STUDIES IN MULTIVARIABLE CONTROL OF NUCLEAR BWR/PWR POWER PLANTS

BY
P. PRATAPACHANDRAN NAIR

Thesis Submitted
in Fulfilment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY

to the
DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
NEW DELHI - 110016, INDIA

FEBRUARY—1985

TO MY PARENTS

CERTIFICATE

This is to certify that the thesis entitled "Studies in Multivariable Control of Nuclear BWR/PWR Power Plants" being submitted by Mr. P. Pratapachandran Nair, for the award of the degree of Doctor of Philosophy to the Indian Institute of Technology, Delhi, is a record of bonafide research work he has carried out under my guidance and supervision. The results contained in this thesis have not been submitted to any other University or Institute for the award of a degree or diploma.

Dr. M. Gopal
Department of Electrical Engineering
Indian Institute of Technology
New Delhi 110 016

ACKNOWLEDGEMENTS

I deem it a privilege to place on record my deep sense of gratitude towards my supervisor, Dr. M. Gopal, Department of Electrical Engineering, I.I.T., Delhi for his constant encouragement and guidance during the course of this research work. He has extended his invaluable help and suggestions through discussions at every stage of this investigation.

The initial stages of the research work had been carried out at I.I.T. Bombay. I gratefully acknowledge the authorities of I.I.T. Bombay for providing me the necessary facilities.

The financial assistance received from the Ministry of Education, Government of India and the Government of Kerala, under Q.I.P. scheme is gratefully acknowledged.

It is a pleasure to acknowledge the help received from Dr. Joseph Kurien, System Programmer, I.I.T. Delhi and my fellow research scholar Sri J.G. Ghodekar in numerical computations. I would like to thank Sri K.S.M. Panicker, Sri A. Balasubramonian, Sri Hrishikesan, Dr. P.M.S. Nambisan and Dr. E. Gopinathan for making the campus life pleasant.

I wish to thank Sri P.M. Padmanabhan Nambiar for his patient and excellent typing of the manuscript, and Sri R. Kapoor for making neat drawings.

Finally, I wish to appreciate my wife Radha and children Priya and Prem for their patience and understanding throughout the period of this work.

P. Pratapachandran Nair

ABSTRACT

The main focus of the thesis is on light water reactors which are being commercially designed in the U.S.A., U.S.S.R. and France. Specifically, control problems related to boiling water reactors (BWR's) and pressurized water reactors (PWR's) have been investigated.

The following power plants have been chosen for the studies in multivariable control.

(i) Big Rock Point Reactor

This is a direct cycle forced-recirculation 159 MW (thermal) boiling water reactor plant situated in Charlevoix, Michigan, U.S.A.

(ii) H.B. Robinson Nuclear Plant

This is a 2200 MW (thermal) pressurized water reactor plant situated in Carolina, U.S.A.

In order to obtain the multivariable control strategy, a multi-input mathematical model for the Big Rock Point BWR plant is developed and validated using available experimental data. For the H.B. Robinson nuclear PWR plant, a multi-input linear mathematical model developed by Kerlin and co-workers has been used here for studies in optimal control. A simplified single-input model for the PWR plant is shown to give satisfactory optimal control strategy.

In deriving the mathematical model for the nuclear reactor, there are various parameters whose values are approximately determined either through empirical formulae or by using curve-fitting techniques. This necessitates a controller design which takes into account sensitivity to parameter variations from their nominal values without appreciably deteriorating stability and regulation of crucial system variables.

In this thesis, a new multivariable control algorithm is proposed that guarantees prescribed closed-loop eigenvalues and in addition minimizes a selected performance index which is of standard linear regulator type, modified to include a quadratic sensitivity term.

The following computer-aided-design (CAD) package is reported in the thesis :

(i) Sensitivity-reduced design of continuous linear regulator with prescribed closed-loop eigenvalues.

(ii) Sensitivity-reduced design of discrete linear regulator with prescribed closed-loop eigenvalues

(iii) Design of sensitivity-reduced optimal deadbeat controller

(iv) Design of optimal deadbeat reduced-order observer

The CAD package based on the new multivariable control algorithm has been successfully employed for the controller design of the nuclear power plants.

Relevant background material, reviews and suggestions for further work in this area are also included.

CONTENTS