Modular modeling and control of dynamic MHD/steam power plants
by John Carrol Shovic

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Electrical Engineering
Montana State University

Abstract:
The subject of this thesis is the description of a Modular Dynamic Modeling System written in FORTRAN. Previous modeling work done on MHD-steam plants is described. The modular modeling system is fully described and, as a demonstration of the validity of the modular system, the current MHD/steam power plant model (System Model IV) has been translated to the modular system and described. A complete FORTRAN program listing of the modular form of system model IV is provided.

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John Carrol Shovic

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ABSTRACT

The subject of this thesis is the description of a Modular Dynamic Modeling System written in FORTRAN. Previous modeling work done on MHD-steam plants is described. The modular modeling system is fully described and, as a demonstration of the validity of the modular system, the current MHD/steam power plant model (System Model IV) has been translated to the modular system and described. A complete FORTRAN program listing of the modular form of system model IV is provided.

CHAPTER I

INTRODUCTION AND REVIEW OF EARLIER WORK

This thesis describes a research activity directed towards developing a top-down-structured modular modeling system for dynamic simulation of magnetohydrodynamic (MHD) steam power plants, conventional steam plants, and other complex dynamic systems.

The major reason the modular system was developed was that the increasing complexity of Montana State University's MHD-steam plant model had brought the project to a point that changes in complexity or plant topology was a significant problem in terms of time and the manpower needed. Therefore, a need was seen for a program structure that would allow fast changes in plant topology. Thus, the modular modeling system presented in Chapter II was developed. The modular system has reduced the time for modification by an order of magnitude determined by four months experience with using and modifying the MHD-steam plant model under the modular system.

Dynamic simulations are very useful in plant parameter identification, plant parameter variation effects, plant response to disturbances, and dynamic control policy evaluation and synthesis. The model presented in this thesis was specifically developed for control policy evaluation and synthesis although it could easily be used for the other uses mentioned above.

The modular system presented here has been constructed with the primary goal of being simple to modify. No strong effort was made to optimize the modular system with respect to either execution speed or length of compiled code.

Review of Earlier Work

The MHD-Steam plant model currently in use at Montana State University is entitled System Model IV. System models I, II, and III were developed by John Aspnes for his doctoral dissertation in 1976 at Montana State University[1]. A further discussion of these models is pertinent here.

System Model I represented initial efforts in dynamic studies of a large-scale MHD/steam combined-cycle electrical power generating plant. The model operated on power flow variables and contained five first-order differential equations. The steam plant was characterized by a cascade of two first-order lags.

System Model II represents a logical extension of the Model I order of complexity. The heat balance and the power flow variable basis is retained. Several transport delays are added, the air preheater model is more detailed, and a new control loop to control air preheat temperature is added. System Model II contained five first-order differential equations.

System Model III is considerably more detailed than previously discussed models. The Combustor/Nozzle/Channel/Diffuser (CNCD) section is much more sophisticated, being represented by polynomial approximations of data resulting from the solution of energy balance, state, and continuity equations for the combustor and the quasi-one dimensional MHD equations for the channel and diffuser. System Model III contained sixteen first-order differential equations.

System Model IV was developed by Daniel Goldsworthy during 1978-1980[6]. This model contains much more detailed models of the components in the plant, including a sophisticated set of steam plant component models. The major control loops are similar to those in System Model III, although there have been changes and many minor loops added. System Model IV is still in use currently, though greatly modified. It currently contains 103 first-order differential equations.

Other MHD-steam plant models, aside from the Montana State University model, include the Gilbert/Commonwealth model[2] and the Babcox and Wilcox Modular Modeling System (MMS) Model[4].

The Gilbert/Commonwealth model is a simulation of a 200-megawatt electric plant. It contains oxygen enrichment and a reheat cycle for the steam turbines. The model was prepared using IBM's CSMP-III dynamic systems computer language[3].

Babcox and Wilcox have developed a Modular Modeling System (MMS) for studying the dynamic characteristics of steam generation units[4]. The MMS is very similar in concept to the system of modeling described by this thesis. The primary differences are:

1. MMS requires the use of a simulation language (Advanced Con-

tinuous Simulation Language (ACSL) developed by Mitchell and Gauthier, Inc., or EASY, developed by Boeing Computer Services) while the modular system in this thesis is coded in standard FORTRAN.

2. MMS is not as well suited toward control policy simulation synthesis and evaluation as is the modular system described in this thesis.

This thesis describes the development, synthesis, protocol, and structure of a modular modeling system for simulating dynamic MHD-steam power plants. The example in Chapter III shows how this modular system works and the listing in Appendix B shows System Model IV coded in the modular system format.

CHAPTER II

THE MODULAR MODELING FORM

The modular modeling form functions on two major levels: The system level of information flow between modules, and the functional level within modules. The first level is establishment of interconnections between modules, which defines system topology through physical variable connections. The second level is the description of function within each module. The five types of modules are described briefly below, as a general understanding of these is necessary to the description of the system information flow.

1. Supervisory Module - This module contains assignments of physical interconnections between modules, time updating procedures, demand function generation, and initialization and termination procedures for the entire model.

2. Component Modules - These modules contain the physical equations governing the modeled device and also contain the linkage needed to transfer physical information and transducer information between modules.

