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UPDATING OF THE PROGRAM FOR
SIMULATION OF DARLINGTON
SHUTDOWN AND REGULATION SYSTEMS

by

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Research report

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ABSTRACT

This report describes the current status of the developments of a simulation of the Darlington Nuclear Generating Station shutdown and regulating systems, DARSIM (ref. 1) done under contract to the Atomic Energy Control Board (AECB). The DARSIM program simulates the spatial neutron dynamics, the regulation of the reactor power, and shutdown system 1 (SDS1) and shutdown system 2 (SDS2) software. The DARSIM program operates in the interactive simulation (INSIM) program environment. DARSIM was installed on the APOLLO computer at the AECB and a version for an IBM-PC was also provided for the exclusive use of the AECB.

Shutdown system software was updated to incorporate the latest revisions in the functional specificatons (ref. 2,3). Additional developments have been provided to assist in the use and interpretation of the DARSIM results.

RÉSUMÉ

Le présent rapport décrit l'état actuel de la mise à jour d'un programme de simulation pour les systèmes d'arrêt et de régulation de la centrale nucléaire Darlington. Le travail a été fait dans le cadre d'un contrat avec la Commission de contrôle de l'énergie atomique (CCEA). Le programme DARSIM ("Darlington simulation" : simulation de Darlington) simule la dynamique spatiale des neutrons, la régulation de la puissance du réacteur et le logiciel des deux systèmes d'arrêt d'urgence du réacteur (SAU1 et SAU2). Le programme DARSIM opère en milieu INSIM ("Interactive simulation"). DARSIM a été introduit dans l'ordinateur APOLLO de la CCEA et une version DARSIM pour IBM-PC a aussi été remise pour l'usage exclusif de la CCEA.

Le logiciel des systèmes d'arrêt d'urgence a été révisé afin d'incorporer les révisions les plus récentes dans les spécifications fonctionnelles (réf. 2,3). Des perfectionnements additionnels ont été fournis pour aider à utiliser et à interpréter les résultats de DARSIM.

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UPDATING OF THE PROGRAM FOR SIMULATION OF DARLINGTON SHUTDOWN AND REGULATION SYSTEMS

A. INTRODUCTION

This report describes the current status of a computer program for the simulation of the Darlington Nuclear Generating Station shutdown and regulation systems, which was done under contract to the Atomic Energy Control Board of Canada (AECB). This current contract was done to provide AECB staff with a version of DARSIM incorporating recent revisions (Ref. 2,3) of the software for Shutdown System 1 (SDS1) and Shutdown System 2 (SDS2) of the Darlington NGS. Updates and additions were made to the DARSIM program of Ref. 1. Simulation of the SDS1 and SDS2 trip computers' software is based on emulation of the software (Ref. 4,5) and meets the functional specifications (Ref. 2,3). Simulation of the spatial neutron dynamics within DARSIM is based on the SMOKIN code (Ref. 6).

In addition to the updating, the current version of DARSIM incorporates major developments to facilitate use and interpretation of DARSIM results. These are:

- provision of an on-line HELP facility to identify variables and parameters used in DARSIM and their access names.

- provision of features to assist in interpretation of results including extensive use of APOLLO graphics capabilities.

- provision of capability to store and analyse data of selected variables for further off-line analysis and/or plotting.

DARSIM was installed on the APOLLO computer at the AECB Ottawa office and a version for an IBM-PC was also provided for exclusive use of AECB staff.

B. DARLINGTON SIMULATION (DARSIM) MODEL

1. System Model

The system model is constructed from a selection of the eight available modules. The modular structure of the program allows for expansion of the number of program modules.

1.1 System Modules

The present eight modules can be divided into two groups:

- group 1 comprises modules 1 to 6 which simulate the neutronic, regulation and shutdown systems' hardware,

- group 2 comprises modules 7 and 8 which emulates the software and simulates the hardware of the trip computers of the Darlington NGS shutdown systems 1 and 2.

