SAFETY PARAMETER DISPLAY SYSTEM
SAFETY ANALYSIS REPORT

FOR

GEORGIA POWER COMPANY
ALVIN W. VOGTLE NUCLEAR POWER PLANT

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1.0 INTRODUCTION

As a result of the Three Mile Island nuclear power plant accident on March 28, 1979, and the subsequent studies of needed improvements to nuclear power plant safety, the Nuclear Regulatory Commission (NRC) and the nuclear industry identified the need for a Safety Parameter Display System (SPDS). The SPDS will provide a concise display of critical plant parameters to the control-room operators to aid them in rapidly and reliably determining the safety status of the plant. The SPDS is in addition to the control-room instrumentation required by General Design Criteria 13 and 19 of Appendix A to 10CFR50 that provides the operators with the information necessary for safe reactor operation under normal, transient, and accident conditions. The SPDS, therefore, represents an improvement to the control room as it enhances the operator's ability to rapidly comprehend plant conditions and to interact in situations that require human intervention.

Supplement 1 to NUREG-0737, "Requirements for Emergency Response Capability", transmitted in NRC Generic Letter No. 82-33, consolidates the NRC requirements for an SPDS. These requirements are a distillation of the basic requirements from various previously issued NRC guidance documents (e.g., References 3, 4, and 5). Included in NUREG-0737, Supplement 1, is a requirement to submit a safety analysis report that describes "...the basis on which the selected parameters are sufficient to assess the safety status of each identified function for a wide range of events, which include symptoms of severe accidents."

The Georgia Power Co. is currently developing additional generating capacity for the Southern Company system. The Alvin W. Vogtle nuclear generating station, well along in construction, consists of twin Westinghouse four-loop pressurized-water reactor (PWR) nuclear steam supply systems. Each of these units is rated at 1100 MW net electrical power. Balance of plant design and construction management are being furnished by the Bechtel Power Co.

The SPDS for the Vogtle plant will be integrated into a comprehensive computer system that includes the emergency response facilities (ERF) data acquisition, data processing, and display functions. The SPDS will utilize cathode-ray tube (CRT) monitors, strategically placed and having appropriate man-machine interfaces. By means of user-called displays, an abundance of information on the safety status of the plants can be quickly made available to operations and technical staff.

The purpose of this safety analysis report is to document the selection of parameters used for the SPDS being developed for the Vogtle project. This report complements other descriptions and program materials that document the design features and implementation program for the Vogtle SPDS.

Section 2.0 of this report identifies the safety function categories selected by the Georgia Power Co. as the framework around which the Vogtle station SPDS is constructed. Section 3.0 explains the actual bases and origins for the parameters selected to characterize each of the chosen SPDS safety functions. The hierarchy and interrelationships of the SPDS displays are briefly discussed in Section 4.0, while the actual parameters are presented in Section 5.0.

A summary and conclusions as to the adequacy of the selected parameters for SPDS use are given in Section 6.0.

2.0 VOGTLE CRITICAL SAFETY FUNCTIONS

NUREG-0737, Supplement 1, requires that, as a minimum, the SPDS must provide safety status information to plant operators that includes

(1) reactivity control,
(2) reactor core cooling and heat removal from the primary system,
(3) reactor coolant system integrity,
(4) radioactivity control, and
(5) containment conditions.

The specific parameters to be displayed within each of the above categories are to be determined by the licensee.

The Vogtle SPDS will use the following categories based on the Emergency Response Guideline recommendations of the Westinghouse Owner's Group for critical safety function status monitoring:

(1) reactivity,
(2) core cooling,
(3) heat sink,
(4) reactor cooling system integrity,
(5) reactor cooling system inventory, and
(6) containment.

In addition, the Vogtle station will implement its Plant Effluent Radiation Monitoring System (PERMS), which will provide data on any radioactivity releases. The requirements of NUREG-0737, Supplement 1, for function monitoring are therefore fulfilled.

The parameters selected to monitor each of the above safety function categories are discussed in Section 5.0.

3.0 SOURCES AND BASES FOR SPDS PARAMETERS

The primary basis for SPDS parameters is the NRC requirement in Supplement 1 to NUREG-0737 that the SPDS provide a concise display of critical plant variables to the control-room operators to aid them in rapidly and reliably determining the safety status of the plant. The SPDS is intended to supplement and be in addition to, not instead of, the control-room instrumentation required by General Design Criteria 13 and 19 of Appendix A to 10CFR50 that provides all the information necessary for safe reactor operation under normal, transient, and accident conditions. Thus, the SPDS provides an improvement to the control room by concentrating and displaying the critical plant data so that the operator can quickly assess and evaluate the plant safety status and detect abnormal operating conditions.

