POWER SYSTEM APPLICATIONS ENGINEERING
INTERN EXPERIENCE AT
TRW CONTROLS

An Internship Report

by

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Submitted to the College of Engineering of

Texas A&M University

in partial fulfillment of the requirement for the degree of

DOCTOR OF ENGINEERING

August 1984

Major Subject: Electrical Engineering

POWER SYSTEM APPLICATIONS ENGINEERING

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August 1984

ACKNOWLEDGEMENTS

I wish to thank Dr. B.Don Russell for the continuous advice and guidance he gave me during my tenure as a graduate student at Texas A&M, Dr. Norman Griswold for his encouragement and support and Dr. Mehrdad Ehsani and Dr. Don Smith for agreeing to serve on my comittee.

A special thanks to Dr. Neela Mayur, my supervisor at work, and the many staff members whom I worked with at TRW Controls.

Last but not least a big "Thank You" to my wife, Sarojini, for putting up with three years of graduate study, an irascible spouse and yet persist with constant encouragement and support.

ABSTRACT

Power System Applications Engineering
Intern Experience At
TRW Controls (May 1984)

An overview of the author's internship experience with TRW Controls during the period July 1983 through March 1984 is presented. The content of the report tends to weigh towards a more technical rather than a managerial experience. The nature of the projects render it being so.

The importance of Power Systems Control being implemented in an efficient manner necessitates the evolution of more improved Dispatcher Training Simulators, in the Power industry, to train dispatch engineers to confidently control and handle any type of emergency encountered in Systems operations. The author was assigned to two engineering projects during the defined period. The most significant project involved generator dynamics modelling for Hydro and BWR Nuclear generators in a Dispatcher Training Simulator and the other was the generation of software modules to validate data cards for a Hydro Electric project in Chile.

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INTRODUCTION

The Doctor of Engineering program was initiated for the purpose of providing an avenue of graduate study for the engineering graduate with a strong bias toward the practice of engineering and its managerial implications.

The traditional curriculum for a doctoral program of study ,in engineering, invariably had a definite predominance of the usual engineering courses and the inevitable long period of research in a narrow field of one's engineering discipline.

The Doctor of Engineering program not only has a strong content of engineering courses but in addition provides the participant the opportunity of acquiring a significant amount of expertise in the area of Accountancy, Finance and Industrial Management. The truly unique feature of the program is the internship period spent in industry observing and participating in the engineering and managerial aspects of the profession.

The goal of the internship program, in a nutshell, is to expose the Doctoral intern to the "Operating Mechanism" of the engineering profession; the intern actively participates and contributes of his/her knowledge to the solution of engineering problems; in the process the intern puts into practice not only his technical ability but also management techniques learnt at graduate school.

INTERN POSITION WITH THE ORGANIZATION

The author was assigned the position of 'Senior Software Engineer' and reported directly to the Software Development Leader (SDL), who in turn was directly under the supervision of the Power Systems Applications Manager.

The technical nature of the job required the author to modify and/or design software modules for the Power Systems Applications department dealing with Load Flow, Automatic Generation Control, Circuit Breaker Validation, State Estimation and Power System Economic Dispatch and Contingency Analysis.

The Intern supervisor was the Power Systems Application Manager, Dr.Neela Mayur. The two supervisors for the projects I was involved in were Dr.Robert Kilmer and Dr.Will Briggs. All three individuals have extensive experience in Power Systems Applications engineering.

JOB ASSIGNMENTS

Dispatcher Training Simulator

The objective of the assignment was to validate the existing EPRI software modules which deal with modelling of different types of generator prime movers; in the author's case the two types he dealt in detail were the hydro and nuclear Boiling Water Reactor (BWR) model; modifications were effected in the EPRI programs to make them compatible with the Dispatcher Training Simulator being designed at TRWC.

Most of the 24 modules were common to all five(5) types of generator prime movers and the Fossil Fuelled software testing was done by Mr. Carlos Santesteban under the supervision of Dr. Robert Kilmer. The program Design Document explicitly outlines the method adapted to simulate the dynamics of the Hydro and BWR Nuclear modules. Various combinations of parameters were inserted and the resulting graphics were plotted to observe the dynamics of the modules under consideration.

The objectives of the assignment in the Marubeni Hydro-project were to design 26 software modules capable of validating the fields of the customer's data cards,(26) pertaining to the Hydraulic Works Control section of a Hydroelectric project scheme in Chile.

A similar approach exists in the Applications Baseline system and the author modified the master driver (ADBGEN) Applications Data Base Generation to suit the project unique constraints of this particular project. He also designed and coded the 26 software modules corresponding to the 26 types of card images.

TRW CONTROLS

TRW Controls' leadership position in the international marketplace has evolved from the company's pioneering efforts in building successful control systems. In 1959, the company (then known as International Controls Corporation) developed the first solid-state supervisory control system for a major pipeline. This led to other control system applications for the petroleum production and pipeline industries.

In 1968 International Controls Corporation joined TRW, a diversified, high-technology corporation serving worldwide markets. With its new name, and augmented by the technology talents of TRW Inc., TRW Controls expanded its markets to include innovative control systems for the utility and transportation industries.

Today, TRW Controls is a major operating unit of the TRW organization dedicated to serving the energy industries. Its international customers for systems and services include the utility, pipeline, petroleum, and transportation industries. TRW built the first all-solid-state, computer-based supervisory control and data aquisition system, computerized petroleum production control system for offshore operations and the microprocessor-based product line designed to meet demanding environmental extremes.

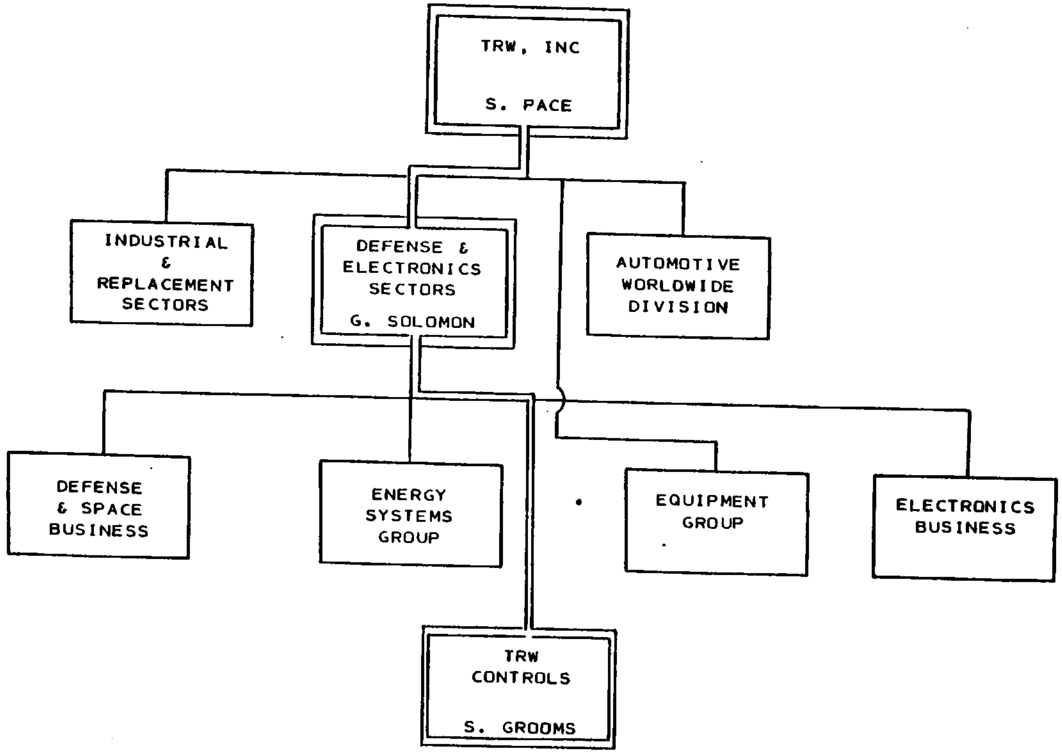


Figure 1: TRW Inc Organizational Overview

Project teams at TRW Controls, are formed to identify customer needs and develop optimum solutions for specific control requirements. All elements influencing adequate system performance are analyzed, including configuration tradeoffs, security, sizing and timing. The systems engineers provide expert design and integration of hardware configurations including master control stations, remote operator consoles, programmable and hardwired remote terminal units. Hardware design involves maximum use of existing, proven equipment, and software is tailored to customer requirements using standard modules as a foundation. All systems feature modular hardware and software for maintainability and expandability.

TRW Controls has complete facilities for production of units, assemblies, and systems incorporating innovative processes, fabrication, and packaging. Strict quality control assures the highest standards of integrity and reliability. Calibrated test instrumentation and automated techniques are employed from assembly checkout to complete system evaluation. This method enables TRW to comply with all design and performance specifications. System operation is always demonstrated before delivery.

Customer personnel, including operators, dispatchers, and technicians, are trained in all aspects of system design and operation. Training is aimed at optimum user understanding for smooth transition to the new system.

Organization and Project Management

One of the key mechanisms through which management strives to reach its goals is the organizational structure itself. The job of the manager is not that of the organization; it is the specialized work of designing the organization,setting its goals, and maintaining its operations. This is accomplished by formulating and defining the purpose and goals, providing the system of communications, and securing the cooperative efforts of the required personnel. The formal organizational structure helps the manager to carry out these functions by:

1. Specializing executive activity.
2. Simplifying the tasks of management.
3. Grouping employees for the purpose of direction and control.
4. Providing the formal channels of communications and coordination.
5. Encouraging the interaction of employees.

Thus, the organizational structure is one of the most important means by which management can bring its limited and precious resources to bear on a problem (1).

The type of organizational structure prevalent at TRWC closely resembles , at times, the 'Functional Organization' structure. This organization is characterized by major subdivision by function, subject matter

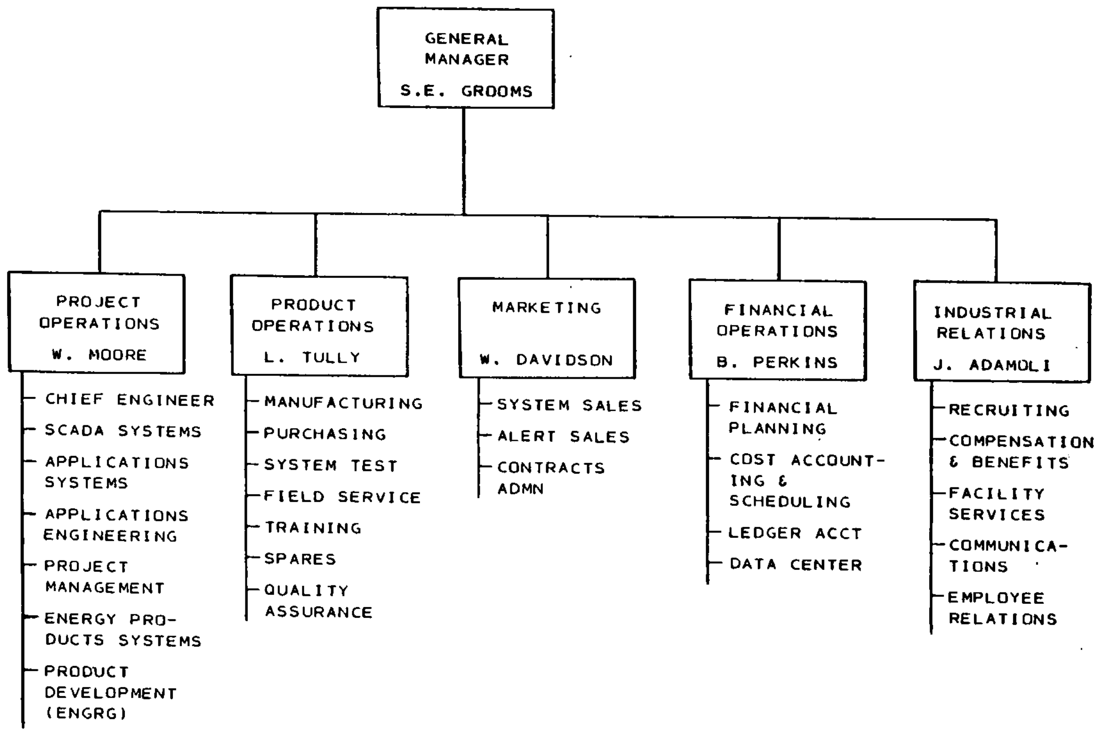


Figure 2: TRWC Organizational Overview

or principal activity. All similar activities are grouped together within and identified by some functional activity title such as manufacturing,marketing, finance, engineering, test, or quality control. Under this concept responsibility and control throughout the organization and at all locations are usually exercised by one executive for each function. The functional concept assumes that the common bond between the individuals and their supervisors (which comes about through their common occupational background) will enhance the cooperation and effectiveness of the individual and the group (2).

Another type of organizational structure inherent in the framework of TRWC is the project concept. TRWC handles many projects all over the world at one given time and thus has been using this concept successfully for the past two decades. It provides a unity of purpose and a basic simplicity that are hard to match in terms of effectiveness. The project organization brings together under one organizational roof, all the administrative, technical and support personnel needed to bring a project from the early stages of development through to operational use (3, 4).

A project organization is formed to accomplish a specific objective that requires special management attention and emphasis for a specified period of time.

(i.e., the design and construction of a specific system). Projects of short duration (weeks or months, few in number) are usually accomplished by a task team or special task force. The objective of the organization is the completion of a specified task within cost and performance goals and on schedule. It is not intended to be a self-perpetuating organization; it maintains viability only as long as the project is not completed. Under each project organization all functional entities required for the development and production of each particular project are duplicated. Each project has a complete line organization that is directed by a project manager who has full authority over all people, facilities, and functions required to produce the specified project or system(5).

Business Areas

The primary business areas are identified as:

- Electric Utility Supervisory Control and Data Acquisition (SCADA) Systems. Computer based real-time systems(Hardware,Software) utilised by Electric Utility companies to monitor and remotely control critical operations of their power systems networks (Transmission lines,Transformers, Switches,Breakers)
- Electric Utility Energy Management Systems (EMS) Includes SCADA and adds real time system wide control of power generation equipment for purposes of optimising system regulation and economics, including the effects of fuel costs, power transmission losses and buy/sell (energy) contracts with other Electric Utility companies. The EMS also provides real-time and study programs which correct metering deficiencies, analyse the operational security of the power system, and predict contingent conditions which could cause the power system to become operationally overloaded or unreliable.
- Petroleum SCADA Systems Computer based real-time systems (Hardware,Software) utilised by companies who produce and transport petroleum products to monitor and remotely control operations (pipelines, compressors,wells,valves,regulators)

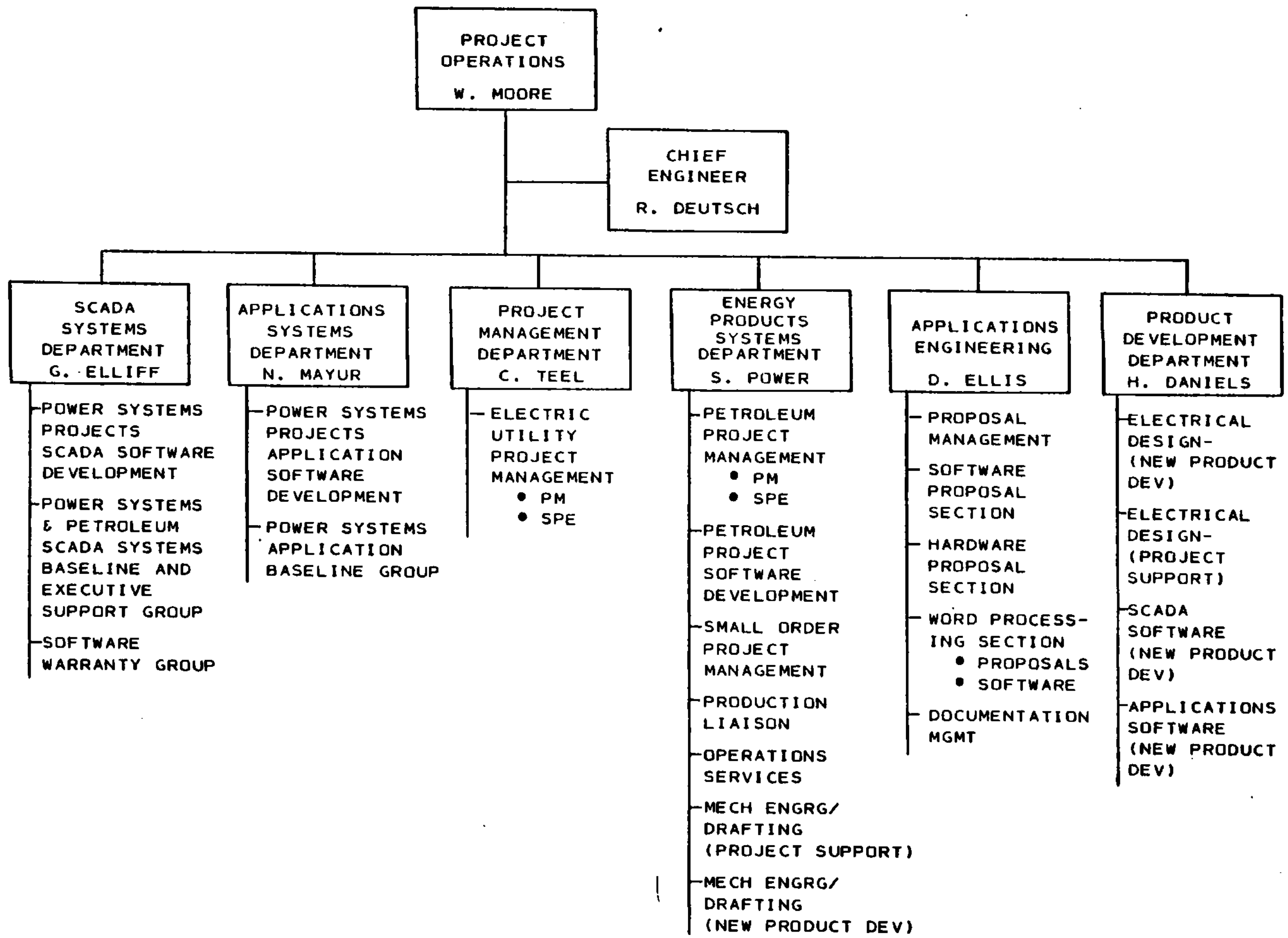


Figure 3.Project Operations Overview

including such operational applications as pipeline leak detection and production (well head) operating tests.

The Secondary business areas are identified as:

- Add-on hardware (to expand delivered system capability and/or capacity)
- Add on software (to expand delivered system capability and/or capacity)
- Hardware spares(to replace or add to customer's store of spare parts for TRW Controls delivered equipment)
- Maintenance services (to provide TRW Controls personnel to support on-site (resident) or on-call (as requested) maintenance services on installed TRW Controls provided systems)
- Replacement Remote Terminal Units (RTU's) (to provide TRW built add-on RTU's to customers with installed systems (and RTU's) originally delivered by other suppliers)
- Training: hardware and software training for customers to provide basic and advanced capabilities in the preventive and remedial maintenance of SCADA/EMS systems.

Project Responsibility and Management Philosophy

Project Managers act as contractors who award "Subcontracts" to functional organizations making up the TRWC Corporation and perform all functions necessary to fulfill all obligations. TRW Functional Organization accepts "Subcontracts" (Technical Requirements, Budget, Schedule)

	APPS ENGRG (INCLUDING WORD P.)	PROJ MGMT	ENERGY PROD SYS	SCADA SYS	APPS SYS	SW SERVICES	ENGINEERING	TEST (INCLUDING PE)	FIELD SERVICE	TRAINING	MANUFACTURING	Q.A. (INCLUDING AVAIL. TEST)
SYSTEM DESIGN												
• HARDWARE	X	X	X				X					
• SOFTWARE	X	X	X	X	X							
DETAIL DESIGN												
• HARDWARE							X					
• SOFTWARE			X	X	X							
BUILD/BUY												
• HARDWARE		X	X					X			X	X
• SOFTWARE			X	X	X							
INTEGRATE												
• HARDWARE								X				
• SOFTWARE			X	X	X	X						
TEST												
• HARDWARE								X				
• SOFTWARE			X	X	X	X						
DOCUMENT												
• HARDWARE							X	X				
• SOFTWARE	X		X	X	X	X						
PACK, SHIP												
• HARDWARE		X	X					X				X
• SOFTWARE		X	X	X	X	X						X
INSTALL, TEST												
• HARDWARE									X			X
• SOFTWARE			X	X	X							X
TRAINING												
• HARDWARE										X		
• SOFTWARE			X		X					X		

Figure 4 Matrix of Organizational Responsibilities

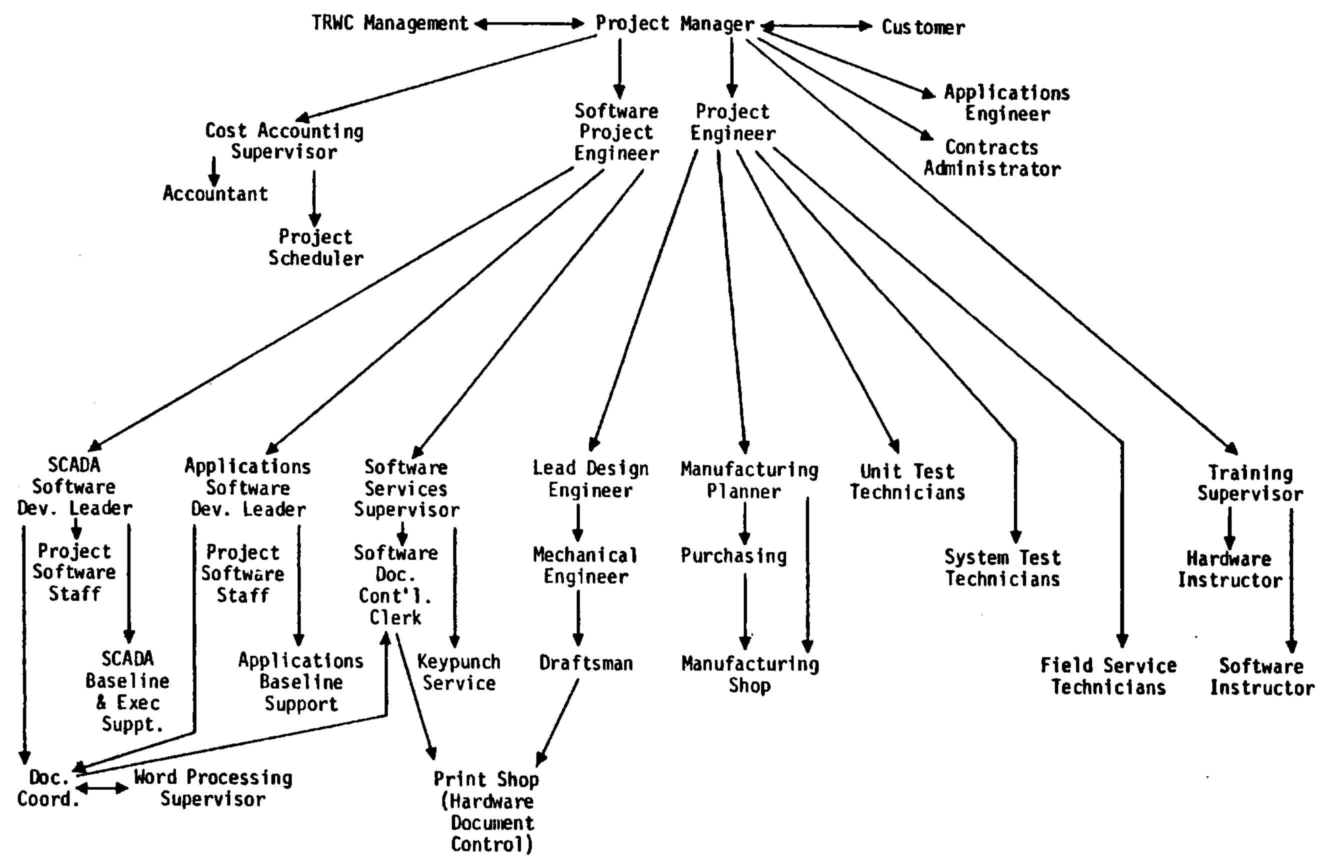


Figure 5 Project Organization Overview

Project Managers utilize Software Project Engineers (SPE) and (Hardware) Project Engineers (PE) to define Technical Requirements of work to be "Subcontracted" to Functional Organizations , which review and agree upon the technical content of the work to be performed. The project manager (and SPE,PE) establish Project Level Budget and Schedules for work to be "Subcontracted" to Functional Organizations based on related proposal costs and schedules. Functional Organizations review and agree upon Financial (Man-hours, Other Direct costs) Budgets and Schedules (elapsed time) necessary to satisfy the Technical content of the work to be done (6).