1.1.1 Neutronic, Regulation and Shutdown System Modules

The six modules in this group are:

- Module 1 = SPANK
- Module 2 = SDS-N.SIG.
- Module 3 = SDS1-SOR
- Module 4 = SDS2-PI
- Module 5 = RRS-CONTINUOUS
- Module 6 = RRS-DISCRETE

1. SPANK: this module simulates the spatial analog neutron kinetics and computes:

- neutron spatial dynamics,
- delayed neutron precursor concentrations,
- Xe and I concentrations and associated reactivity,
- power feedback reactivity,
- reactivities due to regulation, shutdown system devices and other user-defined perturbations.

2. SDS-N.SIG.: this module simulates the response of the neutron sensors and computes:

- in-core neutron detectors' response,
- ion chambers' response,
- ion chambers' log rate.

3. SDS1-SOR: this module simulates actuation of the shutoff rods (SOR) which comprise the final elements of SDS1 and computes:

- insertion of shutoff rods into the reactor core as a function of time after initiation of a SDS1 trip.

4. SDS2-PI: this module simulates actuation of the poison injection (PI) system which comprises the final elements of SDS2 and computes:

- insertion of highly neutron absorbing liquid (poison) into the reactor core as a function of time after initiation of an SDS2 trip.

5. RRS-CONTINUOUS: this module simulates the reactor regulating system devices whose motion is of a continuous nature (reactor regulating system - continuous). The modules computes:

- positions of liquid zone level control valves,
- levels and volumes of H_2O in liquid zone controllers,
- positions of mechanical control absorbers (MCAs) and adjuster rods (ARs),
- position as a function of time for user-defined induced perturbations.

6. RRS-DISCRETE: this module simulates the action of the digital computer control of the bulk and spatial neutron flux (reactor regulating system - discrete). The module computes:

- the bulk and spatial power errors,
- the bulk and spatial components of the liquid zone controller's valve lifts,
- response to requested power changes.

1.1.2 Computerized Trip Parameter Modules

The two modules in this group are:

- Module 7 = S1TCMP
- Module 8 = S2TCMP

1. S1TCMP: this module emulates the software and simulates the hardware of the Darlington SDS1 shutdown system trip computers (Ref. 2,4). The modules computes:

- compensated trip setpoints for the neutron overpower trip detectors based on the detector signals output from module 2*,

- neutron signal conditioning of process parameters based on output from module 2* including computation of the detectors' compensation,

- trip setpoints which are a function of neutron power,

- enable/disable conditioning of trip parameters at the specified power levels,

- channel and shutdown system trips by the neutronic and the process trip parameters.

2. S2TCMP: this module emulates the software and simulates the hardware of the Darlington SDS2 shutdown system trip computers (Ref. 3,5). The modules computes:

- compensated trip setpoints for the neutron overpower trip detectors based on the detector signals output from module 2*,

- neutron signal conditioning of process parameters based on output from module 2* including computation of the detectors' compensation,

- trip setpoints which are a function of neutron power,

- enable/disable conditioning of trip parameters at the specified power levels,

- inhibition of a SDS2 low flow parameter trip by the Power Rundown Discriminator, PRD.

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*If module 2 is not selected, default values for the neutron signals are used. These values can be changed by the user.

- channel and shutdown system trips by the neutronic and process trip parameters.

1.2 Time Simulation

Scheduling and execution of the model's modules requires a capability for both continuous and discrete event simulation.

The program executes a complete cycle of the selected modules at a fixed simulation time interval of 0.01 seconds. Selected modules are executed only if the current simulation time minus the last execution time is equal to or exceeds the module's execution time interval.

1.2.1 Continuous Time Simulation

The output of modules 1 to 5 is computed based on a continuous time simulation. The output at the selected times is integrated over the time interval. An exponential integration routine is used to simulate rapid changes while an Euler integration routine is used to simulate slow changes such as those due to Xenon, Xe, and Iodine, I.

Output of modules 1 to 5 is computed at the same time value and uses the same time interval.