3. Control Module - This module contains the controller equations which generate control signals based on transducer values.

4. Data Output Module - This module contains the code needed to output variables computed by other modules to data files for plotting or other interpretation.

5. Dynamic Solution Module - This module contains the code which implements a fourth order Runge-Kutta integration algorithm.

Each of the above modules is fully described later in the system module section.

SYSTEM INFORMATION FLOW

The modular modeling form has been designed to make all information transfers in the system to be under one of the following six forms:

1. Node (physical variable) transfer.
2. Transducer transfer.
3. State-variable transfer.
4. State-variable derivative transfer.
5. Valve-area transfer.
6. Output-variable transfer.

Node Transfer

Node transfer is the method that component modules use to communicate information concerning current conditions of physical variables (pressure, enthalpy, flow rate, etc.) within component modules to adjacent component modules. A node is defined as the physical junction between any component module and another component module. Each component may have as many nodes associated with it as there are other component modules connected to it. Node transfer information flow occurs only between component modules as diagrammed in Figure 1.

Transducer Transfer

Transducer transfer is the method of information flow between the component modules and the control module. As the name implies, this transfer is used to present the controller with information about current plant conditions. Transducer transfer information flow is diagrammed in Figure 2.

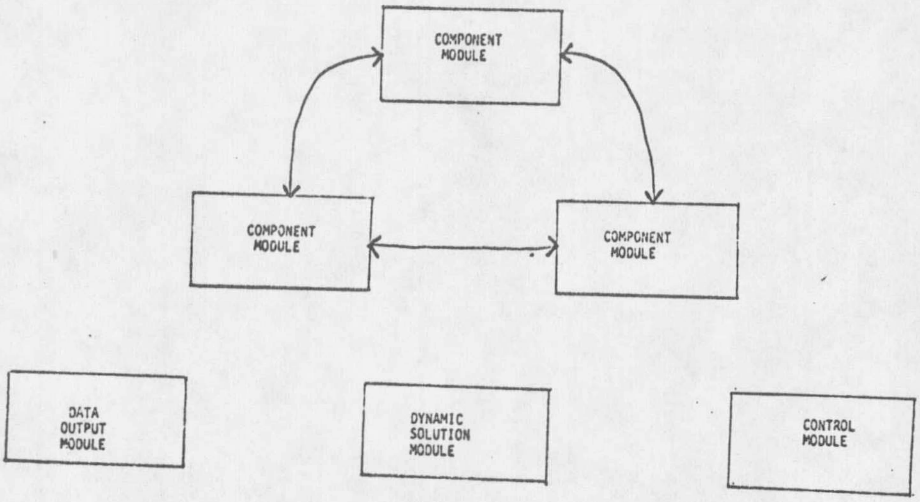

Figure 1. Node Transfer Flow

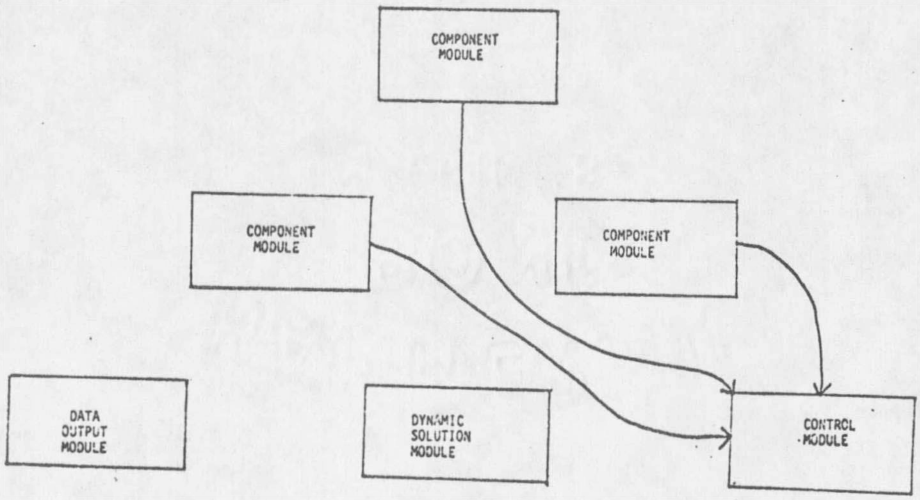

Figure 2. Transducer Transfer Flow

State-Variable Transfer

State-variable transfer is the method of information flow from the dynamic solution module to other modules that contain state variables (i.e., controller and component modules). The dynamic solution module integrates the differential equations, and then using state-variable transfer, returns results to the proper module. State-variable transfer information flow is diagrammed in Figure 3.

State-Variable Derivative Transfer

State-variable derivative transfer is the method of information flow from system modules to the dynamic solution module. The system modules calculate the numerical derivative values for the first-order differential equations, and then using this mode of transfer, send the results to the dynamic solution module. State-variable derivative transfer information flow is diagrammed in Figure 4.

Valve-Area Transfer

Valve-area transfer is the method of information flow from the control module to component modules. The control module calculates the numerical values of valve areas through algebraic or differential equations and then transfers valve areas through valve-area transfer to the appropriate component module in which the valve is located. Valve-area transfer information flow is diagrammed in Figure 5.