Characteristics of TRWC Project Organization Concepts

Advantages

Project teams within Functional Organizations (SCADA,Applications Systems,Energy Products Systems).

Standardization of Product application (use of SCADA and Applications Baseline).

Staff Administration is maintained at the Functional Organizational level.

Disadvantages

- Conflicts between Project Management (minimize project cost and schedule) and Functional Organizations (staff training and assignment diversity).
- Short term staff assignments for certain functions (as compared to projected concepts) limiting

" Project ownership " advantages.

DISPATCHER TRAINING SIMULATOR

Power Systems Controls

Electric power systems are continually becoming larger, more interconnected, and are being forced to operate with lower capacity reserves in both generation and transmission. Transmission voltage levels are increasing so that each line can carry more and more real power. An extra high voltage (EHV) transmission line may carry up to 2500MWe. The individual generating units are often capable of generating 1000-2000 MW of real power. These trends, coupled with the fact that most large units under construction or recently built are located far from the load centers, place a heavy responsibility on the dispatch control operator who makes the decisions that control the operation of the overall power system.

The dispatch control operator's decisions must be consistent with the purposes and objectives of an electric power system,which described briefly are:

1. To generate sufficient power for present and future consumption.
2. To transmit electric power to load centers in a safe and efficient manner (transmitted at high voltage, thus, at relatively low current, to minimize power loss).
3. To distribute electric power to specific

users (distributed at relatively low voltage for safety and to facilitate the final utilization).

4. To provide a continuous and uninterrrupted supply of electric power.
5. To provide high quality electric power (good regulation, little harmonic content, with minimum spikes and transient content).
6. To cause minimum disturbance to the environment.
7. To operate the system in the most efficient manner possible consistent with security restraints.

The control dispatch operator must also work in harmony with a variety of automatic control equipment in order to make decisions such as whether or not the system is operating in a normal state, whether the equipment scheduled for maintenance can be serviced without having a detrimental effect on system performance, and which generation units should respond to unexpected large changes in system operation, such as unplanned outages. The dispatcher's most important responsibilities are to know the state of the system at all times and when and how to intervene during emergencies in the largely automated system control procedures.

In many ways, the systems operator is similar to an aircraft pilot. Under normal flying conditions, the plane can be flown by an autopilot system. A computer control system that can literally fly the airplane and allow the pilot to relax or concentrate on other things for a short time. Even when the pilot is actually flying the plane, the computer provides valuable data concerning the condition of the plane and the flight.

It is quite clear that what is needed is a training capability that not only models the trainee's power system realistically, but also interacts with the trainee in exactly the same way as the man/machine interface in the actual control room. This is, in fact, the same concept implemented in the training of aircraft pilots and nuclear power plant operators. With such a design, the trainees are almost unaware that they are operating a simulator and not the real aircraft or the actual nuclear power plant (7).

<u>Area Control Simulation</u>

Power system dynamics have been studied by many different models and for many different purposes for more than 40 years. Models have been used to simulate dynamics ranging from the extremely fast electrical transients such as switching surges to quasi-steady state studies such as hydro scheduling and spinning reserve studies. Normally, the extremely fast transients are simulated and studied over a short real time period (a few seconds or less) whereas very slow dynamics are of concern over a much longer time frame (in order of minutes, hours, days or even weeks). To perform a meaningful simulation at reasonable cost, especially when many case studies or design alternatives are examined, the simulation model must be tailored for the specific dynamic region of concern.

The dynamics of concern in area control and automatic generation control are relatively slow phenomena with time constants normally on the order of seconds to minutes and greater. However, to simulate the desired dynamics with a reasonable degree of accuracy and to represent frequency fluctations due to the random load, time constants as fast as a few seconds should be approximately represented where required. High frequency synchronizing swings between power plants are assumed to be too fast and of no concern in automatic generation control. Therefore, an energy balance method is used to eliminate the power plant swings and, as a result, generators, excitation systems and explicit network models are not represented in the simulation.

For the control simulation, the basic system variables that must be represented include unit generation output, control area frequency, control area net tie flows, area control error (ACE), and other automatic unit control signals. All models of power system components are reduced to a level of simplification consistent with accurate representation of these basic system variables. Likewise,the interconnection of the power plant models can be simplified to eliminate the electromechanical intermachine rotor oscillatations while still retaining a valid representation of the average frequency of the total power system. The elimination of these intermachine oscillatations results in a uniform model. All units swing together with identical frequency excursions as if they were all on one common turbinegenerator shaft (8).

Digital simulation consists of solving a system of ordinary differential equations using a digital integration algorithm. The equations describing the dynamic relationships of the system being simulated are broken down into first-order differential equations similar to the procedure required for implementation on an analog computer. However, instead of using analog integrators a digital procedure is used to integrate the equations and in this manner the computation of all the system variables is performed as the model responds to given system disturbances (such as load magnitude fluctuations) and automatic control commands. The results of a simulation are usually examined by studying plots and/or tabular data of the variables of concern. The Area Control Simulator will function in a manner similar to other standard simulation programs like Continuous System Simulation Language (CSSL) and Continuous System Modeling Program (CSMP) except that the simulator has been streamlined to include only the necessary functions, program storage, and data storage required for the power system models. A coarse integration step size of one second is used for most of the simulator although, a one-half second step size is used in the fossil fuel boilers, for numerical stability purposes (9).

The basic components that are modelled in the simulator are eight types of prime movers, a uniform frequency model, a load dispatch office, and a simplified external dynamic model. The prime mover models include five types of fossil fuel boilers,a hydro unit and a boiling water reactor.

The most important variable of each prime mover model is the power plant megawatt output. Therefore, the power plant models do not require the level of detail necessary for power plant design or control studies. Accordingly, the prime mover models have been simplified to include only those plant dynamics that significantly affect the mechanical power input to the turbines, and thus retain a reliable representation of the plant's

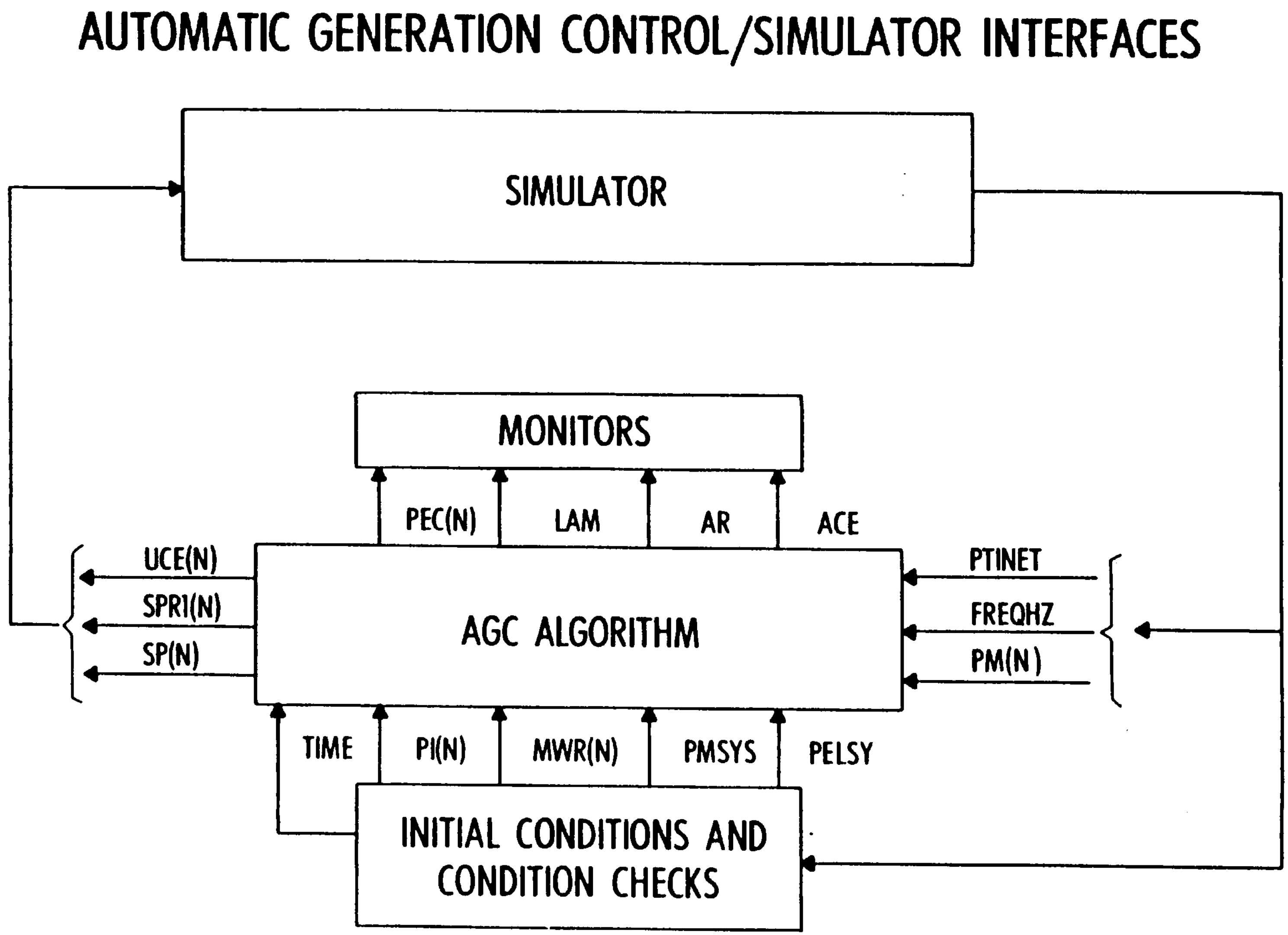


Figure 6. AGC/Simulator Interface

response to automatic generation control and regulation signals.

In this simulator, no attempt has been made to model special dispatch control algorithms although a basic control algorithm has been included. One of the main uses intended for this model is the study of various automatic generation control (AGC) schemes and each utility or control vendor has its own approach to how this should be designed. It is expected that most users will develop a subroutine that simulates their own AGC algorithms to replace the basic representative algorithm that has been included. All the basic signals of frequency, unit generation, and net tie flow are available as inputs and the ability to represent each unit or composite unit by a separate cost curve is provided. With a basic understanding of both FORTRAN and the program structure of the simulator, the user will be able to integrate his own control scheme as part of the simulator and perform a wide variety of studies as indicated in the following section (10).

Uses For The Area Control Simulator

It has been stated that the Area Control Simulator is capable of studying the performance of automatic generation control systems. In addition it is also capable of evaluating the impact of prime mover dynamics, generation mix, and load characteristics on the overall performance of a power system's load-frequency control. In general the simulator can be used to study the effects of generation plant designs and generation control on a power system's energy balance performance. Most power system dynamic transients which would not require the representation of the individual transmission system elements fall in to this category and can be evaluated with the Area Control Simulator.

Automatic Generation Control Studies

The simulator can be used to accurately represent most power systems that are not primarily hydro-based. Various control center methods of economic dispatch and load-frequency control can be simulated and evaluated. The most valuable asset that this tool has is its repeatability of case studies. For example, RMS values of the area control (ACE) and standard deviations of ACE will provide a quantitative analysis of each controller. This simulator provides a valuable "off-line methcd of testing new automatic generation control systems before their implementation on the real power system. Even hydro-based systems could be examined by adding additional hydro models that represent with more detail the variety of dynamics that exist in modern hydro units.

Economic Dispatch

A user of the simulator can program a specific economic dispatch algorithm and enter it as part of the load dispatch office model. In economic dispatch studies, system problems that can affect the long term automatic load following capability such as telemetry failures and other data errors can also be studied and simulated. Loss of generating unit and a smooth transition to a new economic operating point are important considerations in evaluating automatic dispatch and load following strategies. Usually a means of load prediction is required for automatic load-following and the performance of such algorithms can be evaluated through simulation.

Load-Frequency Control (LFC)

Various load -frequency regulation algorithms for following the short-term fluctuations in the load trend can be integrated into the LFC model and their performance evaluated. Quantitative studies can be performed to determine the amounts of power required for effective regulation and to investigate various methods of distributing the regulation function among the generating units. There are different requirements for various load conditions such as morning pick-up and the peak of the day. Many parameters of the data acquisition system can have a significant effect on the regulation performance(11).

Power System Models

The various components of the power system are modelled to a level of detail which permits the significant dynamics of the power system to be accurately simulated within the limitations of available computation (CPU) time and data quality. As it applies to the DTS, the term "significant dynamics" signifies those transient electromechanical effects which are active for a period of one second or longer and have pronounced affect on the power system frequency and/or interchange.

In order to allow for maximum simplification of the power system model while, at the same time, maintaining a representation which adequately reflects the significant dynamics of the power system, the following assumptions are judged to be appropriate:

1. The duration of the transient power swings between generators following a disturbance is much shorter than the one-second solution step which will be used to calculate the dynamic response of the power system. Accordingly, such swings will be ignored, i.e., all generation sources within a given island will be assumed to be in synchronism at all times. (Note: It is implicitly assumed that the power system dynamic model is transiently stable.)
2. The transient electrical performance of synchronous

machines (generators) and exciters do not need to be modelled since the duration of such a transient is less than the one-second solution time step which is to be used to calculate the dynamic response of the power system.

3. The transient response of governors for thermal generator units is faster than the basic one-second solution period and accordingly, need not be modelled. The transient response of governors for hydraulic units spans a period of several seconds; therefore, they must be represented within the dynamic model of the power system.
4. Power system load dynamics are not being modelled since the duration of such dynamics is typically small (tenths of a second) relative to the one-second dynamic solution time step which will be used.
5. The level of detail proposed for generator unit models in this document is based solely upon engineering considerations. Accordingly, during the design phase for the DTS, appropriate tests will be performed to ascertain whether or not the CPU time required by the proposed model is excessive. If it is, further tests will be performed to determine the best way to reduce

the complexity of the proposed models such that the CPU timing requirements are satisfied and minimum impact on the accuracy of the dynamic simulation is realized.

Generator Unit Model

The static representation for generator units that is currently employed by the applications baseline is expanded to a dynamic model which considers those electromechanical transients that are significant relative to the one-second integration time step which is to be used to solve for the dynamic response of the power system. As described above, the electrical transients associated with the synchronous machine and the exciter, as well as the governor for thermal units, are sufficietly brief to permit the omission of these elements from the generator unit dynamic model. The remaining generator unit elements that are modelled are related to the prime mover and its associated controls which exhibit a transient behavior for one or more seconds.

Three types of generator unit prime mover models are supported:

1. Fossil Fueled Thermal
   - Once-Through Supercritical or Subcritical Boilers
   - Drum Type Oil-Fired, Coal-Fired or Non-Reheat boilers
2. Nuclear - Boiling Water Reactor (BWR)
3. Hydraulic Turbine

DGUTES Flowchart

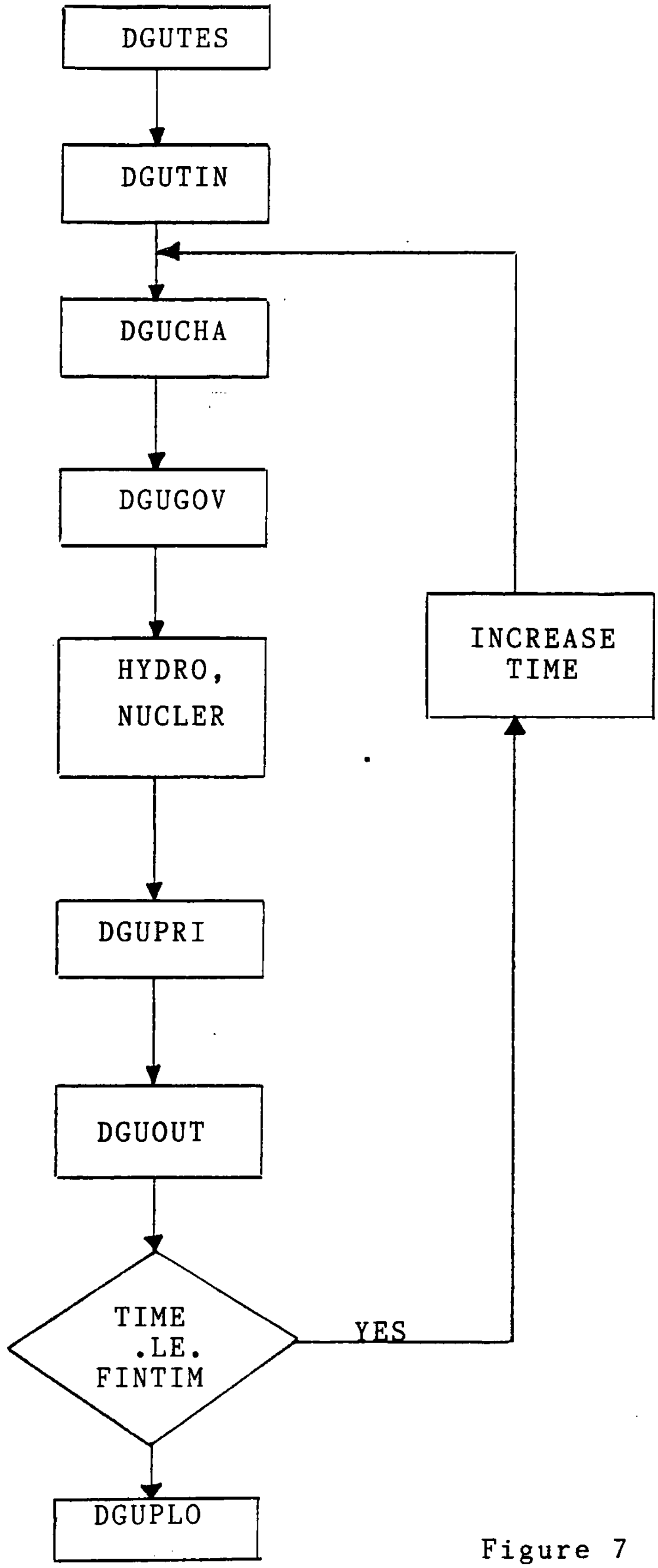


Figure 7

1.Fossil-Fueled Thermal Unit Models

Once-Through Type Boilers The functional diagram for the model of a generator unit which is supplied by a fossil-fueled once-through type of steam supply system is shown in Figure 9. By supplying appropriate parameters to this model, the performance of supercritical or subcritical units maybe modelled.

For sake of an example, two sets of model parameters are shown in Table 1, one for supercritical, the other for a subcritical type of fossil fuelled thermal unit.

Drum Type Boilers The functional diagram for the model of a generator unit which is supplied by a fossil-fuelled drum type of steam supply system is shown in Figure 10. By supplying appropriate parameters to this model, the performance of oil-fired, coal-fired, and non-reheat units may be represented.

Example parameters for an oil-fired, drum type unit are shown in Table 2.

2. Nuclear Boiling Water Reactor (BWR)

Nuclear Prime Mover Subroutine (NUCLER) describes the dynamics of a Boiling Water Reacter (BWR) with respect to its pressure regulator offset and recirculation flow effects on the unit's mechanical power output. A functional flow diagram is given in Figure: 11. A more detailed single line drawing of the same model is given in Figure 12. In Figure 13 omega represents system speed (frequency/60), CSPEDF is the frequency setpoint, SPYB is governor setpoint, and PMYB is the mechanical power output. The following is