1.2.2 Discrete Event Simulation

The output of modules 6, 7 and 8 is computed based on samples taken at discrete time intervals. This discrete event simulation capability is required to simulate the:

- bulk and spatial control of the neutron power by the station's direct digital control computers which is simulated by module 6,

- SDS1 trip computers' software functions which are simulated by module 7,

- SDS2 tip computers's software functions which are simulated by module 8.

Capability is provided for input of different sampling intervals for: (a)both bulk and spatial control, (b) SDS1 trip computers and (c) SDS2 trip computers.

The asynchronous nature of the physical system is simulated by allowing the user to input a phase factor. This phase factor shifts the module's sampling interval relative to the basic time interval or the process neutronics. For example, with a basic time interval for module 1 of 50 m sec. and a discrete event sampling time interval of 100 m sec. the phase factor allows the first (and subsequent) time samples to be taken at times with up to a 100 m sec. delay.

2. Program Structure

The DARSIM program had been developed to operate within the interactive simulation (INSIM) system environment which is an independent development by the Contractor. The main features of the INSIM program are:

- modular structure,
- extensive user interactive simulation capabilities.

2.1 Modular Structure

The modular structured programming capability gives the user flexibility in selection of modules to create his model and to add additional modules if required. To preserve this modular independence, each module has its own separate input, output and parameter change and examine routines.

2.1.1 Input Data Files

Each module has its own input data file. These data files are considered to be the reference data bases and have been revised to reflect the updated functional specifications (Ref. 2,3). With separate data files for each module, the user does not have to edit the input data file each time he alters the number of modules in his model. Only the input data files for the selected modules are read by the program.

All available data on each of the files are read in. The user has the capability to alter these data after the final input data file has been read in. In the case of reactivity perturbation data, all the available perturbation data are read in but on completion of the read the perturbation initiations are disabled. The user selects from the available perturbations which one he wishes to initiate by enabling the corresponding perturbation.

Provision is made for the user to read in other data files by changing the default file names on initial setup of the model.

N.B. The input data files for modules 7 and 8 contain not only the parameter values but also a physical description of the parameters and variables used by the module.

2.1.2 Initialization Routines

A common initialization routine is used for modules 1 to 6. This arises because of the interdependence of this group of modules. This initialization routine sets the initial values of the modules' variables and establishes the initial reactivity balance with the reactivity devices at their given position.

The initialization routines for modules 7 and 8, SDS1 and SDS2 trip computers respectively, set the module variables to their initial conditions.

2.1.3 Screen/Printer Output

The progress of the simulation is monitored through output of variable values to the screen and to a printer. If a printer is not immediately available, output destined for the printer can be re-routed to a file. Two different groups of variables (27 to the screen and 33 to the printer/file) selected from the same common group of 242 can be output at a time interval selected by the user. Default values are provided for the two groups of variables and the output time interval. These default values can be changed by the user at any time during the simulation. The selected group of variables for both the present time step and the immediately preceding time step are presented on the same screen. Actuation of individual trip parameters and shutdown system trips are identified at the bottom of the screen.

2.1.4 Module Output to File

The user can select output options from each module to a file. This output can be reviewed at any time during the simulation and supplements the screen/printer output.

Three output options are provided for each module which are:

- 0 = no output,
- 1 = partial output,
- 2 = full output.

The default value for each module is 0 but this can be changed for each module by the user during initial setup of the model.

N.B. Output options are established on initial setup of the model and cannot be changed during the simulation.

The user is given the option to change the output file name from its default name, DAR001.

A capability is provided to create formatted data files of variables written to file(s) which can be reviewed during the simulation and used for further off-line analyses.

In addition to the above outputs, a standard SMOKIN type output is written to file DARSMO.

2.2 User Interaction

The INSIM program provides a "user-friendly" operating environment through provision of:

- on-line HELP facility to identify trip computers' software variables and their access names,
- menus from which user makes selections,
- prompts,
- extensive error checking of user keyboard input and echoing of input,
- ability to highlight changes in selected displayed parameters (IBM-PC version)
- windowing features (IBM-PC version)

- a keyboard interrupt capability which allows the user to interrupt the simulation at the end of a basic time cycle, change parameters and then continue with the simulation.

