

Chair : Associate Professor Samsul Bahari B. Mohd Noor, PhD

Faculty : Engineering

In steam generator, water quality is part of mandatory aspects that must be complied by industries especially in power generation due to its significant impact on plant operation. The corrosion and scale formation are the major impact which lead to tube damage and can cause a catastrophic failure due to poor heat transfer. The most common methods to control water quality in steam generator are internal water treatment and external water treatment process. This study focuses on the control and a modeling of highly nonlinear internal water treatment process by using various control strategies. The On-Off control, PID control and Fuzzy Logic control systems have been used to perform intelligent control based on the development of empirical modeling equation dilution of ammonia hydroxide solution. These systems are designed to perform an auto tuning process during forward and reverse action for pH correction. The LabVIEW virtual instrumentation (VI) has been used to verify the performance of each control strategy in term of the system accuracy and effectiveness. The simulation results show that these strategies can be applied to

perform intelligent control in this dilution process. In non-linear static system, the On-Off controller shows remarkable results in forward and reverse action in maintaining the acceptable pH level. However, the Fuzzy Logic controller shows higher accuracy measurement compared to PID control strategies in both actions. The PID controller is only applicable in forward action. In order to model the non-linear dynamic system, various tests to model the pH plant for both forward and reverse behavior has been carried-out by using Matlab system identification toolbox. The result shows the linear ARX model reached 91% best-fit performance, while it reached 89% with ARMX Model. Therefore, in linear system model ARX is the best-fit represented compare than ARMAX and state space models. On the other hand, the nonlinear modeling result shows that NARX model much more fit compare than Hammerstein-Wiener with 98.02%, which indicate the system is act more nonlinearity in process. The PID controller has been used to measure the performance of NARX and Hammerstein-Wiener model in controlling the dynamic pH response. The simulation results show that the PID controller based on NARX model provides better response than Hammerstein-Wiener based model, the reason mostly that the nonlinear function that has been used for mapping the output signal fit better than piecewise functions that been used in Hammerstein-Wiener.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PERBANDINGAN PRESTASI DIANTARA KAWALAN ON-OFF, PID DAN FUZZY LOGIC UNTUK PROSES pH DIDALAM APLIKASI DANDANG

Oleh

BALBIR SHAH @ MOHD FADDULLAH

Jun 2013

Pengerusi : Professor Madya Samsul Bahari B. Mohd Noor,PhD

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Industri penjanaan stim adalah diwajibkan untuk mematuhi garis panduan kualiti air seperti yang telah termaktub dibawah akta kilang dan jentera. Pengaratan dan pembentukan kerak ke atas tiub adalah punca utama yang menghalang pemindahan haba yang efektif serta mengakibatkan keretakan dan kerosakan yang teruk keatas tiub. Didalam penjanaan stim, kaedeah untuk rawatan air adalah terbahagi kepada dua kaedah iaitu, proses rawatan air secara kaedah dalaman dan luaran. Fokus utama kajian ini tertumpu kepada process rawatan air secara kaedah dalaman dimana kesan dinamik yang tinggi diuji dengan menggunakan pelbagai aplikasi teknik kawalan. Eksperimen telah dilaksanakan untuk menghasilkan formula proses bagi campuran ammonia hidroksida. Formula proses untuk campuran ammonia hidroksida telah dikenal pasti dan diaplikasikan didalam pelbagai teknik kawalan diantaranya adalah teknik kawalan secara On-Off, kawalan secara PID dan kawalan secara Fuzzy Logic. Teknik kawalan ini direka untuk beroperasi secara automatik didalam tindakbalas yang positif dan negatif untuk membuat pembetulan pada nilai pH. Selain itu,

prestasi untuk setiap teknik kawalan juga dianalisa dan dikenal pasti dengan menggunakan perisian LabVIEW virtual instrumentation (VI). Didalam aplikasi perubahan dinamik untuk sistem statik, keputusan simulasi menunjukkan bahawa kesemua teknik kawalan boleh diaplikasikan untuk kawalan bijak. Manakala, teknik kawalan yang terbaik berdasarkan tindakbalas masa adalah teknik kawalan secara On-Off didalam tindakbalas yang positif dan negative bagi mencapai bacaan pH yang tepat.Manakala, kawalan Fuzzy Logic menunjukkan bacaan yang paling jitu berbanding dengan kawalan PID didalam kedua-dua tindakbalas. Selain itu, kawalan PID hanya boleh diaplikasikan untuk tindakbalas yang positif sahaja. Untuk aplikasi perubahan tetap dan rawak pada sistem dinamik, perisian Matlab telah digunakan menguji pelbagai kaedah untuk mengenal pasti kaedah yang terbaik untuk menghasilkan formula yang tepat bagi proses pH. Keputusan simulasi telah menunjukkan bahawa kaedah ARX telah menunjukkan bacaan ketepatan yang tinggi iaitu 91% berbanding dengan kaedah ARMX iaitu 89%. Manakala, pengujian perubahan rawak pada sistem dinamik telah menunjukkan keputusan bahawa kaedah NARX mencatat ketepatan yang tinggi iaitu 98.02% berbanding dengan kaedah Hammerstein-Wiener. Didalam aplikasi perubahan rawak, kawalan PID telah digunakan untuk menguji kecekapan kaedah NARX dan Hammerstein-Wiener. Keputusan simulasi menunjukkan bahawa kawalan PID didalam kaedah NARX adalah yang terbaik berbanding dengan Hammerstein-Wiener.

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BALBIR SHAH @ MOHD FADDULLAH

I certify that a Thesis Examination Committee has met on **28 June 2013** to conduct the final examination of Balbir Shah @ Mohd Faddullah on his thesis entitled "Comparative Performance of On-Off, Pid and Fuzzy Logic Controllers for pH Process in Boiler Application" in accordance with Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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BALBIR SHAH @ MOHD FADDULLAH

Date: 28th June 2013

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