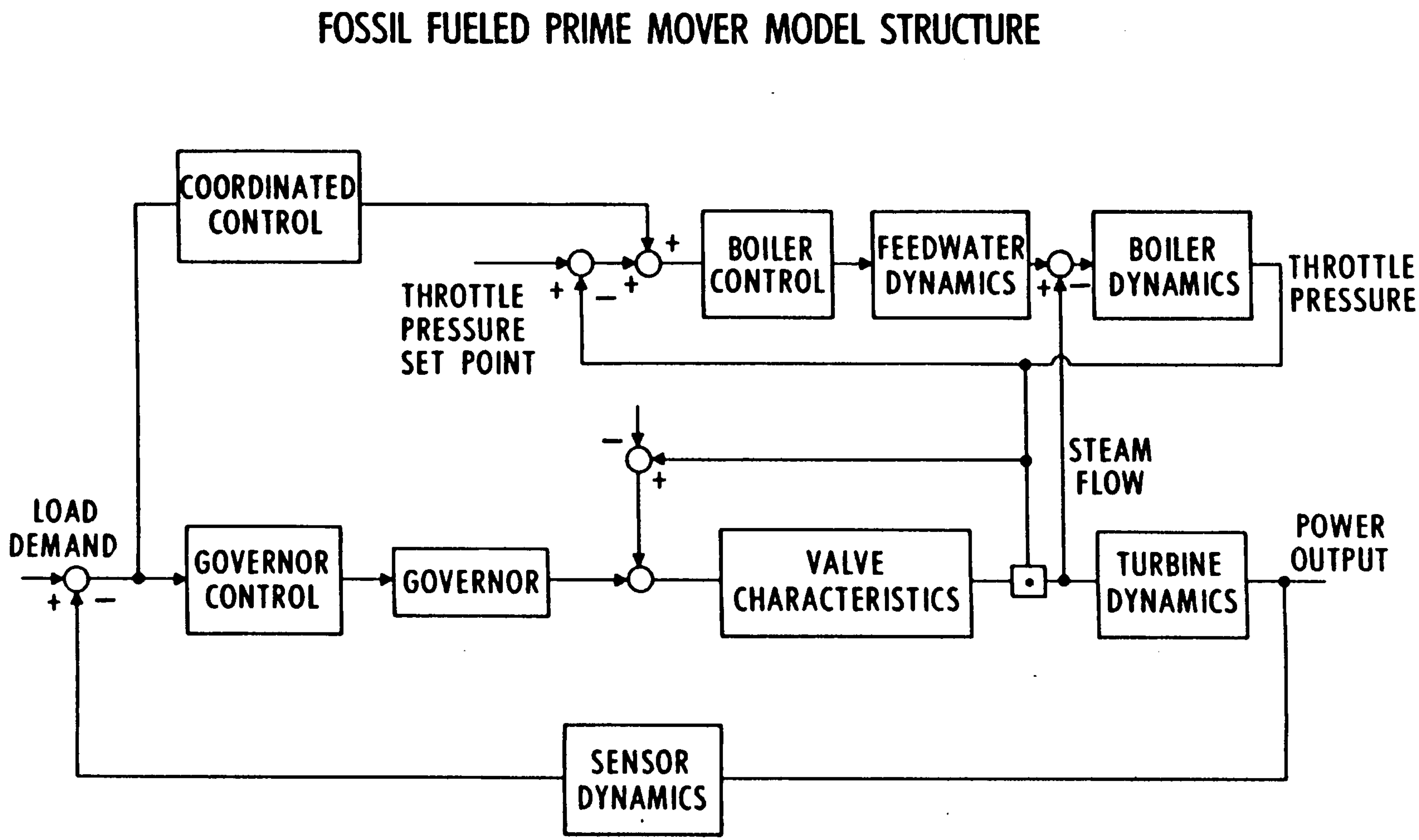


Figure 8. Fossil Fueled Prime Mover Model Structure

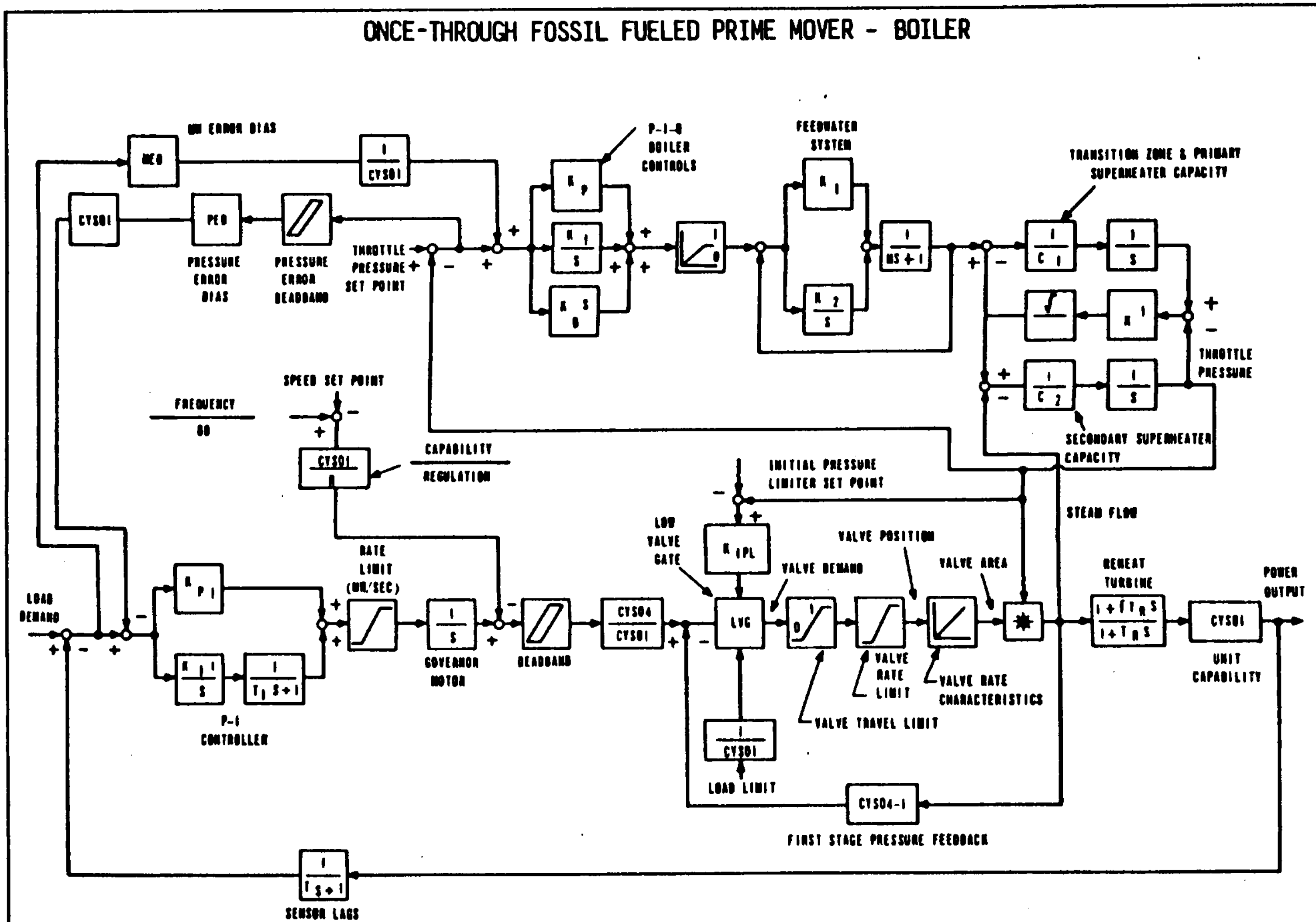


Figure 9. Once-Through Fossil Fueled Prime Mover

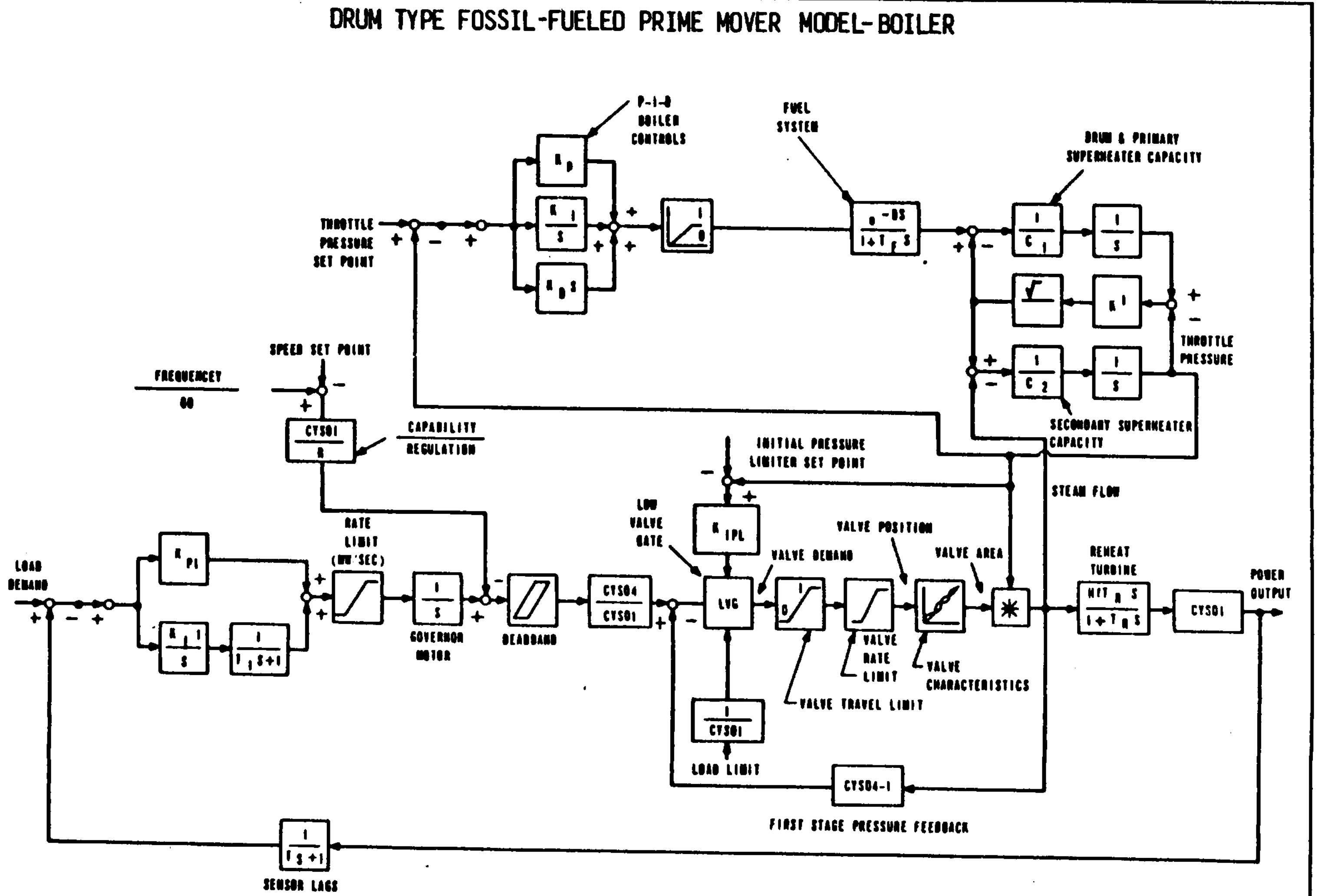


Figure 10. Drum Type Fossil Fueled Prime Mover Model

EXAMPLE PARAMETER VALUES FOR THE FOSSIL-FUELED, ONCE-THROUGH PRIME MOVER MODEL

		SUBCRITICAL	SUPERCRITICAL
K_s	MANUAL LOAD DEMAND GAIN	TBP	TBP
	RAISE/LOWER DEMAND RATE LIMIT	0.3 MW/SEC	1.0 MW/SEC
	DEMAND ACCUMULATOR OUTPUT LIMIT	138 MW	538 MW
CYS01	BASE VALUE OF UNIT (MECHANICAL)	191 MW	745 MW
R	SPEED REGULATION	0.05	0.05
K_{P1}	GOV. CONTROL PROPORTIONAL GAIN	0.01	0.095
K_{I1}	GOV. CONTROL INTEGRAL GAIN	0.10	0
T_1	GOV. CONTROL TIME CONSTANT	100 SEC	175 SEC
CYS03	DEADBAND	3 MW	10. MW
CYS04	FIRST STAGE PRESSURE FEEDBACK INDICATOR	1.0	1.0
K_{IPL}	INITIAL PRESSURE LIMITER GAIN	10	10
	VALVE RATE LIMIT OPENING	0.025 SEC^{-1}	0.025 SEC^{-1}
	VALVE RATE LIMIT CLOSING	0.100 SEC^{-1}	0.100 SEC^{-1}
	VALVE TRAVEL LIMIT	0 $\rightarrow$ 1 p.u.	0 $\rightarrow$ 1 p.u.
	INITIAL PRESSURE LIMITER SETPOINT	0.85 p.u.	0.85 p.u.
	SPEED SETPOINT	1.0 p.u.	1.0. p.u.
	LOAD LIMIT	191 MW	745 MW
F	PORTION OF POWER DEVELOPED BEFORE REHEATER	0.28	0.28
T_R	REHEAT TURBINE TIME CONSTANT	8 SEC	8 SEC
T	SENSOR LAG TIME CONSTANT	1 SEC	1 SEC
C_1	TRANSITION ZONE PLUS PRIMARY SUPERHEATER STEAM CAPACITY REPRESENTATION	27.042 p.u.	6.5938 p.u.
C_2	SECONDARY SUPERHEATER STEAM CAPACITY REPRESENTATION	6.0417 p.u.	3.8771 p.u.
K_1	FEEDWATER SYSTEM PROPORTIONAL GAIN	0.9881	0.9881
K_2	FEEDWATER SYSTEM INTEGRAL GAIN	0.0214	0.0214
M	FEEDWATER SYSTEM INERTIA TIME CONSTANT	20 SEC	20 SEC
K_P	BOILER CONTROL PROPORTIONAL GAIN	4.5	1.76
K_I	BOILER CONTROL INTEGRAL GAIN	0.03	0.112
K_D	BOILER CONTROL DERIVATIVE GAIN	44.	88.
T_p	THROTTLE PRESSURE SETPOINT	1.0 p.u.	1.0 p.u.
MEB	MEGAWATT ERROR BIAS	0.0382	0.514
PEB	PRESSURE ERROR BIAS	3.926	1.0
	PRESSURE ERROR DEADBAND	0.004 p.u.	0.006 p.u.

Table 1. Parameter Values for the Fossil- Fueled Once-Through Prime Mover Model

EXAMPLE PARAMETER VALUES FOR AN OIL-FIRED, DRUM-TYPE PRIME MOVER MODEL

K_S	MANUAL LOAD DEMAND GAIN	TBP
	RAISE/LOWER DEMAND RATE LIMIT	0.3 MW/SEC
	DEMAND ACCUMULATOR OUTPUT LIMIT	163 MW
K_{P1}	GOV. CONTROL PROPORTIONAL GAIN	0.0094
K_{I1}	GOV. CONTROL INTEGRAL GAIN	0
T_1	GOV. CONTROL TIME CONSTANT	100 SEC
CYS01	BASE VALUE OF UNIT SIMULATED	225 MW
R	SPEED REGULATION	0.05
DEADBAND	DEADBAND	0.06 MW
CYS04	FIRST STAGE PRESSURE FEEDBACK INDICATOR	1.0
K_{IPL}	INITIAL PRESSURE LIMITER GAIN	10.0
	VALVE RATE LIMIT OPENING	0.025 SEC^{-1}
	VALVE RATE LIMIT CLOSING	0.100 SEC^{-1}
	VALVE TRAVEL LIMIT	0 $\longrightarrow$ 1 p.u.
	INITIAL PRESSURE LIMITER SETPOINT	0.85 p.u.
	SPEED SETPOINT	1.0 p.u.
	LOAD LIMIT	225 MW
f	PORTION OF POWER DEVELOPED BEFORE REHEATER	0.28
T_R	REHEAT TURBINE TIME CONSTANT	8 SEC
T	SENSOR LAG TIME CONSTANT	1 SEC
C_1	DRUM PLUS PRIMARY SUPERHEATER STEAM CAPACITY REPRESENTATION	17.430 p.u.
C_2	SECONDARY SUPERHEATER STEAM CAPACITY REPRESENTATION	11.668 p.u.
D	FUEL FIRING SYSTEM DELAY TIME	6 SEC
T_F	FUEL SYSTEM TIME CONSTANT	9 SEC
K_P	BOILER CONTROL PROPORTIONAL GAIN	0.8
K_I	BOILER CONTROL INTEGRAL GAIN	0.015
K_D	BOILER CONTROL DERIVATIVE GAIN	30.
T_P	THROTTLE PRESSURE SETPOINT	1.0 p.u.

Table 2. Parameter Values for an Oil-Fired Drum-Type Prime Mover Model

EXAMPLE PARAMETER VALUES FOR THE HYDRO UNIT MODEL

K_s	MANUAL LOAD DEMAND GAIN	TBP
	RAISE/LOWER DEMAND RATE LIMIT	TBP
	DEMAND ACCUMULATOR OUTPUT LIMIT	MW RATING
R	SPEED REGULATION	0.05
r	TRANSIENT REGULATION	0.40
CYP03	DEADBAND	1 MW
T_r	TRANSIENT DROOP TIME CONSTANT	8 SEC
CYP05	RATE OF GATE LIMIT	43.33
MW/SEC		
	(= MW RATING/GATE FULL TRAVEL TIME)	
CYP06	GATE UPPER LIMIT	MW RATING
CYP07	GATE LOWER LIMIT	0 MW
	(= MW CORRESPONDING TO NO LOAD)	
T_w	WATER STARTING TIME	2 SEC