The above INSIM characteristics provide the DARSIM user with the following features:

- model generation from available modules,
- input data file selection,
- menu (option) selections on keyboard interrupt of simulation,
- prompting,
- keyboard input error checking,
- echoing of user's input/changes.

2.2.1 <u>Model Generation</u>

On initial startup, the user is queried whether the case to be simulated is a restart of a previously "saved" simulation. If Yes, the user is prompted for the restart filename if it is not the default filename, DARRS1. For a restart case, the modules used to generate the model are those that were used in the previous simulation. If not a restart case, the user selects from the eight available modules, which are presented in sequence, only those needed to construct his model.

<u>N.B.</u> At present it is recommended the user select any one, two or all three of the following module sets:

- modules 1 to 6,
- module 7,
- module 8.

Following module selection the user is prompted for the input data file names for his selected modules, if the input data is on files other than the default files. (See following Section 2.2.2)

During the initial setup, the user is prompted for selection of an option for output of the values of the modules' variables to a file. (See previous Section 2.1.4)

After initial selection of modules and output options, the user is presented with a summary of his model modules and the selected file output options. At this stage the user is given the option to change his options through a restart of the initial selection process.

2.2.2 <u>Input Data File Selection</u>

Reference data base files are provided for modules 1 to 8. These data files have been discussed in section 2.1.1. The user is provided with a capability to change the majority of the input data for the modules before the start of the simulation. However, these changes apply only to the current simulation and would have to be re-entered for each simulation. For simulations which require considerable changes to the input data, provision exists for the user to create a new data file and use this file as input instead of the default file.

2.2.3 Keyboard Interrupt Menu

The keyboard interrupt menu is displayed following each keyboard interrupt of the simulation and also following completion of reading the input data files for all the selected modules. This latter display of the keyboard interrupt menu allows the user to change module parameters prior to module initialization and start of the simulation.

The available keyboard interrupt options are:

Option	Item
1	Change input parameter values
2	Change printer output parameters
3	Change screen output parameters
4	Status of S1TCMP logical variables
5	Status of S2TCMP logical variables
6	Save for restart
7	Examine value of variables
8	Review variable history
9	Continue with simulation
10	HELP - Trip Logic Variable Identification
11	Stop execution of code

1. Change input parameter values: this option enables the user to change values of the modules' parameters. Selecting this option results in a layered menu; the first menu displays the modules from which the user selects the module whose variables he wishes to change. After selection of the module, the user is presented with the list of the module parameters which he can change. This routine is capable of changing module parameters which are identified by up to three-dimensioned arrays.

   N.B. If a simulation of reactivity perturbation is required, the user has to specify the type of perturbation to be initiated by this "change input parameter" routine.

2. Change printer output parameters: this option allows the user to change the printer output time interval*, the phase factor (see Section 1.2.2) and the variables that will be output to the printer. The user can select any 33 variables from a list of 242. A default list is provided which can be altered by the user. This capability allows the user to select the format (row and column) for presentation of the variables as the list of 33 can be selected in random order from the available list of 242.

3. Change screen output parameters: this option parallels option 2 and allows the user to change the screen output time interval*, the phase factor (see Section 1.2.2) and the variables that will be output to the screen. The user can select a group of 27 variables (a group which is distinct from the group of 33 printer variables) from the

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*The output time interval and phase factor are common for both the printer and screen output.

list of variables which is a common selection list for both the printer and screen selection sets. In the IBM-PC version, a capability to highlight selected displayed variables is provided. The displayed value of the variable is intensified if its value changes by more than the user-specified amount in the time interval between screen updates.

4. <u>Status of S1TCMP logical variables</u>: this option reviews the status of all logcial variables and displays on the screen those which are TRUE along with the array name, element number and physical description of the variable. On initial start, no S1TCMP logical variables should be displayed, since initial state of all the logical variables is FALSE.

