

Preface

In India, Advanced Heavy Water Reactor (AHWR), a heavy water moderated and boiling light water cooled thermal reactor, has been designed. Its design aims at large-scale commercial utilization of thorium and integrated technological demonstration of thorium cycle. Control and operation of AHWR pose several challenges. In this monograph, different spatial control techniques namely, static output feedback, state feedback control, sliding mode control, fast output sampling feedback, periodic output feedback, and discrete-time sliding mode control are examined for regulation of spatial power distribution in AHWR. AHWR core is considered to be divided into 17 relatively large nodes. The nodal core model has been obtained based on finite difference approximation of the two group neutron diffusion equations and the associated equations for an effective single group of delayed neutron precursors^{*}, xenon and iodine concentrations. Further, nonlinear model characterizing important thermal hydraulics parameters of AHWR has been integrated with the neutronics model to obtain a coupled neutronics–thermal hydraulics model of AHWR. From these nonlinear equations of AHWR system, a vectorized nonlinear model of AHWR has been developed and is implemented in MATLAB/Simulink environment. The model of the reactor is then linearized at the rated power and put into standard state variable form. It is characterized by 90 states, 5 inputs, and 18 outputs. Viability of achieving control over total power and spatial power distribution of AHWR through static output feedback has been investigated and a strategy utilizing conventional concepts for control of global (total) power as well as spatial power distribution is evolved.

As is the case with several large-scale physical systems, the model of the AHWR is seen to possess the simultaneous presence of slow, medium, and fast varying dynamic modes, thereby exhibiting a multi-time-scale property. Hence, in this monograph further, innovative techniques based on singular perturbation are developed for decomposition of the original multi-time-scale system into smaller order subsystems. Four control techniques based on two-time-scale decomposition and two on three-time-scale decomposition are explored for AHWR.

Finally, all the spatial control strategies are compared in terms of their computational intensiveness, sensitivity, robustness, and response under the same

representative transients. Various time-domain specifications and error performance indices are calculated for each transient and the most appropriate control technique is identified for spatial control of AHWR. Although the mathematical model of reactor core, controller design and simulation methodologies have been proposed for AHWR, they can be easily adopted to other types of nuclear reactors.

This monograph can be beneficial to mathematicians, scientists, as well as researchers working on nonlinear modeling and control for a better fundamental understanding of numerically ill-conditioned large-scale systems. The authors acknowledge IEEE and Elsevier for granting the permission to reuse materials copyrighted by these publishers in this monograph. The authors express sincere thanks to Board of Research in Nuclear Sciences, Department of Atomic Energy, Government of India for funding the project entitled “Comparison of Controllers for Advanced Heavy Water Reactor” under the grant 2009/36/102-BRNS/3284. The authors would like to express their deep sense of gratitude to their parents and teachers who have made them competent enough to write this monograph. The authors wish to thank many individuals who had helped them directly or indirectly in completing this monograph particularly Dr. S.R. Shimjith and Mr. P.S. Londhe. Finally, authors wish to acknowledge the support, patience, and love of their spouses and children during the preparation of this monograph.

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Ravindra Munje
Balasaheb Patre
Akhilanand Tiwari

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Munje, R.; Patre, B.; Tiwari, A.

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