Table 3. Parameter Values for the Hydro Unit Model

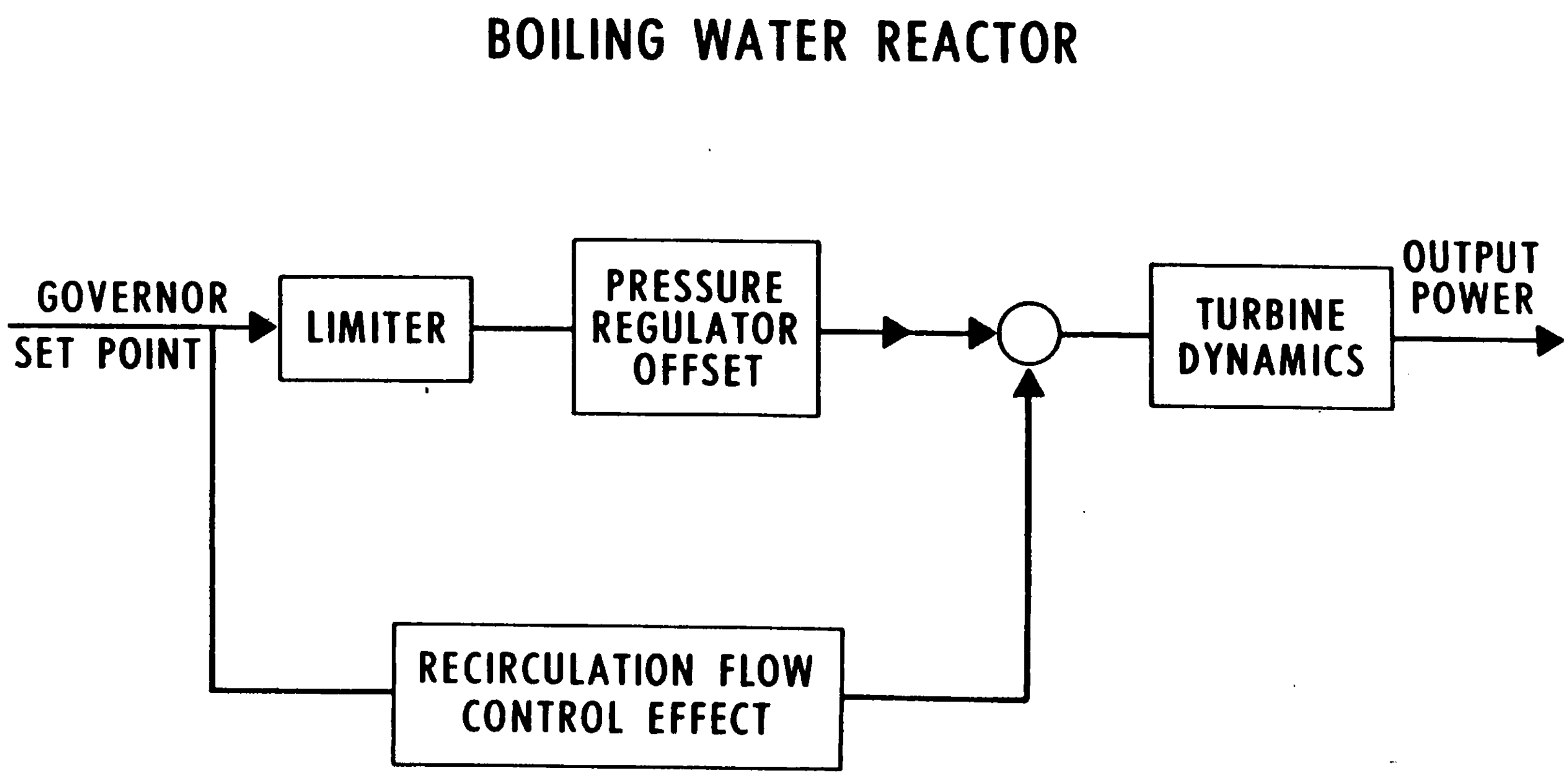


Figure 11. Nuclear Boiling Water Reactor

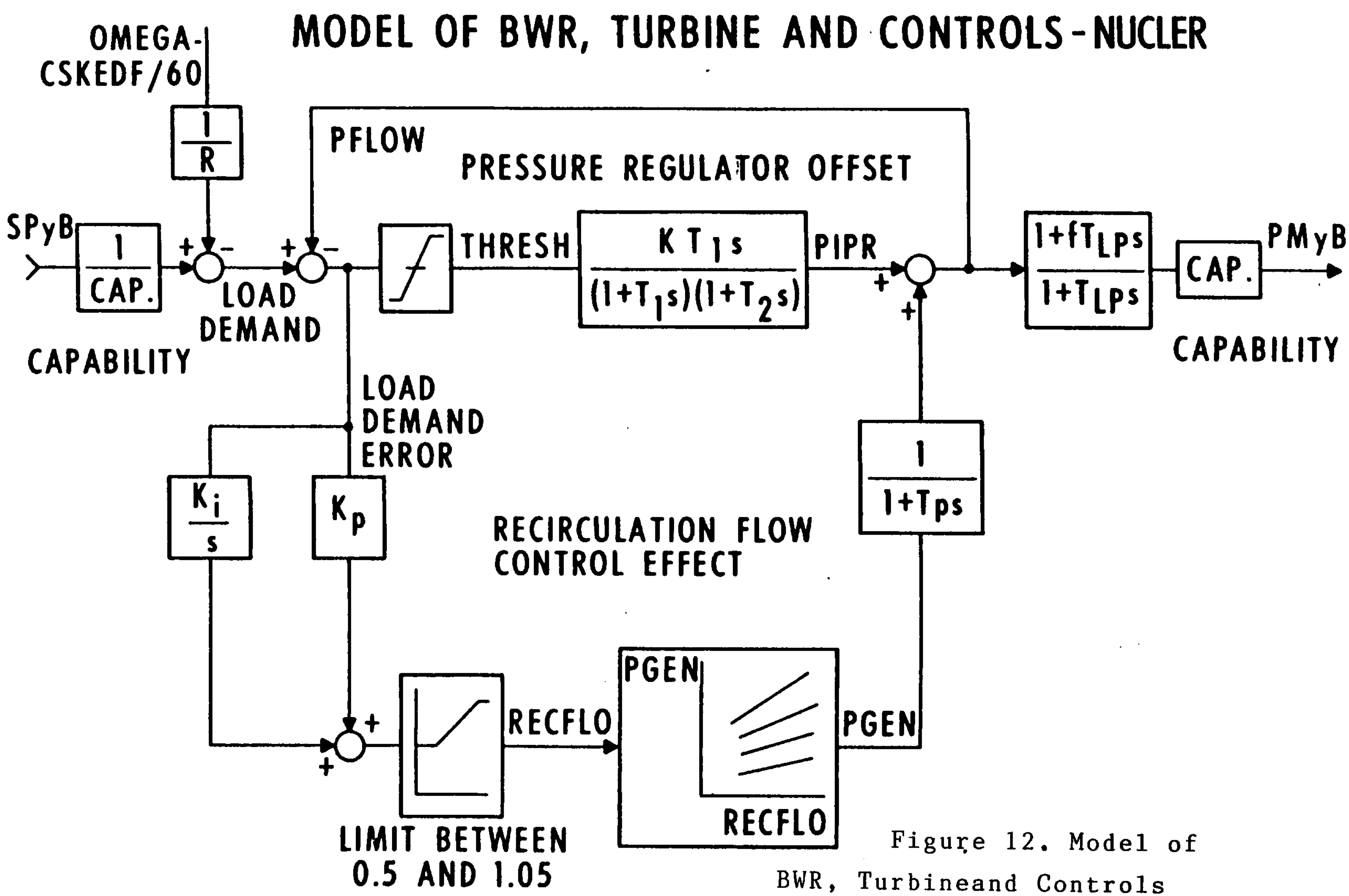


Figure 12. Model of BWR, Turbineand Controls

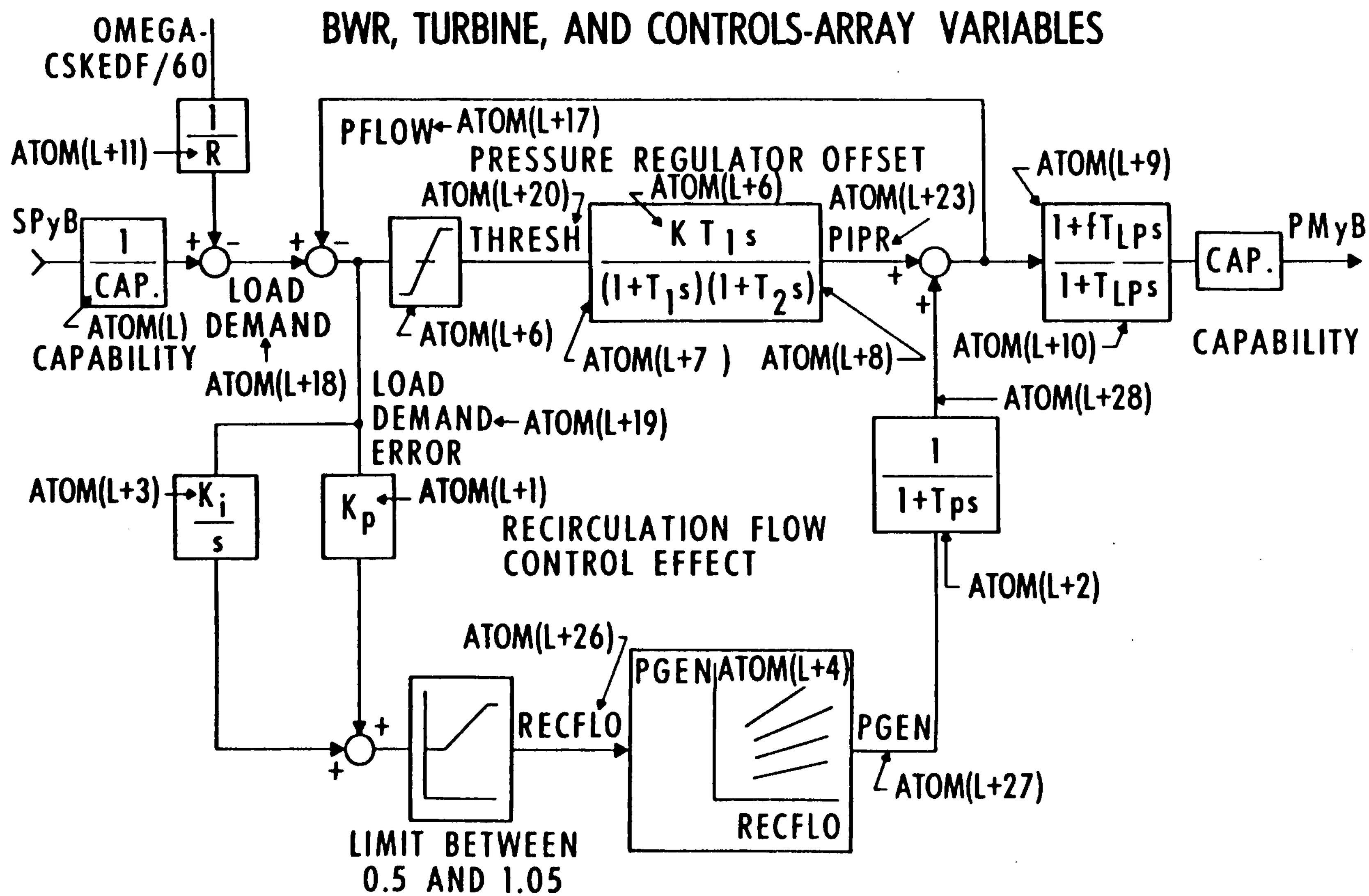


Figure 13. BWR,Turbine and Controls-Array Variables

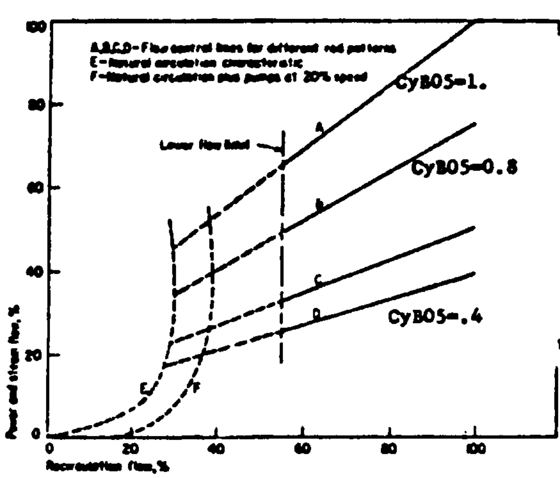
Table 4. Parameter Values for the Nuclear BWR Unit Prime Mover Model

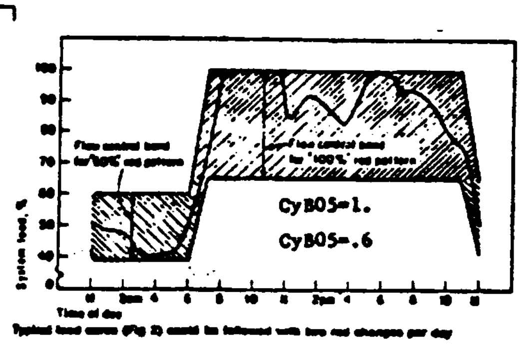
EXAMPLE PARAMETER VALUES FOR THE NUCLEAR (BWR) UNIT MODEL

K_s	MANUAL LOAD DEMAND GAIN	TBP
	RAISE/LOWER DEMAND RATE LIMIT	TBP
	DEMAND ACCUMULATOR OUTPUT LIMIT	1550 MW
CAP	CAPABILITY, MW, PER UNIT BASE FOR POWER (ELECTRICAL)	1550 MW
K_p	PROPORTIONAL PART OF RECIRCULATION CONTROL	0
T_p	IN-CORE THERMAL TIME CONSTANT	7 SEC
K_I	INTEGRAL PART OF RECIRCULATION CONTROL	0.15
	LIMIT TO SIGNAL TO PRESSURE REGULATOR	$\pm$ 0.1
K	GAIN OF PRESSURE REGULATOR OFFSET	0.6
T_1	TIME CONSTANT OF PRESSURE REGULATOR OFFSET	25 SEC
T_2	TIME CONSTANT OF PRESSURE REGULATOR OFFSET	5 SEC
f	PORTION OF POWER DEVELOPED BEFORE THE CROSSOVER MOISTURE SEPARATOR	0.3
T_{LP}	TIME CONSTANT OF STEAM FLOW IN MOISTURE SEPARATOR AND CROSSOVER	4.5 SEC
R	SPEED REGULATION	0.05

BWR POWER TO RECIRCULATION FLOW RELATIONSHIP

Figure 14.





a list of the variables and the values used in these simulations. This list also includes controller settings.

This model is valid for load demand errors less than 10 % magnitude. Power generation PGEN (see Figure 14) is related to recirculation flow by

PGEN = (RECFLO + 0.3) (CYBO5) / 1.3

where RECFLO is the recirculation flow and CYBO5 relates the power to recirculation flow. This constant accounts for base rod position. For 100% rod pattern CYBO5 = 1., for 60% rod pattern CYBO5 = .6. Figure 14 shows the relationship of power to recirculation flow for the precent rod pattern.

The power corresponding to full recirculation flow is PGEN, where PGEN = (RECFLO + .3) / 1.3. Finally, it is noted that the nuclear model is a per unit model and the governor setpoint input is normalized and the mechanical power output is converted back to megawatts. This model can be used for any size unit on the system as long as the appropriate initial conditions are supplied.

In a manner similar to the other prime mover subroutines, NUCLER uses array variables in its equations allowing the one model to represent many units. The array ATOM(L) is used for this subroutine and is defined at the beginning of the listing. The data is stored in the associated block data in the array ATOM1(LL). The index L is again used to allocate 31 variables for each nuclear unit modeled.

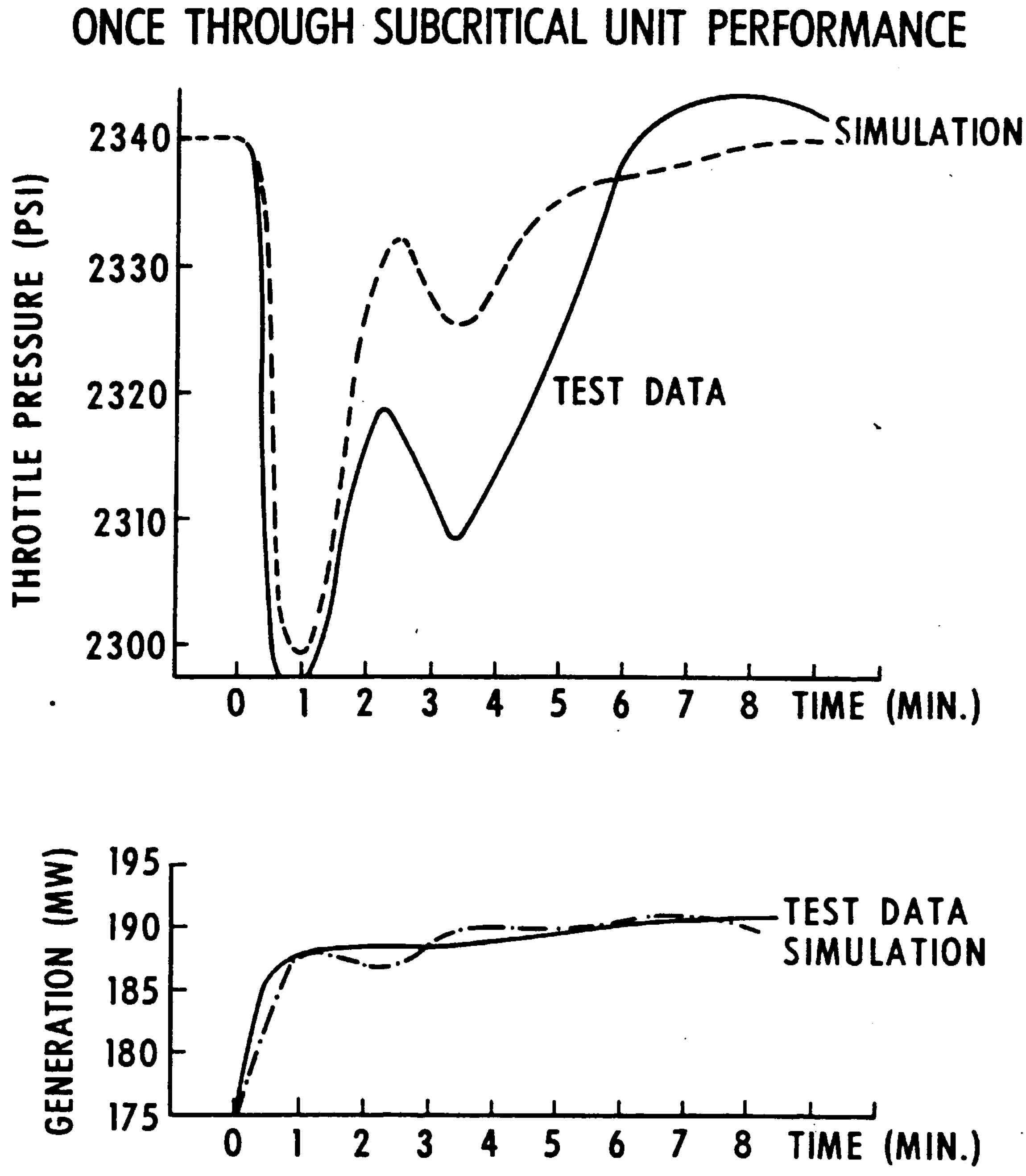


Figure 15. Once Through Sub-Critical Unit Performance

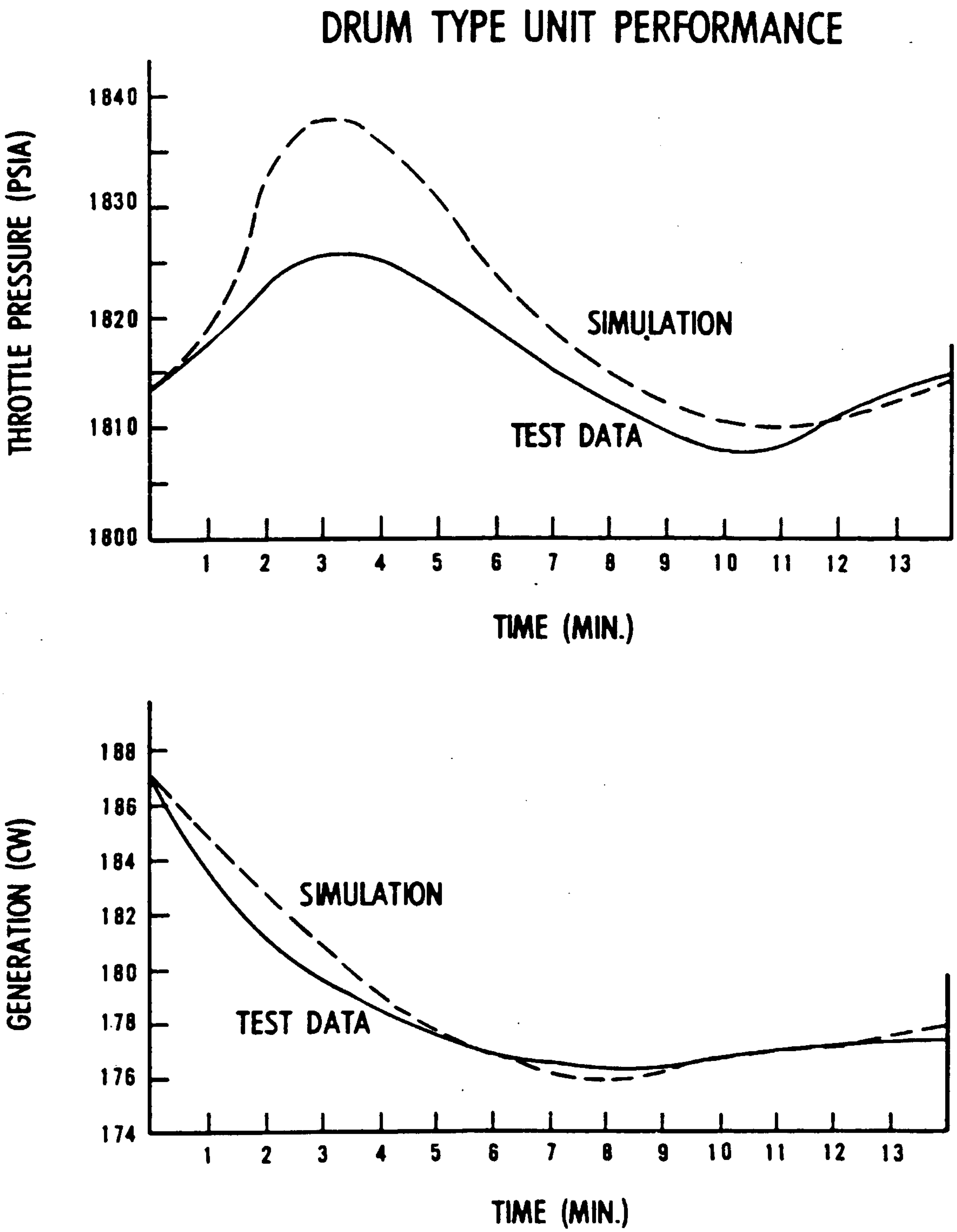


Figure 16. Drum Type Unit Performance

3. Hydraulic Turbine

Hydro Prime Mover Subroutine (HYDRO) represents the dynamics of a hydro unit; including governor wicket gate travel rate limits, and the turbine. This model is able to follow economic dispatch and regulation control signals, and is applicable for run of river and pumped storage plants.

The governor representation includes transient droop compensation. The transient droop time constant, Tr, must be greater than two times the integration interval. This model uses an eight-second time constant. If the transient droop were not to be included then the ratio R/r, would be set to 1. and T_r may be arbitrarily chosen. The governor and gate dynamics are further illustrated in Figure 18. This approximates the gate servo-loop with rate and position limits and proportional and derivative feedback action. The feedback gains establish the steady state regulation and transient droop and its washout time.

The servo time constant of the gate is about one second or less and is masked by the temporary droop effect. The model does not include water column or surge tank effects since these are short-term characteristics when compared to the integration step. In order that the model will be valid for both high head and low head hydro generation a Z-form algorithm was used for the turbine simulation, see Figure 19. The Table 3 is a list of the variables used in this component model.

This model also uses array variables (WATER(L)) thus enabling

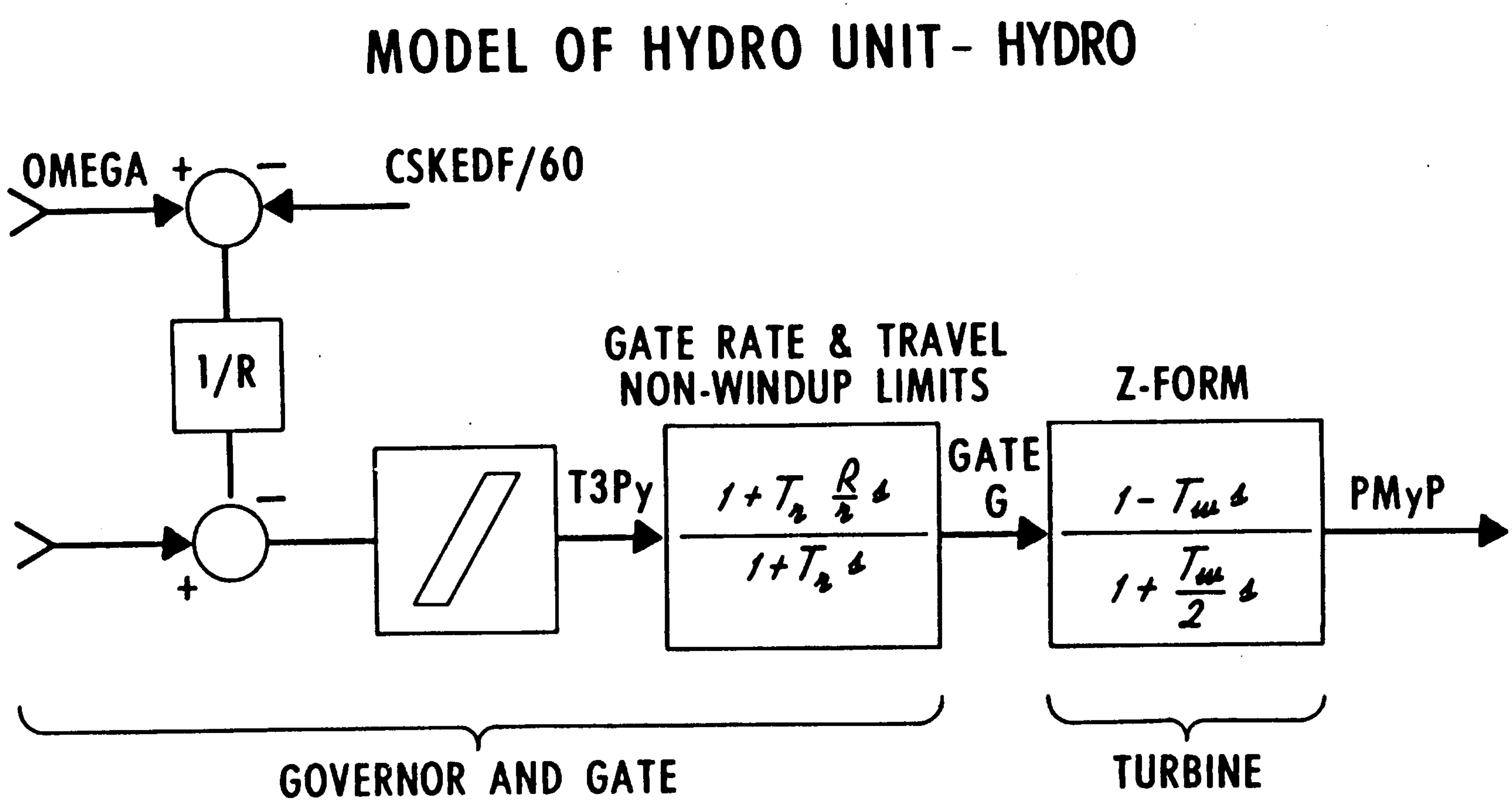


Figure 17. Model of Hydro Unit - HYDRO

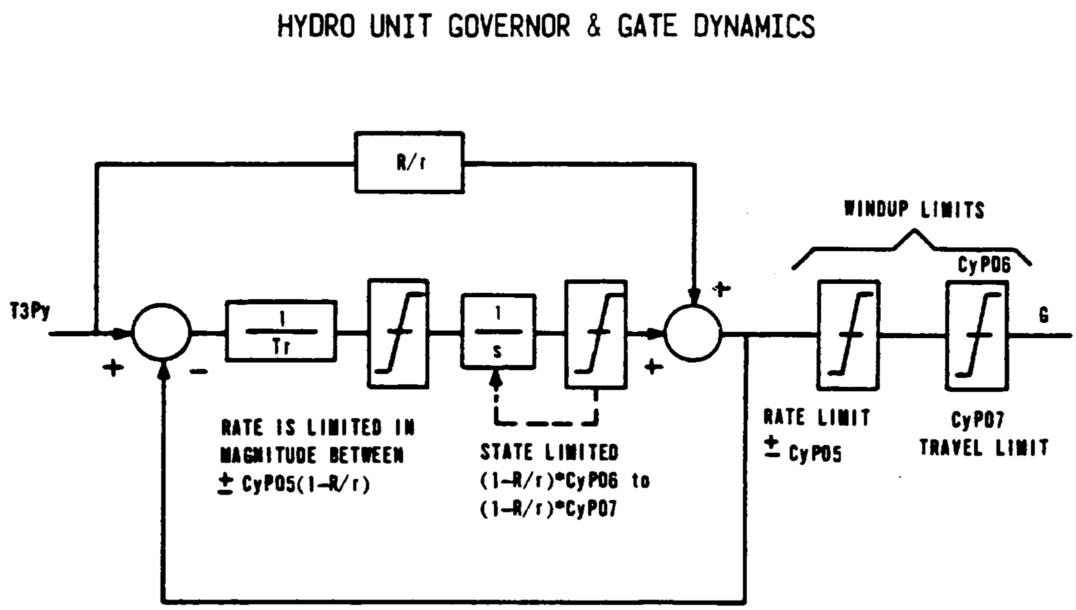


Figure 18. Hydro Unit Governor & Gate Dynamics

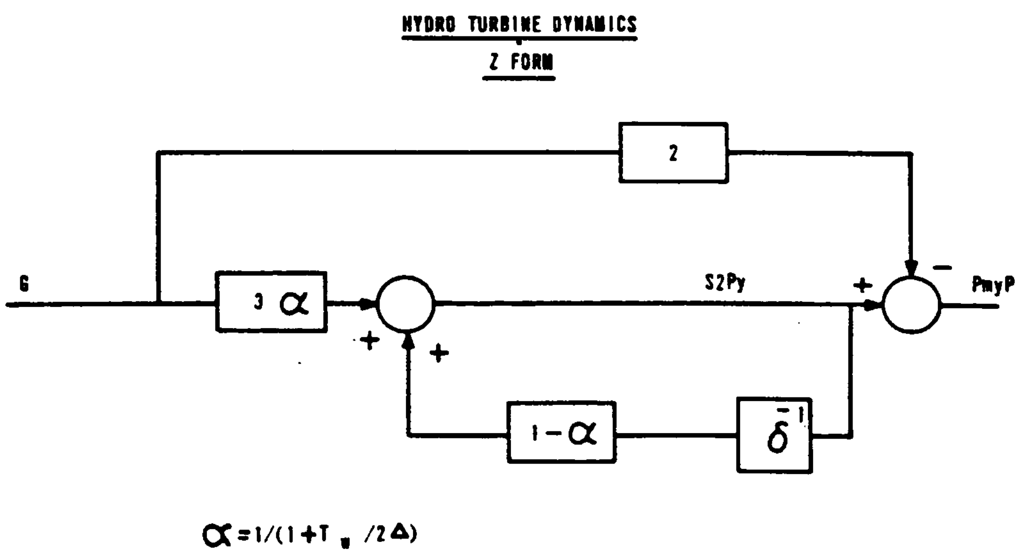


Figure 19. Hydro Turbine Dynamics Z Form

one subroutine to simulate many different hydro units merely by changing the data fed into the array variables. The parameters are defined at the beginning of subroutine HYDRO and the data from the associated block data set is fed in to the array parameters.
For example:

WATER (L + 5) = WATER1 (LL + 2)

where WATER is the array used in subroutine HYDRO, WATER is block data, L is the index number of a particular unit of this type (UNTYPE = 5) which corresponds to the value of NUMBER(N) calculated in the LDO model. Therefore, the first hydro unit uses WATER(1), to WATER(22), the second WATER(23) to WATER(44), etc. The index LL is similarly used for the data WATER(LL).