5. <u>Status of S2TCMP logical variables</u>: this option is identical to option 4 but presents the status of S2TCMP logical variables which are set to TRUE. It should be noted that the normal state of S2TCMP logical variables, except for a few variables, is FALSE. The variables initially set to TRUE can be determined by requesting this option before the start of the simulation.

6. <u>Save for restart</u>: this option allows the user to save the current status of his simulation. The simulation can be continued at a later time using this file as the input.

7. <u>Examine value of variables</u>: this option allows the user to examine variables and parameters for the modules during the simulation. A layered menu structure and approach, common to option 1 (see option 1 above) is used. In addition to the parameters that the user is allowed to change under option 1, the user can also examine the values of the module variables.

8. <u>Review variable history</u>: this option allows the user to review the modules' output written to file (see Section 2.1.4). The number available for review at any one time is fixed at 30. This list can be composed of variables selected from the different modules. Successive review of different goups of 30 variables can be accommodated. In addition, the user has the option to obtain a graph (in the APOLLO version with alpha-numeric display for the IBM-PC version) which can give a simultaneous display of up to four variables versus time on the screen. Only the first four (excluding the time variable which must be the first variable) will be displayed for any selected group of up to 30 variables. Displays of different groups of four variables can be obtained by successive calls of this option. A capability is also provided in this option to write groups of up to 30 variables and their identifiers to formatted files which can then be used for further off-line analyses.

9. <u>Continue with simulation</u>: this option results in continuation of the simulation from its current status.

10. <u>HELP - Trip logic variable identification</u>: this option allows the user to identify on-line all variables and data used in modules 7 and 8 by providing a physical description and the global name and element number to use to access the variable. A layered menu structure is provided to facilitate identification. Menus are presented from which the user can select: trip computer module, trip parameter subroutines (Ref. 4,5) and real, integer or logical variable identification information.

11. <u>Stop execution of code</u>: this option results in termination of the simulation and closure of files used during the simulation.

2.2.4 Prompting

The user is assisted in setup and control of the simulation by use of screen windows combined with prompt commands. Response to prompts can be of the following form:

- C/R , entering "carriage return" leaves the default value unchanged or permits a keyboard entry to change the default parameter,
- a Y/N (Yes/No) response to a query,
- a specific response as defined in the prompt statement.

In addition to the prompts, messages are output to the screen to inform the user of the operational status of his simulation. These messages are in addition to the normal screen output (see section 2.1.3).

2.2.5 Keyboard Input Error Checking

Extensive error checking of user input from the keyboard is incorporated into the program. Input variables are checked for type and array variables are checked for range. This reduces the probability of inadvertently changing module variables or inputting data which could disrupt the simulation. Furthermore, most keyboard input changes are echoed on the screen to the the user for verification. If the wrong value was entered, the user can input the correct change.

3. Simulation Modules

The DARSIM program modules can be divided into two groups which are those simulating:

- the neutron spatial dynamics, the reactor regulation system and the shutdown systems' final elements,
- the shutdown systems' trip computers.

3.1 Neutron Spatial Dynamics, Reactor Regulation and Shutdown Systems

The equations simulating the neutron spatial dynamics, flux sensor dynamics, reactor regulation and shutdown systems are based on those in the SMOKIN program provided to the Contractor and contained in modules 1 to 6 of DARSIM. Input data to simulate the neutron spatial dynamics of the Darlington reactor to changes in status of reactivity devices or perturbations were supplied by the Client to the Contractor (Ref. 7,8).

Input data used to define the Platinum-clad Inconel detectors' response are as recommended in reference 9 except the amplitude of the longest delayed component was added to that of the second longest delayed component. Input data for the Inconel detectors' response are as recommended in reference 10.