Subsystem Design

This subsystem provides the tools to test and tune a generator unit's prime mover dynamic model software before its integration with the other dynamic models. This subsystem includes several programs, one by each dynamic prime mover model to be tested. With the programs included in this subsystem, it is possible to test the response of the prime mover for several typical inputs:

- Step Input
- Ramp Input
- Sine Wave Input

The prime mover in this test bed is isolated from the power system network and the mechanical inertia phenomena of the power system is not simulated.

The dynamic model is represented in a block diagram in figure 7; within these dynamic models the following prime mover's devices are simulated:

- Governor Controller
- Governor Motor
- Prime Mover Machine
- Mechanical Power Output Remote Sensor

Control Flow

All the programs in this subsystem have the same control flow, and it is explained below:

The Test Initialization Process: The main program transfers the control to the input routines to read the test input parameters, these test input parameters define:

- If the input used in the test will be the Generator Demand Set Point or the Governor's Scheduled Frequency Set Point.
- Type of function used to change the input of the prime mover dynamic model, e.g., ramp equation,Sine equation, etc.

These input routines also read the test integration parameters: integration time step size and time to finish the simulation run, the initial conditions for the mechanical power output, frequency, and generation demand set point.

Dynamic Model Initialization: After finishing the Test Initialization step described above, the main program uses cards and data processor routines to read card images with prime mover's dynamic parameters and store them in the respective data structure.

The mentioned cards and data processor routines are a modified version of the similar module that is used in DTS Data Base Generation program (DDBGEN), to read, validate, and store the following card images that are described in the DTS ADRM:

- GD1- Generation Unit Dynamic Model Data card form 1.

card form 1.

-GD2- Generator Unit Dynamic Model Data card form 2.

-GV- Generator Unit Governor controller Data Card.

-NUG1- BWR Nuclear Generator Model Generic . Data card form 1.

The mentioned card and data processor routines are a modified version of the similar module that is used in DTS Data Base Generation program (DDBGEN), to process the above mentioned cards.

Dynamic Simulation: After that, the test and tuning program starts a loop to perform the dynamic simulation.

That loop is necessary to perform the numerical calculations to integrate the differential equations involved in the dynamic model.

In each loop, the actual integration time is advanced one integration time step Δt.

Therefore, the control flows through the following routines:

1.Dynamic Model Test's Input Changes Calculation: The Dynamic Model Test's Input Changes Calculation routine, calculates the new value of the test input for the dynamic generator unit model under test.

2. Governor Dynamics Simulator: This routine

simulates the dynamics of the governor and the governor control device.

3.Generator Unit's Prime Mover Dynamics: The calculations at this step are performed by the respective prime mover dynamic model subroutine, e.g., Fossil Fueled Prime Mover Dynamic Model, Hydraulic Prime Mover Model, etc.

4. Output Time Depend Results: This step is performed by two subroutines:

4.a. Subroutine Dynamic Model Test Print Preperation (DGUPRI): The DGUPRI subroutine prepares the values to be printed by the subroutine Dynamic Model Test Output (DGUOUT).

This is a key subroutine which permit change in the co-ordinates of the variables to be printed by the Test and Tuning program.

4.b. Subroutine Dynamic Model Test Output (DGUOUT): It prints a listing with the test input and the test output as a function of the time by each numerical integration loop.

When the integration time is greater than the required simulation total time, the dynamic calculation loop is interrupted and the control is transfered to DGUPLO to plot the input/output of the dynamic model as a function of the time.

Dynamic Model Test Plotter (DGUPLO): When the integration time is greater than the required simulation total time, the dynamic calculation loop is interrupted and the control transfered to DGUPLO to plot the input/output of the prime mover dynamic model as a function of the time.

Program and Support Library

The program list contains TGFOFU, HYDRO and NUCLER.

TGFOFU: Test and Tuning Fossil Fueled Dynaic Generator Unit Model.

HYDRO: Test and Tuning Hydraulic Dynamic Generator Unit Model

NUCLER: Test and Tuning Boiling Water Reactor Dynamic Generator Unit Model.

The above mentioned programs give to the user the possibility to calculate and plot the mechanical output changes when the inputs for the dynamic generator unit model changes like a step, ramp, or sine function.

The support library is as follows;

DDBERL- Print Error Messages: This subroutine is the same module that is used in program DDBGEN. This subroutine prints error messages on the line printer.

DELAY: Generator Unit Model Delay Function. This is a FORTRAN user defined function which simulates a time delay in the dynamic generator unit model's loops.

FREADI- Integer Read Function: This function reads the integer test parameters. Function FREADI writes on the user computer terminal messages related with the test data necessary for the TGFOFU run. The user should enter the required data in the indicated integer format.

FREADR- Real Read Function: This function reads the real test parameters. Function FREADR writes on the user computer terminal messages related with the test data necessary for the TGFOFU run. The user should enter the required data in the indicated real format.

INTGRL- Generator Unit Model Integration routine: INTGRL is a FORTRAN user defined function which uses the trapezoidal method for numerical integration of the generator unit dynamics equations.

LIMIT- Generator Unit Model Limiter Function: This is a FORTRAN user defined function which simulates a nonlinear limiter device in the dynamic model.

PRTMNG- Print a Line With Format Control: This subroutine is the same module that is used in program DDBGEN. The subroutine PRTMNG provides format control for a printed listing. Pages are automatically numbered and the user supplied headings are printed at the top of each page.

DGUCHA- Dynamic Models Input Changes Calculation: Subroutine DGUCHA calculates changes in the test input selected to test the dynamic model. DGUCHA can use either a ramp, step or sine to calculate the test input changes as a function of the time.

DGUOUT- Dynamic Model Test Output: This subroutine print a listing with the mechanical power output and the selected input: Scheduled Frequency or generation Demand Set Point.

DGUPLO- Dynamic Model Test Plotter: This subroutine plots the test input and the corresponding output of the dynamic generator unit model as a function of time.

DGUPRI- Dynamic Model Test Print Preparation: This subroutine prepares the program output to be printed for DGUOUT.

Data Structures

The following are the data structures defined in this subsystem. With exception where it is indicated, all of them are used in the programs in this Test and Tuning of of the Dynamic Models subsystem.

ATTOM- This labelled common has the parameters for 10 Boiling Water Reactor units. This data structure is used in the program NUCLER only.

BOILRS- This local common data structure has the fossil fueled prime mover parameters for 10 types of units

Super-critical Once-Through, Subcritical Once-Through, Oil Fired Drum Type, Coal Fired Drum Type, Non ReheatDrum Type and five more that at this time are not defined. Point BOTYPE identifies the boiler type and ranges from 1 to 10. This data structure is used in the program TGFOFU only.

CONOUT- This data structure contains the parameters used to control the output routine DGUOUT.

CONST1- This local common data structure has the governor parameters.

CUVAL1- These local common data structures have information covering the current value of the parameters used to represent the dynamics of the generator unit.

CUVAL2- These local common data structures have information used to represent the dynamics of the generator unit.This information covers the current parameter values.

CUVAL3- These local common data structures have information used to represent the dynamics of the generator unit. This information covers the current parameter values.

INITAL- This labelled common has the initial condition values, data for integration purpose, unit type, test function parameters and selected inputs.

TINIT- This common structure has the test control parameters.

WATT- This local common data structure is the storage area used to store the parameters for 6 Hydro units. This data structure is used in the program HYDRO only.

Nuclear Testing Input Parameters

Initial Mechanical Power	-120 MW
Installed Capacity	-180 MW
Initial Frequency Set Point	-60 HZ
Initial Speed of System	-1.0 p.u
Integration Time Step	-1.0s (For1,2,3,4,5) -0.5s (For6,7,8)
Start Changes Time	-0.0s
Simulation Time	-300.0s
Input Option 1	-Generation Demand Selected.
Test Function Option	-1-Step(For 1,6) -2-Ramp(For4,5,7,8) -3-Sine(For 2,3)
Step Values	-For 1 : 10 MW -For 6 : 30 MW
Ramp(Slope) Values	-For 4 : 0.125MW/s -For 5 : 0.5MW/s -For 7 : 0.125MW/s -For 8 : 0.5MW/s
Amplitude for Sine Values	-For 2 : 5.0MW -For 3 : 10.0MW
Oscillation Period Values	-For 2 : 10s -For 3 : 5s

Table 5. Nuclear Unit Testing Input Parameters

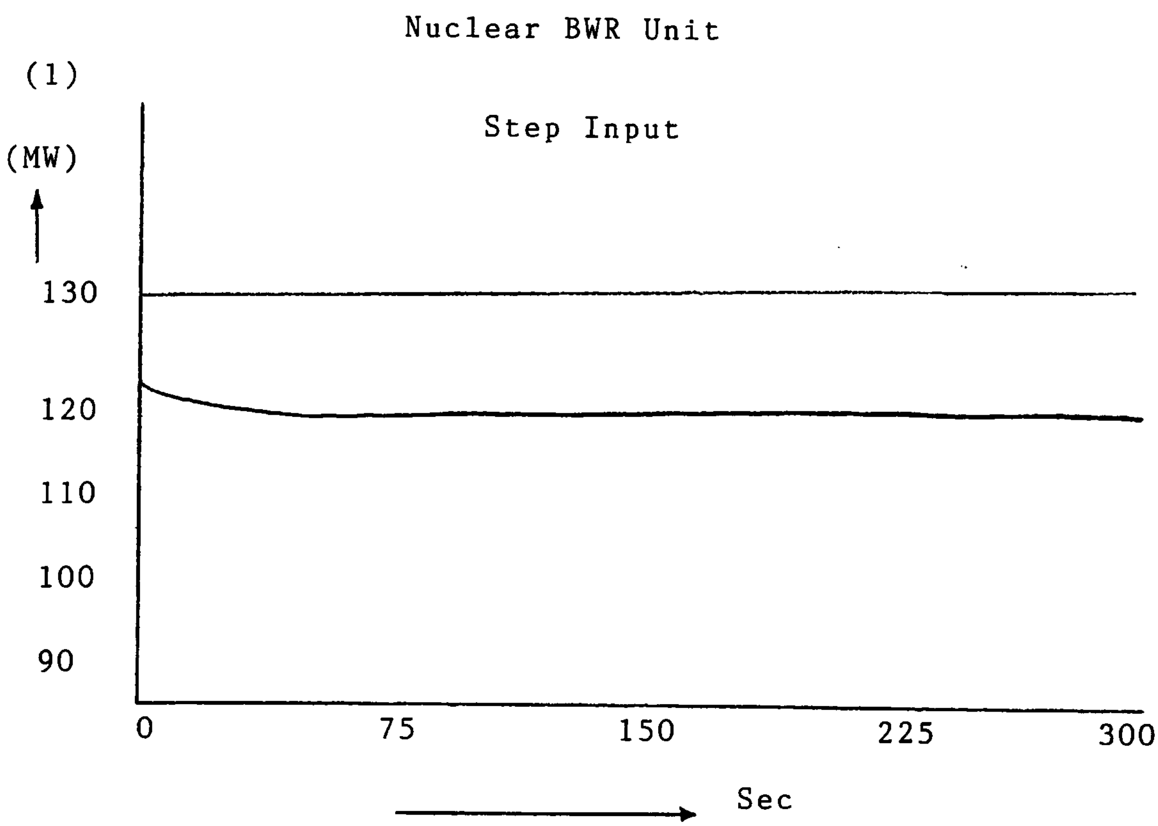


Figure 20. Nuclear Unit Step Input

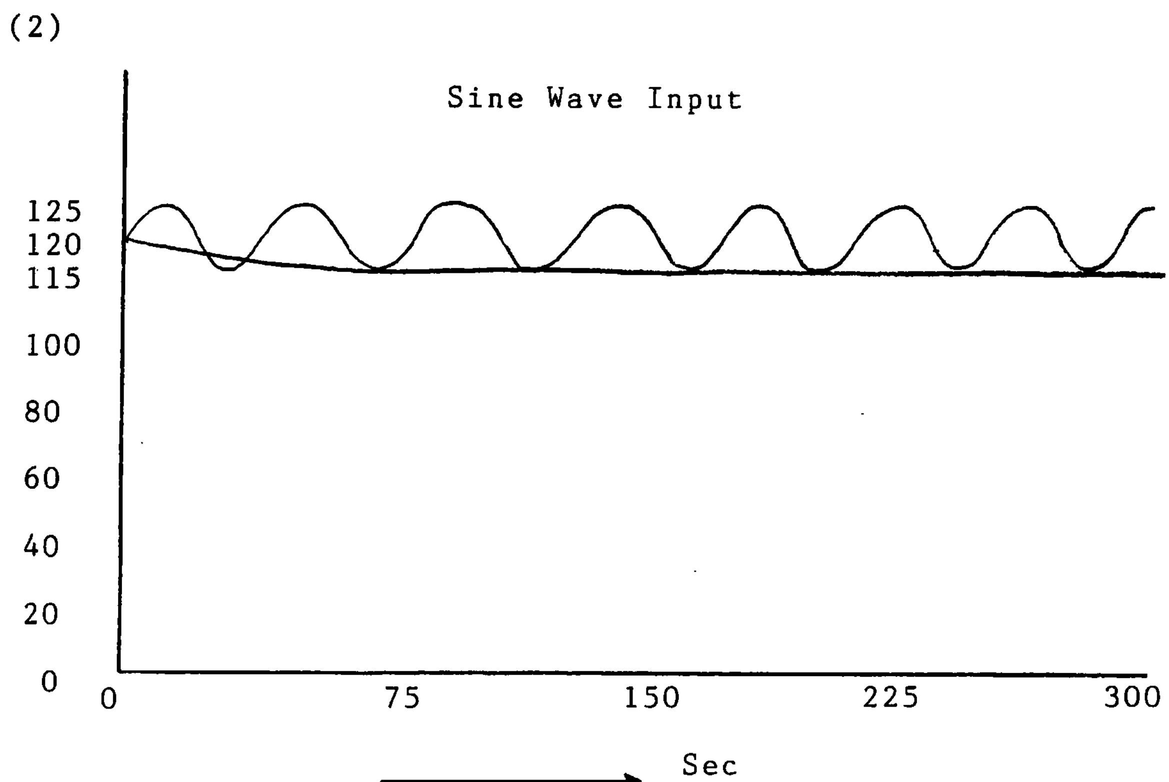
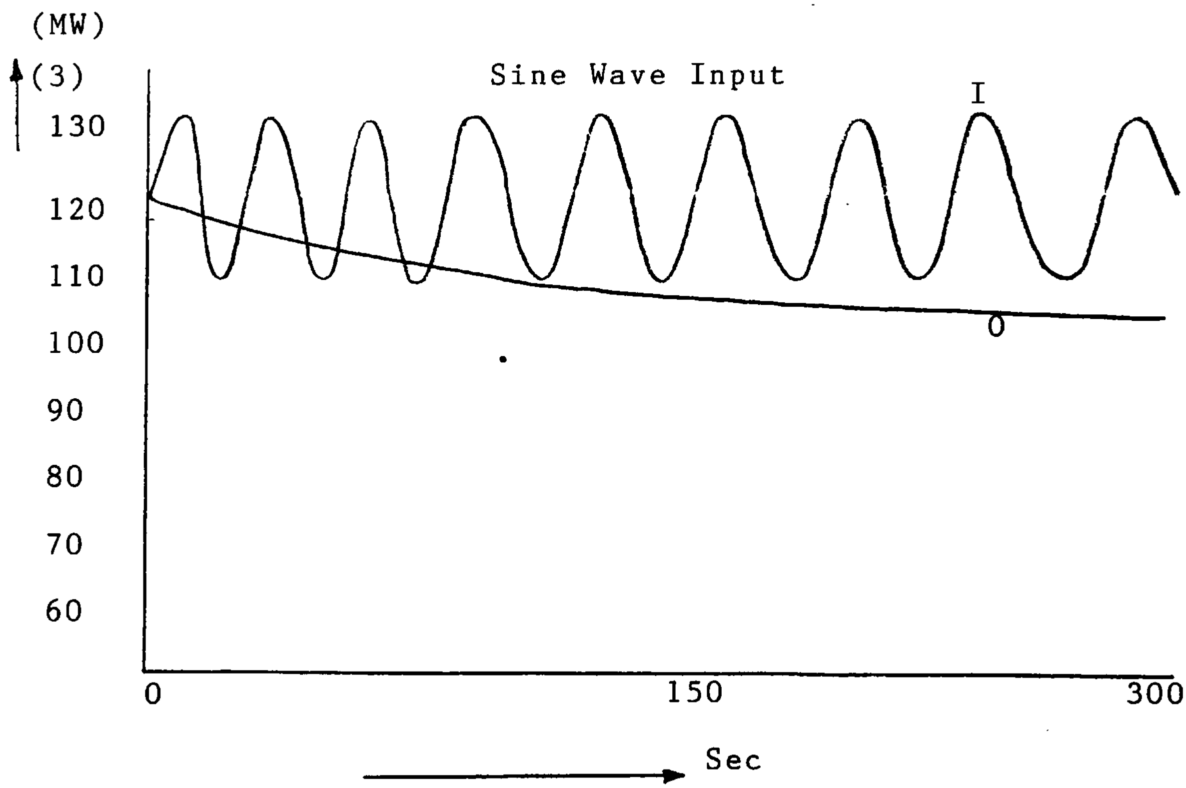


Figure 21. Nuclear Sine Wave Input



Figur 22. Nuclear Sine Wave Input

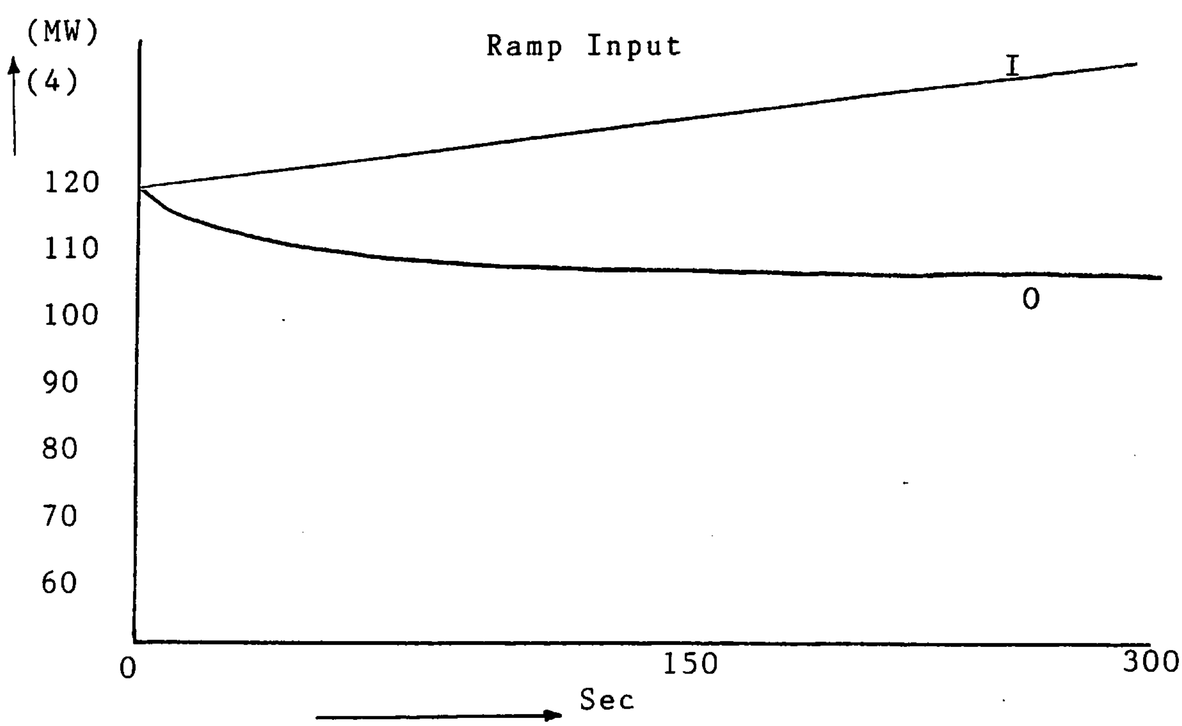


Figure 23. Nuclear Ramp Input

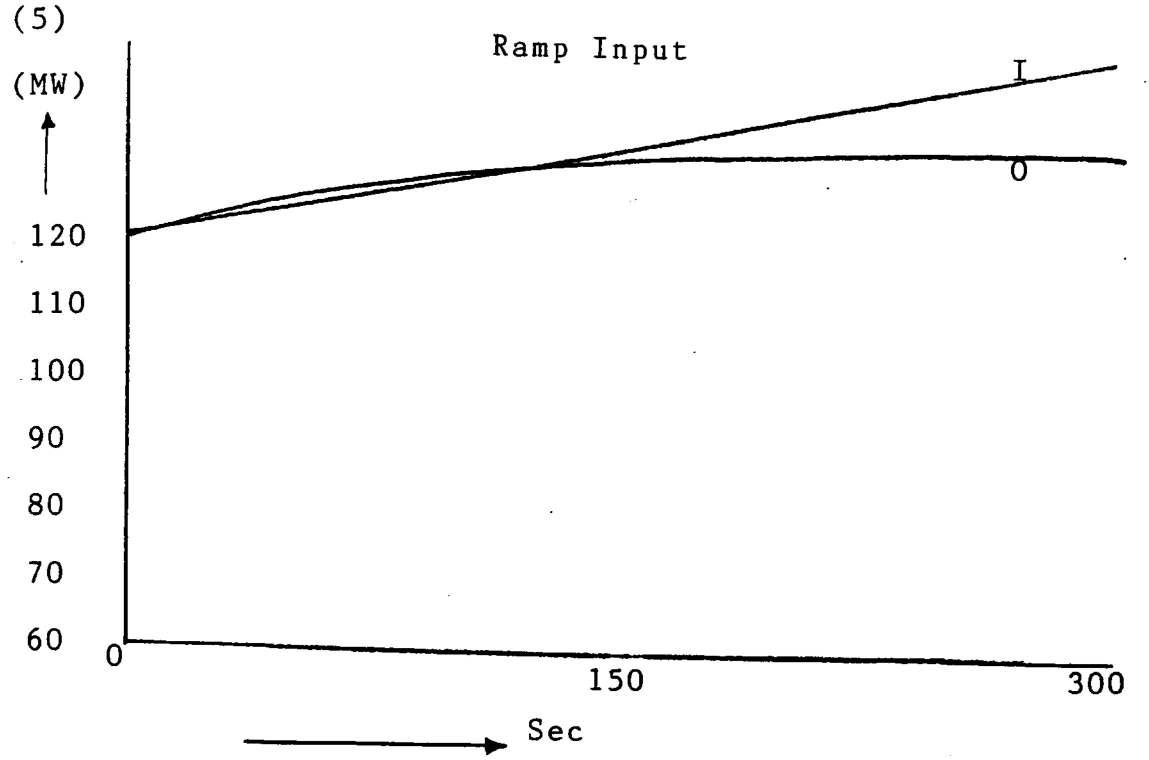


Figure 24. Nuclear Ramp Input

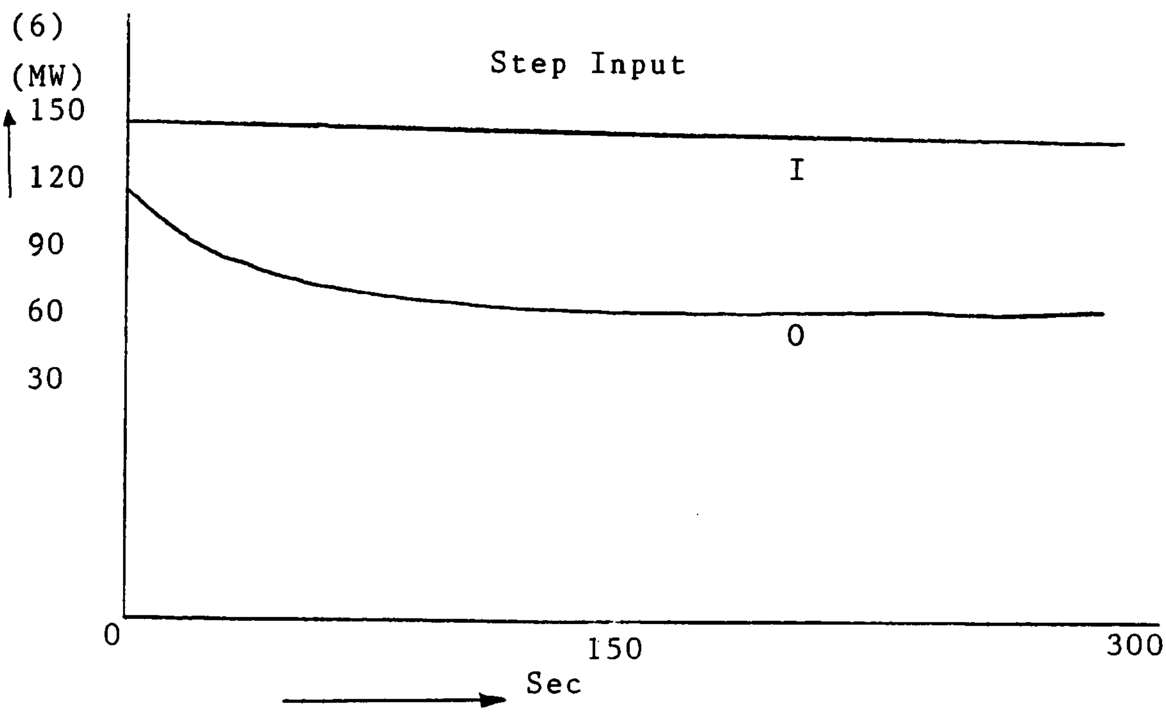


Figure 25. Nuclear Step Input

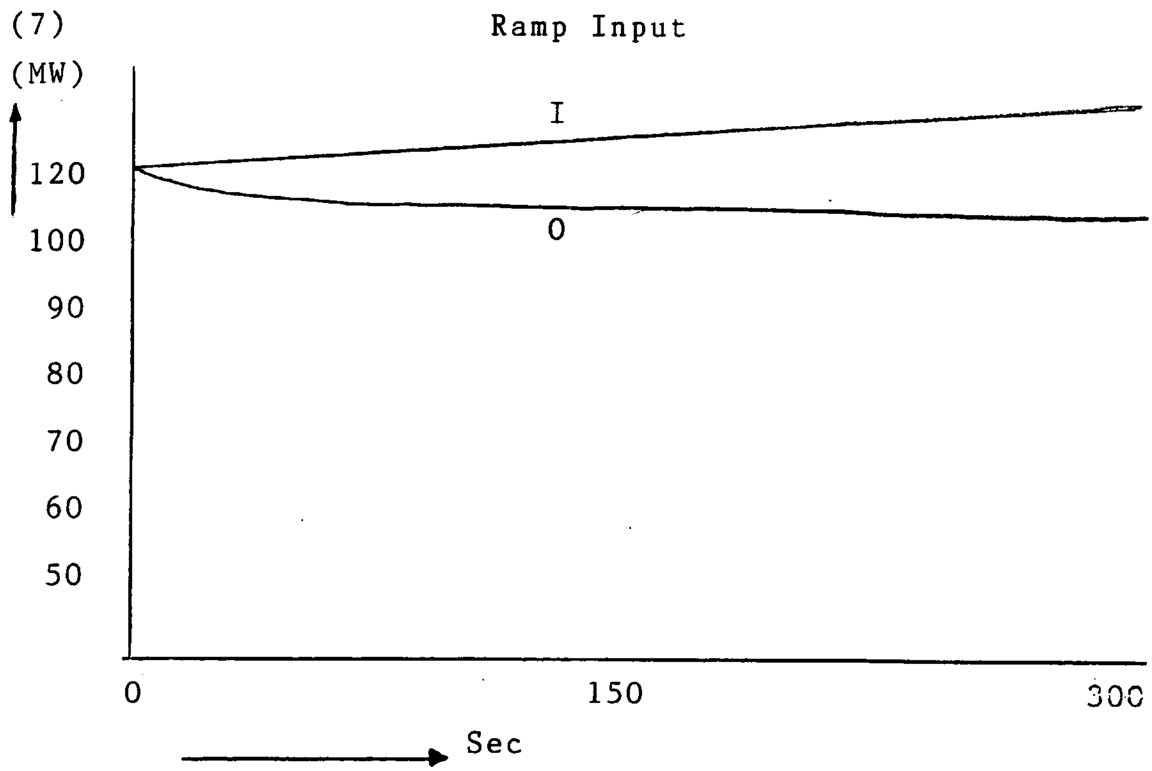


Figure 26. Nuclear Ramp Input

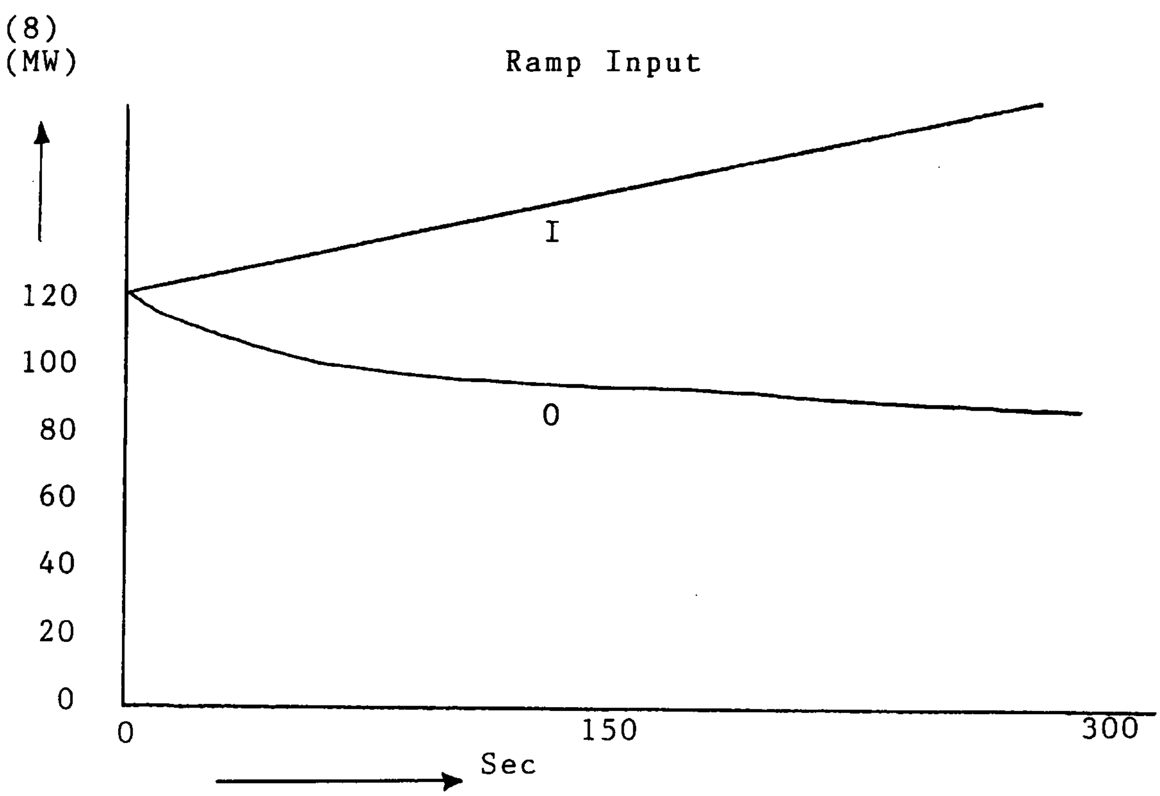


Figure 27. Nuclear Ramp Input

Hydro unit Testing Input Parameters

Initial Mechanical Power		-120 MW
Initial Frequency Set Point		-60 Hz
Initial System Speed		-1.0 p.u
Integration Time Step		-1.0 Sec
Start Changes Time		-0.0 Sec
Simulation Finish Time		-250.0 Sec
Input Option -1 Generation Demand Selected		
Test Function Option	-1- Step (For 10,12)	
	-2- Ramp (For9,13,15)	
	-3- Sine (For11,14)	
Step Values	-For 10- 10 MW	
	-For 12- 20 MW	
Ramp(Slope) Values	-For 9 - 0.125 MW/Sec	
	-For 13- 0.35 MW/Sec	
	-For 15-0.55 MW/Sec	
Amplitude for Sine Values		-For 11- 10 MW
		-For 14- 10 MW
Oscillation Period Values		-For 11- 5 Sec
		-For 14- 20 Sec