3.1.1 Simulation Capabilities

Modules 1 to 6 of the current DARSIM program simulate the following Darlington reactor characteristics:

- the first 14 spatial flux modes,
- response of the two different types of in-core self-powered detectors and the out-of-core ion chambers.
- initial 100% full power steady-state conditions,
- automatic control of the bulk and spatial distribution of the neutron power by the zonal controllers,
- automatic IN/OUT drive of adjuster banks on high/low average level of zone controllers.
- automatic shutdown of the reactor by SDS1 and/or SDS2 when initiated by the shutdown system trip computers.

The DARSIM reference input data files establish the above conditions. Following reading of these input files, the user can initiate, prior to initialization or during program execution, simulation of:

1. Initial steady-state conditions other than 100% full power.
2. Changes in reactor power setpoint or power manoeuvres at selected times.
3. Reactor flux response with less than 14 modes.
4. Partial or total insertion of one or more mechanical control absorbers in or out-of sequence at user changeable insertion rates.
5. Changes to parameters of the bulk and spatial control programs.
6. Malfunctions of zonal controller(s).
7. Spurious in-sequence withdrawal of adjuster banks at user changeable rates.
8. Reactivity transient resulting from a 20% reactor inlet header break.
9. Failure of SDS1 or SDS2.

The above items illustrate the range of events that can be simulated with the current DARSIM. Details on simulation of the above and other conditions are given in the DARSIM support documentation (DARSIM User's Manual and DARSIM Tutorial) provided.

No Darlington test case results from SMOKIN were provided to the Contractor to verify simulation fidelity for the above range of simulation conditions.

3.1.2 Simulation Limitations

3.1.2.1 Reference Input Data Files

With the reference input data files provided, a user cannot simulate:

1. Xenon dynamics.
2. Reactivity feedback due to fuel temperature and power changes.
3. Thermal power calibration of regulation system in-core detectors.
4. Accurate spatial flux distributions arising from spurious out-of-sequence withdrawal/insertion of adjuster banks.
5. Spurious partial or total insertion of a shutoff rod.
6. Accurate decrease of bulk flux in the Darlington core following initiation of SDS2.
7. Steady-state conditions without an initial perturbation of about 2% on start of the simulation.

3.1.2.2 DARSIM Program Modules

The current version of DARSIM modules 1 to 6 does not simulate:

1. Regulation system actions of:

   - automatic initiation of setbacks or stepbacks,
   - automatic setpoint capture upon large power reductions due to negative reactivity insertions,
   - automatic IN/OUT drive of mechanical control absorbers on average level of zones.

2. The discrete spatial distribution of reactivity elements which make up SDS1 and SDS2. The multitude of discrete elements which collectively make up each shutdown system are simulated as a single reactivity device.

3. A user selectable failure of one or more of the discrete reactivity devices of SDS1 or SDS2.

4. Changes in process trip parameters of the primary heat transport system and the secondary side arising from reactivity perturbations.

3.1.3 Discussion of Limitations

Current limitations, items 1 to 5, of Section 3.1.2.1 can be eliminated by expanding and/or modifying the reference input data files to include the required data. The limitation imposed by item 6 can be eliminated by replacement of the existing Bruce GS 'A' poison injection system data with that for the Darling GS poison injection system. The limit on performance imposed by item

7 can be eliminated by changing the non-zero amplitude coefficients for the higher spatial flux modes to zero on the input data file. Upon initialization the reactivities associated with these higher spatial modes are set to zero and since these higher spatial modes are sub-critical, their amplitudes decay quickly to zero. Consequently this gives an initial transient of a few seconds duration on start of a simulation.

Because of unavailability of the data, DARSIM program performance has not been verified for above simulation conditions listed in items 1 to 6, Section 3.1.2.1. DARSIM simulation fidelity under these conditions would have to be validated before DARSIM results are accepted.