Table 6. Hydro Unit Testing Parameters

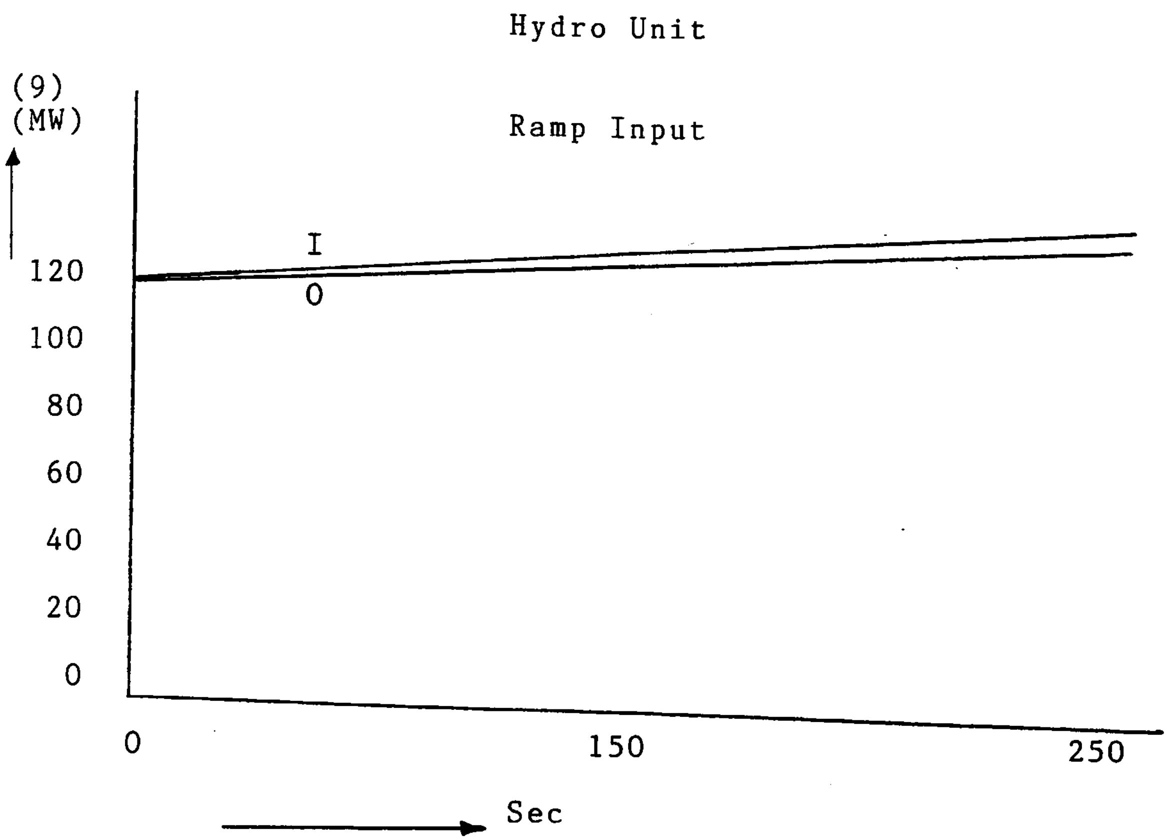


Figure 28. Hydro Ramp Input

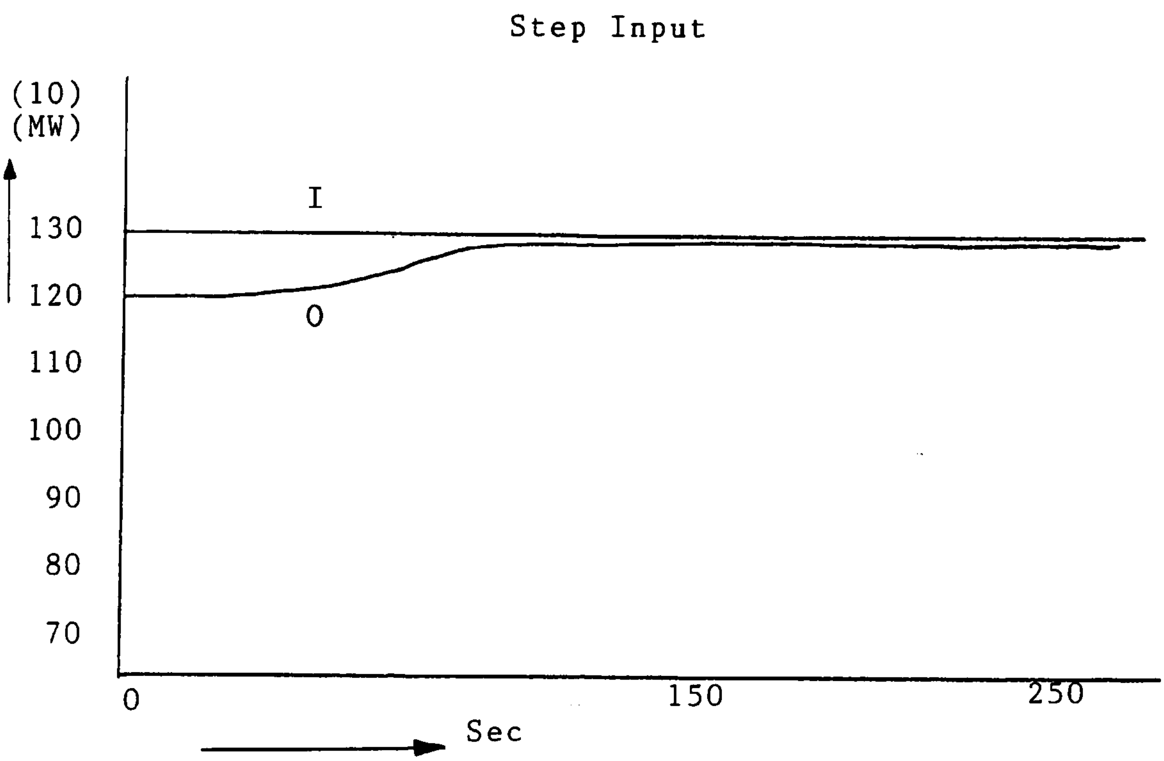


Figure 29. Hydro Step Input

Sine Wave Input

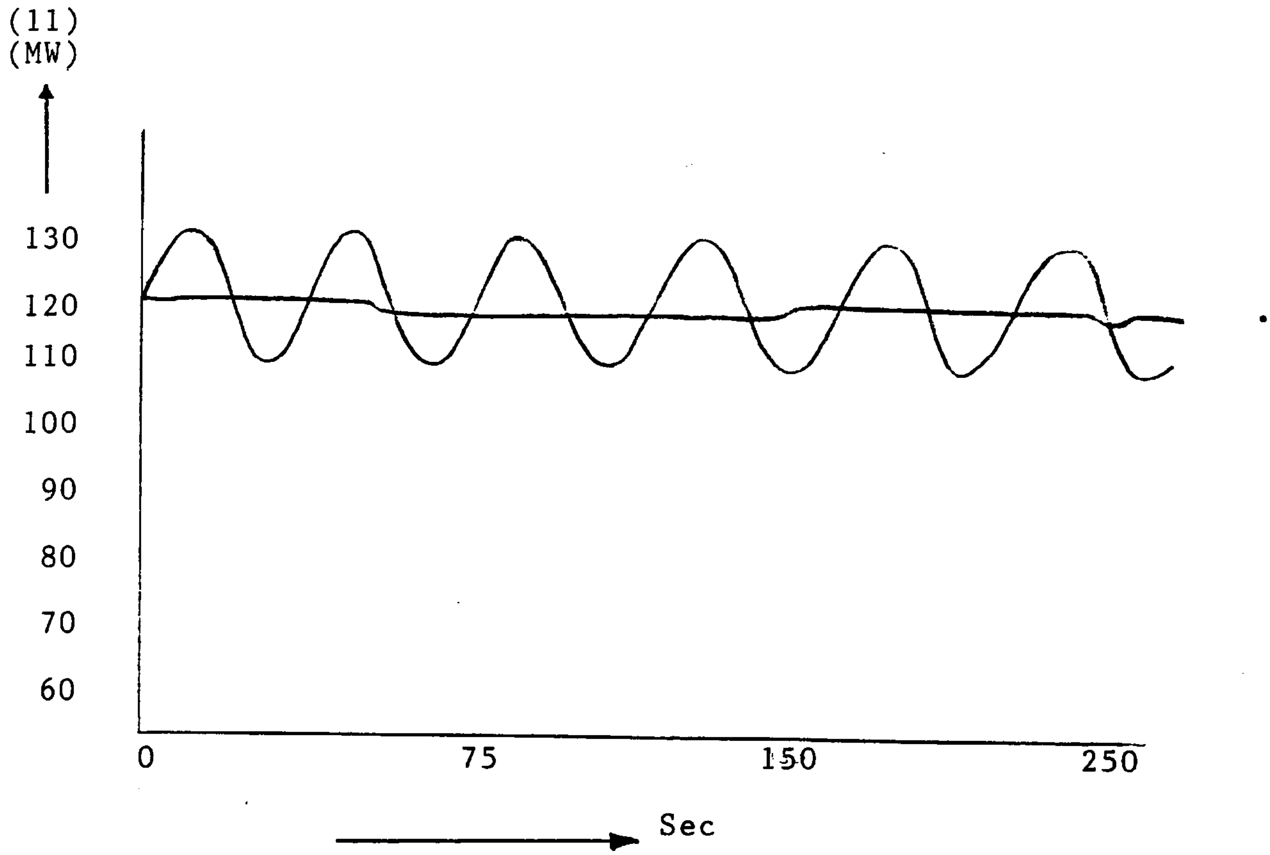


Figure 30. Hydro Sine Wave Input

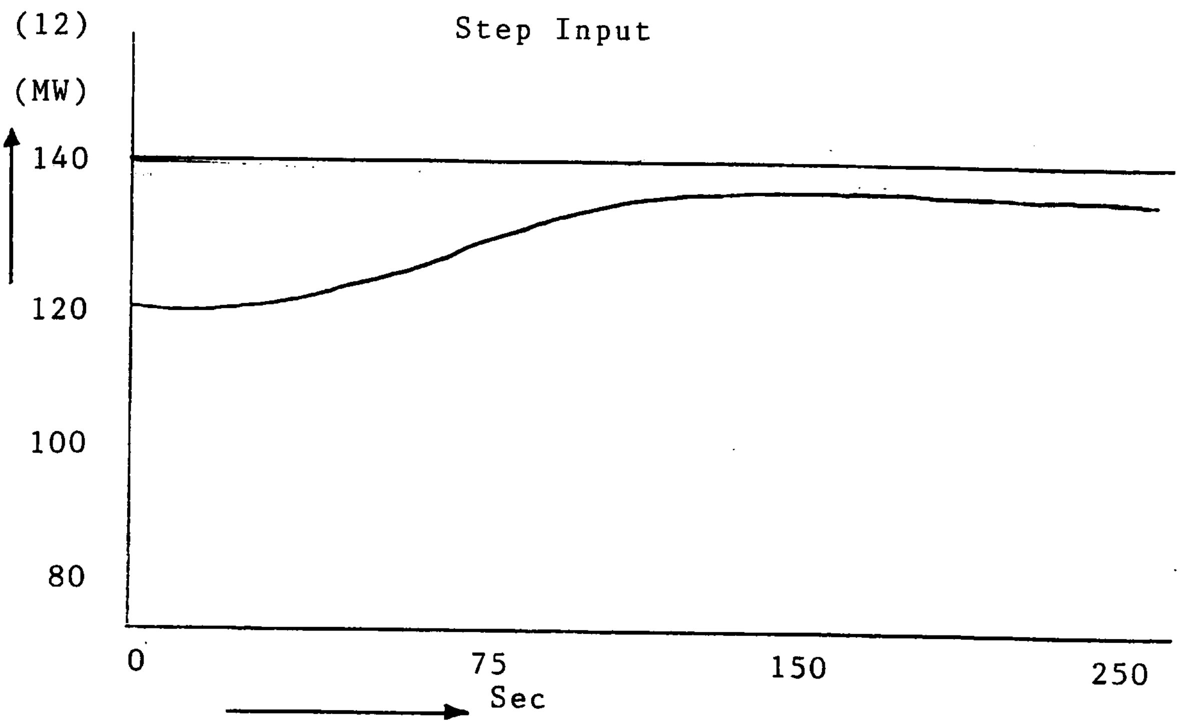


Figure 31. Hydro Step Input

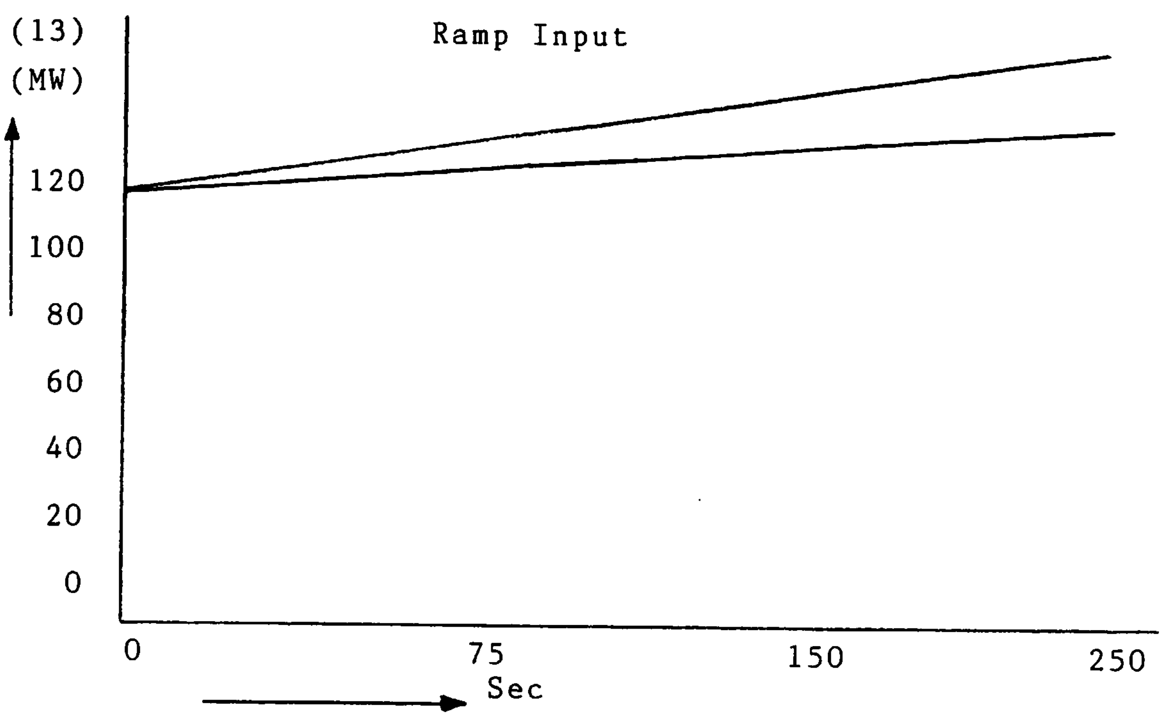


Figure 32. Hydro Ramp Input

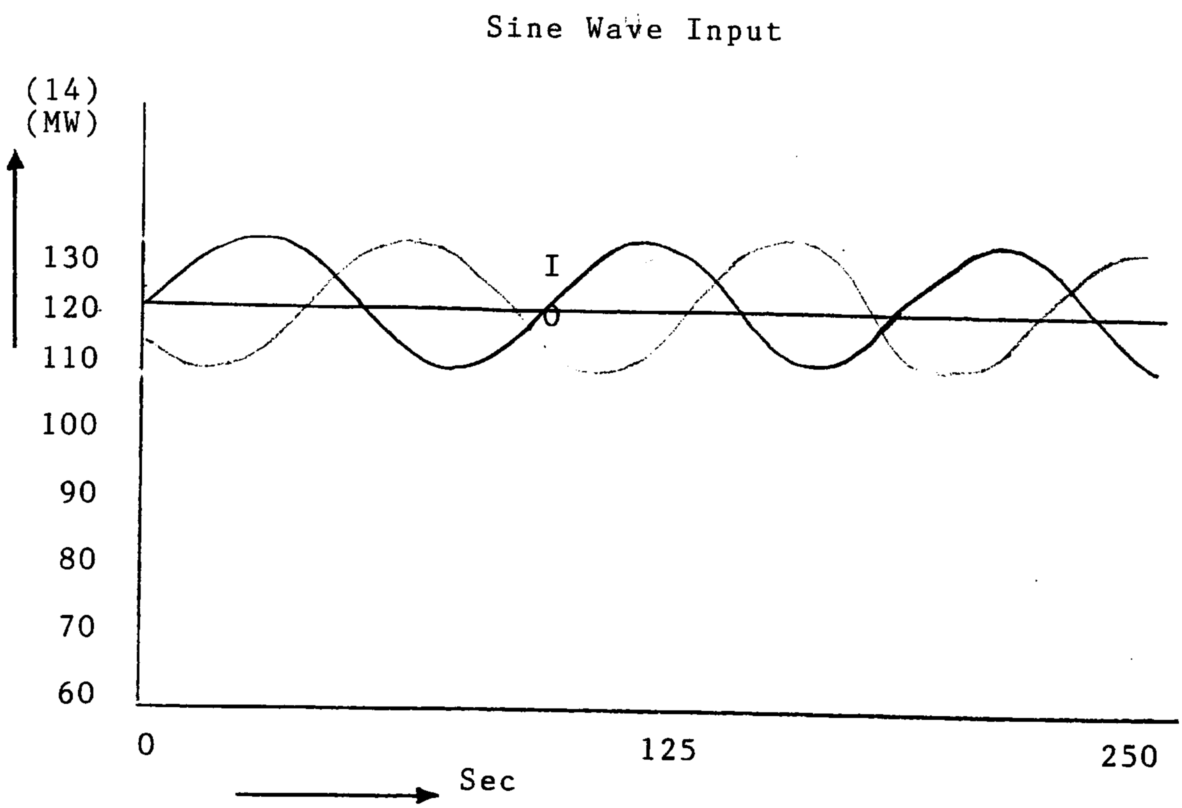


Figure 33. Hydro Unit Sine Wave Input

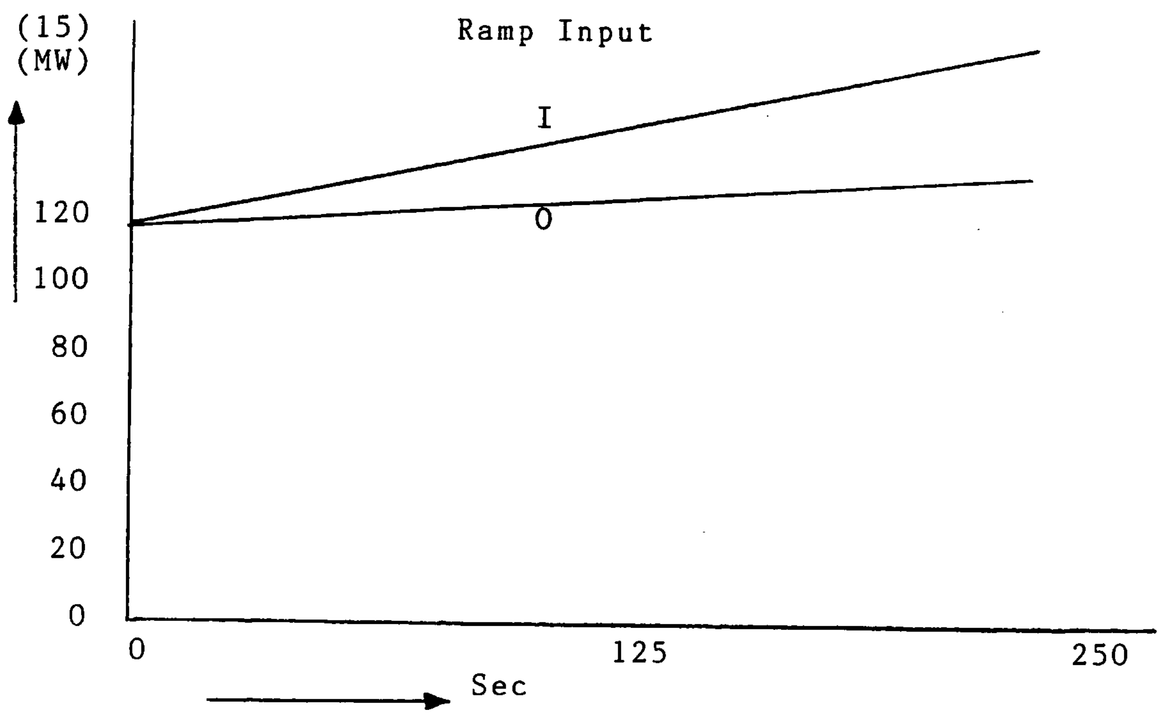


Figure 34. Hydro Unit Ramp Input

MARUBENI/ENDESA HYDRO PROJECT

This is a hydroelectric complex in Chile owned and operated by ENDESA, a utility company in that country. MARUBENI, a Japanese engineering consultancy company has requested TRW Controls to supply the Energy Management System for this hydro-complex. There are three reservoirs supplying both the irrigation and power requirements of this system; namely, Colbun, Machicura, and Pehuenche.

Dr. Will Briggs, the Software Development Leader for the project, assigned me the task of designing the programs to read and validate the fields of the data card images corresponding to the customer supplied data. The area of concern was the Hydraulic Works Model data.

There were twenty six types of data cards, and each required a separate subroutine to validate its field and a master driver , called EDBGEN(ENDESA DATA BASE GENERATION) program, to execute the program.

An example of a typical data type has been included to clarify the above description. The Flow Chart gives a clear idea of the logic underlying the execution of the program.

Hydraulic Works Model Information

As observed in the Flow Chart the data cards requiring validation pertain to the Hydraulic Works model data base. This data base is used by the Generation Scheduling Hydraulic Works Control and REG Adjustment subsystems. The following data cards are required:

Category 1- Reservoir Data

RD - Resovoir Definition Data Card

RC - Reservoir Control Data Card

RM - Reservoir Model Data Card

Category 2 - Irrigation Data

IRI - Irrigation Point Data Card One

IR2 - Irrigation Point Data Card Two

Category 3 - Spillway Data

SW - Spillway Definition Data Card

SP1 - Spillway Model Data Card One

SP2 - Spillway Model Data Card Two

UR - Spillway Unrestricted Flow Model Data Card

SC1 - Spillgate Control Data Card One

SC2 - Spillgate Control Data Card Two

ST - Spillgate Control Hardware Address Definition Data Card

Category 4 - Generator Plant Data

PL - Generator Plant Definition Card

DG - Generator Plant Discharge/Generation Model Data

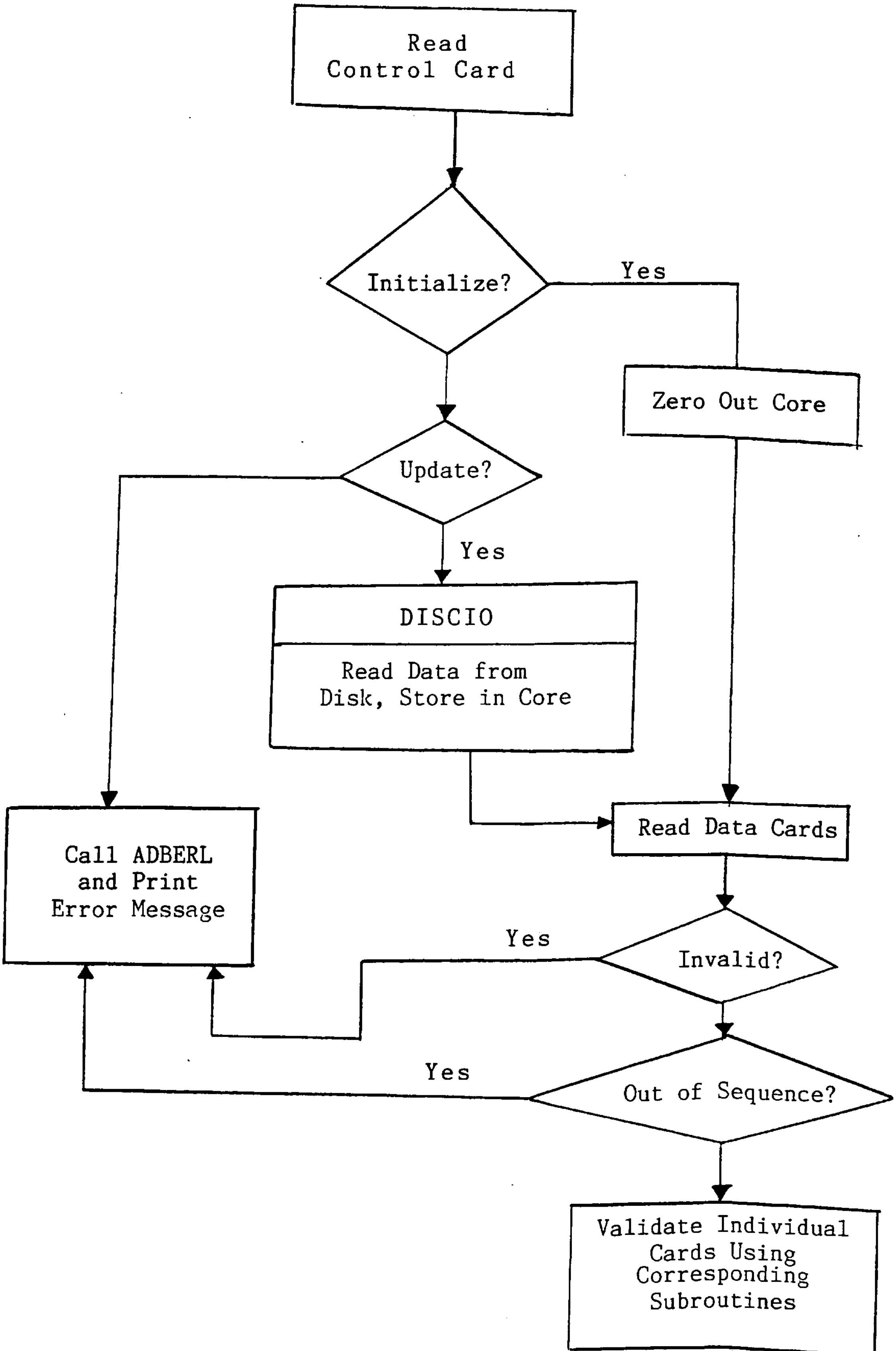


Figure 35. Flowchart for ENDESA Card Image Validation

Card

EF - Generator Plant Efficiency Data Card

NH1 - Net Head Model Data Card One for Linear Programming

NH2 - Net Head Model Data Card Two for Linear Programming

TD - Real-Time Turbine Discharge Model Data Card

RH - Real-Time Net Head Model Data Card

IV - Irrigation Valve Model Data Card

Category 5 - Miscellaneous Data

MR - Maule River Model Data Card

EM - Hydro Complex Efficiency Model Data CArd

TG - Generation Scheduling Subsystem Tuning Data Card

Th1 - Hydraulic Works Control Subsystem Tuning Data Card One

Th2 - Hydaulic Works Control Subsystem Tuning Data Card Two

TR - REG Adjustment Function Tuning Data Card

The above data cards must be grouped and input in the above sequence.

Reservoir Definition Data Card (RD)

A Reservoir Definition Card must be supplied for each reservoir modelled in the hydraulic system model data base. A mximum of MAXRES (set to 4) reservoirs can be defined in the system model data base.

Card Type (Col. 1-2)

RD

Reservoir Name (Col. 4-15)

This field contains a 12-character reservoir name. A unique name must be supplied for each reservoir.

Reservoir ID Code (Col. 17-19)

The 3-character reservoir ID code is used to distinguish the reservoir within the complex. The following ID codes are valid:

- COL - Colbun reservoir
- MAC - Machicura reservoir
- PEH - Pehuenche reservoir

Maximum Reservoir Normal Elevation Level (Col. 21-28)

This field contains the maximum reservoir normal elevation level. The value must be positive and larger than the minimum reservoir normal elevation level. A decimal point must be included if a fractional value is entered in this field.

Minimum Reservoir Normal Elevation Level (Col. 30-37)

This field contains the minimum reservoir normal elevation level. The value must be positive and smaller than the maximum reservoir normal elevation level. A decimal point must be included if a fractional value is entered in this field.

Maximum Reservoir Exceptional Elevation Level (Col. 39-46)

This field contains the maximum reservoir exceptional elevation level. The value must be greater than or equal to the maximum reservoir normal elevation level and greater than the reservoir exceptional elevation level. A decimal point must be included if a fractional value is entered in this field.

Minimum Reservoir Exceptional Elevation Level (Col. 48-55)

This field contains the minimum reservoir exceptional elevation level. The value must be less than or equal to the minimum reservoir normal elevation level and less than the maximum reservoir exceptional elevation level. A decimal point must be included if a fractional value is entered inthis field.

Reservoir Index (Col 57-59)

This field contains the reservoir index number. It must be one or greater and not exceed the maximum number of reservoirs MAXRES. This index is used to store the reservoir data in the data base array.

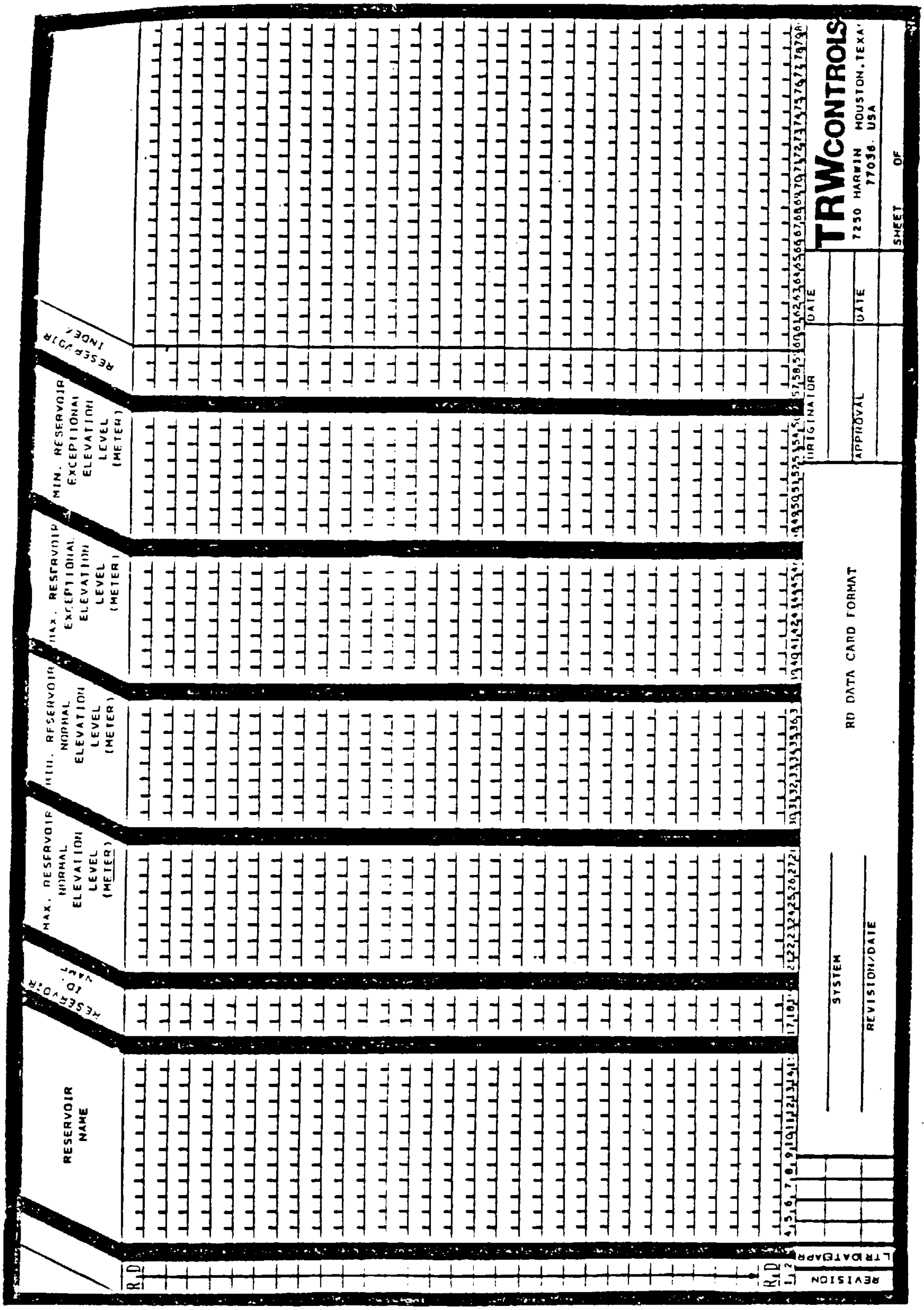


Figure 36: Card Image

SUMMARY AND CONCLUSION

The report spotlighted the salient features of the period of internship at TRW Controls.

The internship experience was interesting and gave me a first hand experience of how American industry functions. I was introduced to the prevailing management styles and the highly technical aspects of project engineering in the Power Systems Applications field.

I feel that my sojourn at TRWC adequately exposed me to the various goals of the Doctor of Engineering internship program and fulfilled the requirements of the internship.

I am grateful to TRWC for allowing me to gain such an experience and use it towards my Doctoral internship.

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VITA

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APPENDIX - I

The models for the generator units, external bus injection generation points and island frequency are defined to a level of detail which permits accurate simulation of long-term dynamics that last up to 20 minutes following major disturbances. These dynamic models will provide a realistic response for disturbances such as the loss of significant generation or load. At this time , it is not known if these models will require too much CPU time and memory, or if less detailed models can be used. Therefore, during the design phase of the DTS implementation, a study will be made using a program that contains the detailed dynamic models to:

(a) Determine the CPU time and memory required for the models

(b) Determine the technique for solving the differential equations

(c) Determine if realistic responses can be obtained for less detailed models

Based on the results of this study, the actual dynamic models that will be used in the DTS will be defined.

Key Features

1. FORTRAN 78/66 - The new programs developed for this DTS development effort will take in to consideration the FORTRAN 78 language but they will be coded in

FORTRAN 66.

2. Realistic Information Presentation - Special efforts are made to assure that the information presented to the trainee resembles what he expects from the real world. One example is when an equipment change of status indication.is reflected in the simulated EMS real-time data base, the change of affected analog values is simultaneously reflected. This is to avoid the situation where a circuit breaker opens and its status change is stuffed in the simulated real-time data base; but because the DTS load flow program has not run, the old circuit flow value is still unrealistically presented. It should be noted that data is always transferred from the Fast Decoupled Load Flow solution data area to the simulated EMS real-time data base.

3. Security Analysis Program Execution - While the DTS is performing a dynamic simulation, the following security analysis functions may be manually requested by the trainee:

   - Real-Time System Status Processor
   - State Estimation
   - Real-Time Contingency Analysis
   - Circuit Breaker Validation
   - Dispatcher's Load Flow

- Study Mode System Status Processor
- Study mode Economic Dispatch calculation
- Study Mode Contingency Analysis

These applications functions will obtain a valid solution that can be presented on the baseline applications displays. Due to the computer resources that the DTS is using, these applications functions will take longer to complete their execution.

4. Multi-Island Solution - Fast Decoupled Load Flow solution of each of up to the 5 largest in-service islands in the simulated power system network model is continuously computed. The solution includes all the bus voltages and circuit flows in these islands. The solution values are stuffed in the simulated real-time base. The following features are included:
   - Summaries of generation , load and interchange for the largest island are computed on demand by the instructor for his display purposes.
   - The circuit flows for equipment that are not in the above islands are set to zero.
   - Over/under frequency relaying on generator units are included to realistically simulate the affect of islanding.
   - The internal generation control area can be split into multiple islands but each defined external

generation control area can exist in only one island. Islands that only contain bus injection generation points are in-service if they contain at least two buses in the internal generation control area. Each external generator control area must have at least one defined bus injection generation point.

5. The instructor will have a dispatcher's Load Flow function to establish the steady state load flow solution of the interconnected power system network prior to starting the dynamic simulation. All capabilities for the Dispatcher's Load Flow will be available along with the capability to solve multiple islands and to provide area interchange control.

Program Design

Test and Tuning BWR Nuclear Dynamic Generator Unit Model

1. Function

The Test and Tuning BWR Nuclear Dynamic Generator Unit Model Program DGUTES, provides the capability to detect conceptual errors in the mathematical model of the prime mover generator unit dynamics, its coding, and its parameters.

With this program, the user is able to tune the dynamic generator unit model and its parameters, to find the required response for the model under test before its integration with the other DTS's models.

2. Description

Program DGUTES specifically simulates the prime mover generator unit dynamics in the time domain in response to the test inputs given below:

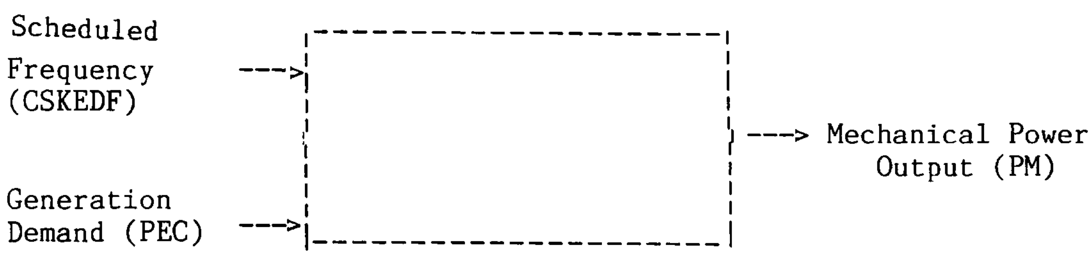

Fig 37. Dynamic Model's Inputs and Outputs

This program tests the dynamic model by changing the Power Generation Demand Set Point PEC, or the Scheduled Frequency Set Point CSKEDF, using one of the following types of input (test input) functions:

- Step Equation
- Ramp Equation
- Sine Equation

Internally, the BWR NUclear powered prime mover dynamic generator unit model subroutine NUCLER calculates the difference between the Scheduled Frequency CSKEDF and the island speed OMEGA.

Similarly, the Governor Dynamic Simulator DGUGOV calculates the difference between the Generation Demand Set Point PEC and the Telemetered Mechanical Power Output PMS. Both, frequency and generator demand error signals activate the dynamic reactions in the model. The BWR Nuclear Prime Mover Dynamic Generator Unit Model subroutine and its associated data structure ATTOM represent the BWR Nuclear Prime Mover, and one subroutine is capable of being automatically restructured and revalued for each unit.

Only one subroutine is necessary for a simulation study case. In order to accomplish this, all the dynamic equations are in array form. Each variable is called as one of the 31 entries of the array ATOM. These sets of 31 ATOM parameters are derived from 10 ATOM1 parameters for

for each type of prime mover stored in the data structure ATTOM. Each BWR Nuclear Prime Mover in the system model is put on a per-unit basis upon calling subroutine NUCLER and re-evaluated to its own base upon return from it.

Program DGUTES calls the Dynamic Model Test Parameter read DGUTIN to read the Test Input Parameters;

- Input Option
- Test Function Option

These parameters define if the model will be tested by changing the Generator Demand Set Point or the Governor's Scheduled Frequency Set Point. The Test Input parameters will also define the function or equation to use in the subroutine Dynamic Model Test's Input Changes calculation DGUCHA to change the input selected to tedt the dynamic model, e.g., Step, Ramp, etc.

The program DGUTES uses also the subroutine DGUTIN to read the Test Integration parameters:

- Integration Time Step Size
- Time to start changing the dynamic model's input
- Time to finish the simulation

and the initial conditions for the Mechanical Power Output, Scheduled Frequency and the Generation Demand Set Point. Then the driver DGUTES uses the following subroutines:

- BWR Nuclear Dynamic Model Card Processor DGNUCP
- Generator Unit Dynamic Model Data Card Processor DGNUGD

- Generator Unit Governor Controller Data Card Processor DGNUGV.
- BWR Nuclear Generator Model Generic Data Card Processor DGNUNU.

to read the following card images described in the DTS ADRM:

- GD1 - Generator Unit Dynamic Model Data card form 1
- GD2 - Generator Unit Dynamic Model Data card form 2
- GV - Generator Unit Governor Controller Data card
- NUG1- BWR Nuclear Generator Model Generic Data card form 1.

The above mentioned cards and data processor routines are a modified version of the similar module that is used in DTS Data BASE Generation program (DDBGEN), to process the same cards.

The program output is a listing and plot, with the dynamic model's inputs and output time enolution.

Module List

DDBERL - Print Error Messages: This subroutine is the same module that is used in DDBGEN, the DTS Data Base Generation program. This subroutine prints error messages on the line printer.

DELAY - Generator Unit Model Delay Function:This is a FORTRAN user defined function which simulates a a time delay in the dynamic generator unit model's loops.

FREADI - Interger Read Function: This function reads the interger test parameters. Function FREADI writes on the user computer terminal messages related with the test data necessary for the DGUTES run. The user should enter the required data in the indicated interger format.

FREADI validates the format of the entered value and if it is wrong, it will require another try from the user.

Example:

```
ENTER THE INPUT OPTION:                       |
                                              |
   1 - STEP (INPUT CONSTANT)                  |
   2 - RAMP (INPUT = A x t )                  ] FREADI'S
   3 - SINE (INPUT = A x sin (w x t)          | message
                                              |
                                              |
 X                                            |
                        ]  value entered by the user.
 2
```

FREADR - Real Read Function. This function reads the real test parameters.

Function FREADR writes on the user computer terminal messages related with the test data necessary for the DGUTES run. The user should enter the required data in the indicated format.

FREADR validates the format of the entered value and if it is wrong, it will require another try from the user.

Example:

ENTER INITIAL SYSTEM SPEED--p.u. | FREADR's message

XXX.X
1] value entered by the user

INTGRL - Generator Unit Model Integration Routine: INTGRL is a FORTRAN user defined function which uses the trapezoidal method for numerical integration of the generator unit dynamics equations.

LIMIT - Generator Unit Model Limiter Function: This is a FORTRAN user defined function which simulates a nonlinear limiter device in the dynamic model.

LIMVAL - Limit Validation: Validate card image values against their maximum and minimum limit values.

PRTMNG - Print a Line With Format Control: This subroutine is the same module that is used in DDBGEN program. The PRTMNG subroutine provides format control for a printed listing. Pages are automatically numbered and user supplied headings are printed at the top of each page

DGNDMY : This subroutine calls the adequate card image processing subroutines of the Dynamic Generator Unit Model Test and tuning program DGUTES. DGNDMY calls the DGHxx subroutine, where xx=GD, GV or FG. Subroutine DGNDMY is a modified version of the similar module used in program DDBGEN to process the DTS ADRM cards.

NUCLER - BWR Nucler Prime Mover Dynamic Model: This subroutine simulates the BWR controls, and turbine dynamics.

DGUCHA - Dynamic Model Test's Input Changes Calculation : Subroutine DGUCHA calculates changes in the test input selected to test the dynamic model. DGUCHA can use either ramp, step or sine to calculate the test input changes as a function of the time.

DGNUCP - BWR Nuclear Dynamic Model Card Processor: This subroutine reads the DTS ADRM cards detailed in section . above. DGNUCP reads one card, validates their correct sequencial order and calls the correspondent data processor subroutine.

DGNUNU - Generator Unit Dynamic Data Processor: This subroutine validates the complete set of data in cards GD1 and GD2 calling the adequate subroutine. This subroutine is a modified version of the similar module used in program DDBGEN to process the above mentioned cards. DGNUNU will callPRTMNG to print a card image line in the parameters card listing.

If DGNUGD finds erroneous value/s, it will call module DDBERL to print an error message line in the above mentioned listing. If not, this data processor will store the data in the respective data structure.

DGNUNU1 - Generator Unit Dynamic Model Card Form 1 Processor: Subroutine DGNUNU1 validates data in card image GD1 and stores their data in common ATTOM.

DGNUNU2 - Generator Unit Dynamic Model Data Card Form 2 Processor: Subroutine DGNUNU2 validates data in card image GD2 and stores their data in common ATTOM.

DGUGO - Governor Dynamics Simulator: DGUOUT prints a listing with the mechanical power output and the selected input frequency or generation set point as a time function.

DGNUGV - Governor Controller Dynamic Data Processor: This subroutine validates the complete set of data in card GV. This subroutine is a modified version of the similar module used in program DDBGEN to process the above mentioned card. DGNUGV will call PRTMNG to print a card image line in the parameters card listing. If DGNUGV finds erroneous value/s, it will call module DDBERL to print an error message line in the above mentioned listing. If not, this data processor will store the data in the respective data structure.

DGUOUT - Dynamic Model Test Output: This subroutine prints a listing with the mechanical power output and the selected input which is Scheduled Frequency or Generation Demand Set Point

DGUPLO - Dynamic Model Test plotter: The subroutine

DGUPLO plots the test input and the corresponding output of the dynamic generator unit module as a function of time

DGUPRI - Dynamic Model Test Print Preperation: This subroutine prepares the program output to be printed for DGOUT.

DGUTIN - Dynamic Model Test Parameter Read: Subroutine DGUTIN reads the test input parameters, defining the test input and the evolution time type, the integration parameters and the initial conditions for the mechanical power output and frequency and generation demand set point.

A special consideration is that the DGUTES program is a batch task.

Module Design Documents

The following design documents are the most crucial in the array of modules that were designed. Only three are spotlighted to present an idea of the concept underlying the Functional Flow .

****

DYNAMIC GENERATOR UNIT MODEL TEST AND TUNING PROGRAM

DGUTES

****

DGUTES simulates the dynamic generator unit response in the time domain, to different types of input functions. With this tool it is possible to detect conceptual errors in the mathematical dynamic model and/or its parameter values. DGUTES is the main module of the program. It drives the execution of the other modules.

****

This task is a user initiated off-line program with card data inputs.

Input Arguments :None

Output Arguments:None

****

DGUCHA: Simulates changes in the input of the dynamic generator unit model under test.

DGUGOV: Simulates the governor dynamics.

CALL DGUTIN to read:

-Initial conditions.

-Integration parameters.

-Prime mover type.

-Test functiontype.

-Test function parameters.

-Input selected to apply the test function.

[After initialization do the integration loop:]

DO until TIME. GT.FINTIM

IF TIME.GE.STARTE,time to start with changes in

^ the test input

THEN

CALL DGUCHA to calculate the change in the

^ specified input according with the test

^ function type and the selected input.

ENDIF

CALL DGUGOV to calculate, through NUCLER subroutine, the mechanical output power without changes in the dynamic model output.

IF.TIME.GE.CURPRT

THEN

CALL DGUPRI to prepare the printing.

CALL DGUOUT to print the program output.

update CURPRT

```
ENDIF
CALL DGUGOV to calculate, through NUCLER subroutine, the
     mechanical output power without changes in the
     dynamic model input.
IF TIME.GE.CURPRT
THEN
    CALL DGUPRI to prepare the printing.
    CALL DGUOUT to print the program output.
    Update CURPRT
ENDIF
IF error flag is set to one
THEN
UNDO
    ENDIF
    Increase TIME, the actual simulation time.
    Compare TIME against FINTIM
ENDO
CALL DGUPLO to plot the input and outputs of the dynamic
generator unit as a time function and print a final
report with characteristics values of the test.
IF IERROR is set
THEN
    write error message:
     'SIMULATION TERMINATES DUE ERROR'
ENDIF
END: DGUTES
```

DGUOUT: Prints the output values.

DGUPLO: Plots the input and output of the dynamic generator unit model as a time function.

DGUPRI: Prepares the output to be printed.

DGUTIN: Reads the test parameters.

****

This module calls the test input subroutine DGUTIN to set and process all the input data necessary to define the test.

DGUTES then enters a loop where it calls the input change subroutine DGUCHA, the governor simulation subroutine DGUGOV and the print and output modules DGUPRI and DGUOUT. DGUGOV calls the subroutine NUCLER to calculate the dynamic response of the fossil fueled prime mover.

All the dynamic parameters to be plotted by subroutine DGUPLO are saved in file @PCF.

After that, the driver DGUTES calls DGUPLO to plot the input and outputs of the dynamic prime mover unit model.

****

Language: FORTRAN

****

BEGIN: DGUTES

[This is the driver program for the dynamic generator unit]

[model test and tuning software.]

GOVERNOR DYNAMICS SIMULATOR

DGUGOV

22 JUL 1983

****

This subroutine simulates the governor controller by proportional and integral loops and the governor motor dynamics.

****

This subroutine is called in FORTRAN as follows:

Call DGUGOV

Input Argument: none

Output Argument : none

****

--none--

****

NUCLER

BWR NUCLEAR Generator Unit Dynamic Model subroutine.

DELAY

Delay Function.

INTGRL

Numerical Integration Function.

****

This subroutine uses the DELAY fuction to calculate the time lagg and the INTGRL function for integration of the differential equations.

This module uses the same model configuration for all the prime mover units,changing the parameters only. DGUGOV calls the subroutine NUCLER to calculate the Mechanical Power Output PM.

****

Language: FORTRAN

****

BEGIN: DGUGOV

[This subroutine simulates the governor dynamics and calls]

[NUCLER to calculate the boiler and turbine dynamics.]

Calculate:

- -Unit Control Error UCE.
- -Governor Set Point SP.
- -Telemetered Sensed Mechanical Power PMS.

CALL NUCLER to calculate the Mechanical Power Output PM of the dynamic generator unit model.

END: DGUGOV

NUCLEAR BWR GENERATOR UNIT DYNAMIC MODEL

NUCLER

31 OCT 1983

****

This module contains the simulator software for the

Nuclear BWR Turbine dynamics.

****

This subroutine is called in FORTRAN as Follows:

CALL NUCLER (CSKEDF,OMEGA,SPYB,PMYB,NUMBER,N)

Input Arguments:

CSKEDF

(4-byte real) Scheduled Frequency Set Point in Hz.See common CUVAL2.

N

(2-byte integer) Sequential Index for generator unit. See common CUVAL1.

NUMBER(N)

(2-byte integer) Sequential Number for unit N within the boiler unit type.

OMEGA

(4-byte integer) Actual System Speed in per unit. See common CUVAL1.

PM

(4-byte real) Mechanical Power Output in MW. See common CUVAL3.

SP

(4byte real) Governor Set Point.

See common CUVAL3.

UCE,UCE1

(4-byte real) Generator Unit Control Error.

See common CUVAL3.

Output Arguments:

PM

As above

****

--none--

****

The array ATOM1 is the data storage area name in local common

ATTOM used to store the parameter for the nuclear units.

The array ATTOM1 is dimensioned to store up to 10 different

Nuclear units at 11 parameters per unit.

The internal array ATOM is the working area, its elements represent the dynamic variables for each nuclear unit, dimensioned for NGENU (actual total number of generator units) at 31 variables per unit.

****

Language: FORTRAN

****

```
BEGIN: NUCLER
[ This subroutine simulates the BWR turbine dynamics.]
[ This subroutine uses the LIMIT,INTGRL and DELAY
  functions.                                      ]
IF TIME  Integration Time step
THEN
    perform the initialization routine to initialize
    the  parameters array ATOM.
ENDIF
DO pass through the simulation for:
    -Boiling Water Reactor dynamics,
    -turbine dynamics
ENDDO
END: NUCLER
```

APPENDIX - II

Computer System

The computer system of the Colbun/Machicura system, for example, consists of two MODCOMP CLASSIC II/55 computers. Each computer has the following features:

- One megabyte of resident memory
- Direct Memory Processor
- Extended Arithmetic Unit
- External Interrupt Group

Each computer has two input/output (I/O) busses which interface as follows:

- I/O Bus 0: MODCOMP Interface Controller (MIC) model 4801 for access to the VCIs, General Purpose Data Terminal Model 4805 for direct communication with the other CPU, console controller Model3767 to interface with the TI825 KSR and the switched peripheral enclosure/peripheral selector controller model 4912/4913
- I/O Bus 1: Peripheral controller interface, model 4911, for access to one disk controller, Model 4176-A

Computer Peripherals: The peripherals for the computer system include the following:

- Two console devices (KSRs) for operator input/output TI model 825
- Three moving head disks (MHDs), 67 megabytes of

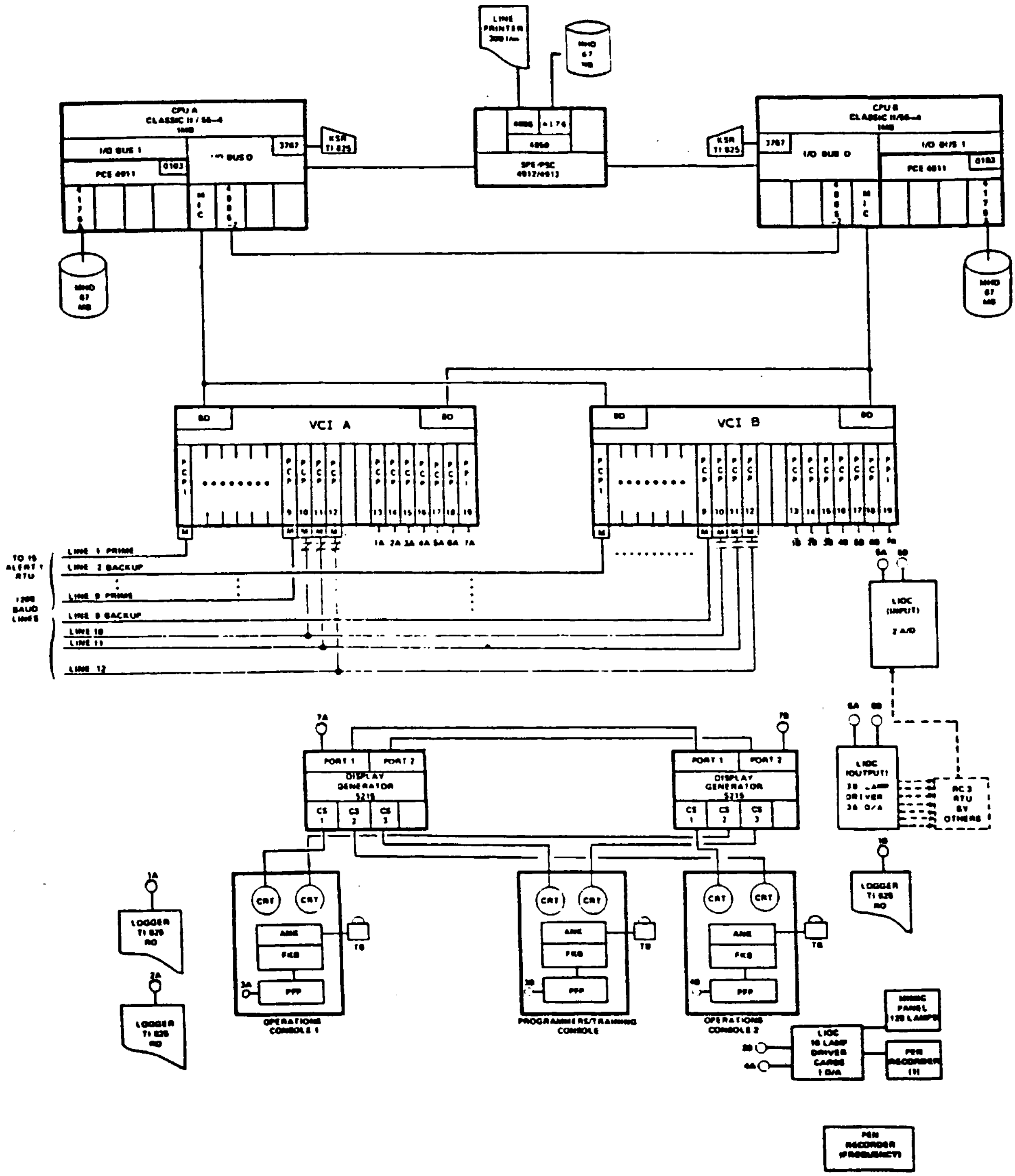

Figure 38.COLBUN/MACHICURA ENERGY CONTROL CENTER

storage

- One Printronix 300 line per minute Line Printer.

Vanguard Computer Interface Unit: The system employs two of the above units to provide an interface with the operator consoles, display generators, loggers, remote terminal units, and local input/output controllers. The VCI provides a high speed multiplexing interface for the redundant host computers. It contains programmable channel processors (PCP) which provide buffering and format conversion capabilities.

Remote Terminal Units (RTUs): This system supports TRW alert remotes using the TRW VAN-COMM message protocal. The Programmable Channel Processors (PCP) in the VCIs translate the TRW VAN-COMM message protocal to the standard protocal used between the host computers and the VCIs.

APPENDIX - III

MEMORANDUM

TO: Dr. Don Russell

FROM: John Balachandra

SUBJECT: Doctoral Internship Report

PERIOD: August 6 to September 6, 1983

For two weeks I attended in-house training sessions which familiarized the new entrants with the mode of operation of the computer system. We went in to detailed descriptions of the SOURCE EDITOR, the CAPITAL DEVELOPMENT SYSTEM and the various functions performed by the modular procedures.

After completing the training sessions I recommenced working on the CIRCUIT BREAKER VALIDATION INITIALIZATION (CBVINI) and CURCUIT BREAKER VALIDATION EXECUTIVE (CBVXEC) program modifications. The modified programs were edited, compiled and run successfully on the batch processing section of the CPU side and then on the REAL TIME section of CPU B.

The modifications in logic from the original CBVINI and CBVXEC were extracted by another program called ALTERED, which is designed specifically to extract the modifications done on a particular source deck from the

APPLICATIONS BASELINE and the resulting changedecks, CBVCHDK and CBVCHG were documented on the XDK file. The XDK file is set aside for collection of all changedecks done on existing APPLICATIONS BASELINE modules.

Modified data format for the Display Header number 1476 and 1482 to make them compatible with the sequence of the data. This was corrective action taken on a SOFTWARW PROBLEM REPORT. These were verified onthe REAL TIME side of the CPU to be format compatible.

MEMORANDUM

TO: Dr. B. Don Russell

FROM: John Balachandra

SUBJECT: Monthly Doctoral Internship Report

PERIOD: September 7 to October 7, 1983

Was assigned task to modify a subsection of the logic in the APPLICATIONS DISPLAY PRINT (APDPRT), which reads a display masterprint card to determine the function to be performed; Printt directory, print specified displays, or create a sequenced card image. The contents directory is then read in by reading the display header. If a specified display is to ve printed, the APPLICATIONS DISPLAY TABLE (ADT) is read and the contents printed. The required modifications were basically to change the inline code in a section of the APDPRT program into FORTRAN using an available subroutine called MOVEB.

The present logic stored N characters into IMAGE; stored decimals points if it were floating data, and stored quotes if it were tabular displays. Using FORTRAN code and the subroutine MOVEB, which moves a specified number of contiguous from the input array to the output array, the logic was modified and tested successfully on the BATCH PROCESSING and REAL TIME sides; CPU A and CPU B.

Was assigned task to modify LOAD FLOW STUFF (LFSTUF), which stuffs the results of the load flow into the REAL TIME DATA BASE in order that if an error is present it duly noted and the type of error and its RTU location is identified.

The software modules which were modified were the subroutines LFADST, which stuffs the results of the load flow A/D results into the RTDB for all A/D points, and LFSTST which stuffs the status of the Breaker and the Switch for all points in the network model into the RTDB. The modified modules performed successfully on the load flow run but when an abnormality was introduced and it was tested on the Real Time CPU B the results were not recorded on the printer.

MEMORANDUM

TO: Dr. B Don Russell

FROM: John Balachandra

SUBJECT: Doctoral Internship Report

PERIOD: 2 month period ends first week of December 1983.

I was assigned to a new project team lead by Dr. Robert Kimler, working on a DISPATCHER TRAINING SIMULATOR (DTS). At present I am working with Mr. Carlos Santestaban on the generator modelling aspects of the project. Mr. Santesteban is in charge of the dynamic analysis of the Fossil Fuelled prime mover and I have been assigned the tasks of analysing the dynamics of the Hydro and BWR Nuclear units. The system design documents have been appended to present an overview of the project. I have thus far successfully coded and executed the hydro unit dynamic analysis program, its module design documents, program design documents, the system design documents and the data structures. In the BWR Nuclear section thus far the module design documents, program design documents, data structures, and system design documents have been completed and I am in the process of coding the Nuclear program.

MEMORANDUM

TO: Dr. Don Russell

FROM: John Balachandra

SUBJECT: Doctoral Internship Report

PERIOD: Jan 1984 to Feb 1984

- Completed all coding procedures, including testing on the CDS system of the software modules modelling the dynamics of the BWR Nuclear and Hydro prime movers.
- Completed all documentation procedures pertaining to Program Design Documents System Design Document and Data Structures as per specifications.

At present I am working on the Marubeni/ Endesa project team engaged in providing an Energy Management System to a Utility company in Chile. Dr. Will Briggs is my supervisor and has assigned me task of designing the software responsible for reading and validating the customer card data images. Thirty (Approximately) subroutines are to be drafted and tested on the CDS. Once they have been throughly tested will be integrated into the project applications software.