The limitation imposed by lack of simulation of all automatic actions by the regulation system, item 1, Section 3.1.2.2 can be overcome with relative ease by the user. This can be done by interrupting the program execution and changing the required variables and/or changing the required variables at the start which will initiate the required conditions at the specified time. Elimination of the limitations given by items 2 and 3, Section 3.1.2.2, single rather than multi reactivity device representation of the shutdown system elements will require modification to the code of modules 3 and 4 and provision of the required input data. Simulation of the changes in the primary and secondary process parameters resulting from reactivity perturbations (item 4, Section 3.1.2.2) will require extensive expansion and modification of the existing code. A large amount of additional input data would also be required.

3.2 Shutdown System Trip Computers

DARSIM Modules 7 and 8 emulate the software and simulate the hardware of Darlington SDS1 and SDS2 trip computers. Input data required for these modules were as defined in references 2 and 3. Required data not defined in these latter references were taken from the data bases in references 4 and 5.

3.2.1 Simulation Capabilities

Modules 7 and 8 of the current DARSIM program provide the user with the capability to:

1. Emulate SDS1 and SDS2 Darlington trip computers' logic software as defined by the functional specifications (Ref.2,3).
2. Simulate the three channelized trip computers for each shutdown system.
3. Assess trip computer automatic actions due to the spatial neutron dynamics resulting from reactivity perturbations.
4. Initiate a shutdown system trip by the process parameters by interrupting the simulation and changing the values of the process parameters' signals.
5. Disable one or more of the individual trip parameters.
6. Change the cycle times of the three channelized trip computers.
7. Change in-core flux detectors used for providing conditioning signals of the process trip parameter setpoints.

8. Change before or during the simulation, if required, the trip computers' software parameters defined in their respective reference input data bases.

The trip computers' logic subroutines were checked extensively against the functional requirements.

3.2.2 Simulation Limitations

Modules 7 and 8 do not simulate:

1. The sequential execution in real time of the trip logic software modules during a cycle.
2. The asynchronous characteristics between the evolution of the physical transient simulated and the execution of the trip computer software logic.
3. The asynchronous characteristics among the three individual computers of each of the shutdown systems.
4. The Darlington trip computers' logic software accurately. (Ref. 4,5).

3.2.3 Discussion of Limitations

The current version of DARSIM uses sequential execution of the program code. This results in the evolution of the system transient being interrupted and selected trip logic software modules being executed using inputs existing at the time of interruption. SDS1 trip computer software routines are executed at the beginning of each SDS1 trip computer cycle time. The SDS2 trip computer software has, during a complete cycle, multiple calls of the trip logic subroutines of a few of the trip parameters which must be checked frequently. These multiple calls arise because of the longer cycle time of the SDS2 trip computer compared to that of the SDS1 trip computer. The time delay between these multiple calls is simulated in DARSIM by dividing the execution of the subroutines, which check the trip parameter conditions, into two groups. The first group is executed at the beginning of the trip computer cycle time interval and the second group is executed at the mid-point of the interval. The above discussion pertains to the limitation listed in item 1, Section 3.2.2.

Items 2 and 3, Section 3.2.2 also arise from use of a single computer and sequential execution of program code to simulate the physical process, the regulation computer and the six shutdown system computers. A phase factor, discussed in Section 1.2.2, eases the limitation listed in item 2, Section 3.2.2.

The limitation imposed by item 3, Section 3.2.2 affects initiation of the local coincidence logic of SDS2. This effect is compensated for in DARSIM by additional calls of the subroutine which checks status of the local coincidence logic after execution of each group of trip logic subroutines.

Item 4, Section 3.2.2 arises because of differences in the actual software and its database compared to that defined in the functional specifications. Modules 7 and 8 emulate the software required to meet the functional specifications (Ref. 2,3).

Differences between the Darlington software and its databases (Ref. 4,5) and the functional specifications (Ref. 2,3), which were considered to prevail, have been noted by comment statements in the emulated software.

3.3 Operating Environment

The DARSIM simulation operates within the INSIM system environment. The INSIM operating environment is a proprietary program that had been developed independently by the Contractor for operation on microcomputers, particularly the IBM-PC. INSIM incorporates the latest interactive and user-friendly features. A version of DARSIM for use on an IBM-PC was provided for the exclusive use of AECB staff.

DARSIM has been installed and checked out on the AECB's APOLLO computer as required by the contractual conditions. A few minor features of INSIM (IBM-PC version) are not available on the APOLLO version of DARSIM. Comparable and/or compensating features are provided by the expanded capability of the APOLLO operating system compared to the DOS operating system of the IBM-PC. This expanded operating system combined with exploitation of the APOLLO graphics capability results in enhanced performance of the APOLLO version of DARSIM compared to the IBM-PC version even when operating on an IBM-PC AT.

The DARSIM simulation was written in Microsoft FORTRAN Version 3.2 for the IBM-PC. Overlays consisting of initialization and user-interaction routines were used to reduce CPU memory requirements. Modifications to the IBM-PC source code were required for operation of DARSIM on the APOLLO.

C. RESULTS

The current status of a simulation of the Darlington NGS regulation and shutdown systems, DARSIM, provided to the AECB under contract, has been presented. This current version updates the previous DARSIM (Ref. 1) to incorporate revisions in the functional requirements given (Ref. 2,3). The present contract also included developments to facilitate use of DARSIM and interpretation of the results. All SDS1 and SDS2 TRIP computer software modules have been checked extensively to ensure the functional requirements (Ref. 2,3) are met.

The present contract also included development, installation and checkout of a version of DARSIM which exploits the speed and graphics capability of the AECB's APOLLO computer system.

D. FUTURE WORK

DARSIM is a very flexible program to simulate the inherent dynamic neutron spatial coupling occurring in a Darlington reactor between the regulation systems and the shutdown systems from a wide range of reactivity perturbations.

Future work is proposed in four areas:

- update/modify DARSIM to incorporate further changes to functional specifications (Ref. 2,3) and/or software structure.

- remove current constraints imposed by limited input data on flexibility and range of reactivity perturbations available for simulation.

- enhance graphics capabilities.

- expand available DARSIM modules to include simulation of process parameters' responses during transients.

1. Update/Modify DARSIM

The current version of DARSIM is based on the functional specifications given in references 2 and 3. The software structure provided in references 4 and 5 is emulated in DARSIM modules 7, S1TCMP (Shutdown System 1 trip computer) and 8, S2TCMP (Shutdown System 2 trip computer). Both the functional specifications and software structure are currently under review. Changes in the functional specifications and/or software structure would require a further updating and/or modification of DARSIM to reflect the Darlington trip computers.

2. Increase Input Data

Recommendations in this area are to:

1. Provide values for those parameters for which no data presently exists.

2. Expand the number of reactivity perturbations which can be simulated by the user, for example, spurious partial or full drop of a shutoff rod.

3. Mofify DARSIM and provide the input data which would allow simulation of the individual reactivity elements of SDS1 and SDS2.

4. Provide additional pseudo-reactivity device perturbations which simulate the reactivity perturbations resulting from specific incidents.

3. Enhance Graphics Capabilities

Recommendations in this area are to:

1. Provide capability to obtain hard copy (plots) of graphs displayed on the APOLLO screen.

2. Provide continuous update of plots or schematic graphics of changes in: reactivity device positions, spatial neutron fluxes and sensor signals during simulation.

3. Provide an integration of the HELP facility with the CHANGE, EXAMINE and REVIEW options.

4. Simulation of Process Parameters

The current version of DARSIM simulates only the spatial neutron dynamics and resulting flux sensor responses to reactivity perturbations. Changes in process parameters arising from these reactivity and resulting flux changes are not simulated. Process parameter trips can be initiated, at present, only through a physical change by the user of the signal value of the process trip parameter.

Recommendations related to this area are:

1. Modify and expand DARSIM to provide a capability to simulate changes in the process trip parameter variables resulting from the induced perturbations. This could be accomplished by:

   a) Providing additional new modules within the DARSIM structure which simulate the process trip parameter variables,

   or

   b) Integrating existing thermo-hydraulics codes within DARSIM.

References

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