The specific safety function categories selected by the Georgia Power Co. for the Vogtle plant have been given in Section 2.0. This section discusses the considerations that were made to select particular parameters to characterize each of those safety functions.

The parameter set selected resulted from three sources:

(1) Emergency Response Guidelines,
(2) Regulatory Guide 1.97, and
(3) specific evaluation of information required for manual operator action.

These are discussed in the following sections.

3.1 Emergency Response Guidelines

Georgia Power Co. has invoked the generic Emergency Response Guidelines (ERGs) as developed by the Westinghouse Owner's Group as its basis for developing plant-specific Emergency Operating Procedures (EOPs) for the Vogtle station.

Upgraded EOPs are required by NUREG-0737, Supplement 1. The EOPs provide for preplanned responses to specific abnormal or emergency status in any of the critical safety functions. The safety function status is determined by a logic-tree methodology that was developed by the Westinghouse Owner's Group. These logic trees are designated as the Critical Safety Function Status Trees, or CSFSTs. The basis for construction of the CSFSTs was to select the minimum number of parameters whose individual conditions could be examined to reliably establish the status of the given safety function.

The EOPs are designed to be usable even in the absence of any specific event diagnosis. This makes them of particular value in situations where multiple events have occurred and whose precise nature may not be immediately apparent. Use of the corresponding function restoration procedures which are indicated by the logic trees would commence immediately to restore the critical safety funciton to an acceptable status. These procedures would generally be complemented by a set of more optimal recovery procedures that would be invoked once diagnosis of the specific plant conditions has been made and confirmed.

The construction of the CSFSTs was the culmination of substantial efforts by the Westinghouse Owner's Group. This effort was conducted over a two-year period. It included exhaustive evaluations to assure that the CSFST-driving parameters comprised a necessary and sufficient set and that, coupled with the decision criteria used, reliable conclusions were drawn for safety function status. Development of the CSFSTs is documented in References 10 and 11. Adaptation of the CSFSTs specifically for Vogtle is documented in Reference 12.

The Westinghouse Owner's Group CSFSTs were selected verbatim as the processing methodology for the critical safety functions. By so doing, the parameters upon which these CSFSTs depend are automatically invoked.

Of course, the Westinghouse Owner's Group CSFSTs were constructed only for posttrip safety function status monitoring. Georgia Power Co. has adopted similar logic trees using the same parameter sets to determine status of the critical safety functions under nontrip operational modes. The decision points for these operational conditions (i.e., nontripped plant modes) have been drawn from, and are directly traceable to, the Vogtle Technical Specifications or procedures.

3.2 Regulatory Guide 1.97

Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident", has identified specific plant parameters required for control-room operating personnel during accident conditions. While Regulatory Guide 1.97 is not a necessary and sufficient basis for selecting SPDS parameters, its purpose and that of the SPDS are closely related. It provides an excellent basis for developing and assessing SPDS parameters.

Reg. Guide 1.97 distinguishes several types of variables as to their usage in accident situations. Specific variables of types B, C, D, and E are given explicitly. These relate to the following:

(1) Type B - variables that provide information to indicate whether reactivity control, core cooling, reactor coolant system integrity, and containment integrity functions are being maintained.

(2) Type C - variables that provide information to indicate a breach, or the potential for a breach, of the fission product barriers:

- (a) fuel cladding,
- (b) primary coolant pressure boundary, and
- (c) containment.

(3) Type D - variables that provide information to indicate the operation of individual safety systems and other systems important to safety.

(4) Type E - variables to be monitored as required for use in determining the magnitude of the release of radioactive materials.

Reg. Guide 1.97 also identifies a Type A classification consisting of plant-specific variables that are to be determined by the licensee:

Type A - variables to be monitored that provide the primary information required to permit the control-room operator to take specific manually controlled actions for which no automatic control is provided and that are required for safety systems to accomplish their safety functions for design-basis-accident events.

Type A variables were evaluated and selected by Westinghouse for the Vogtle station. This study, its results, and its conclusions are documented in Reference 6.

It is quite clear that the Reg. Guide 1.97 variables fulfill needs very close to those of the SPDS. Both parameter sets respond to the needs for establishing an accurate status of plant safety functions, as well as providing the perspective of plant conditions necessary to anticipate challenges to safety.

Reg. Guide 1.97 establishes three levels of importance within each variable type:

(1) Category 1 - key variables,

(2) Category 2 - important backup variables, and

(3) Category 3 - backup variables of lesser importance.

Seismic and environmental qualification as well as signal validation requirements are imposed by Reg. Guide 1.97 for each of these three categories to an extent that is consistent with their importance level.

The Vogtle critical safety functions include all Category 1 variables or at least processed calculated parameters derived from such variables. In addition, certain preferred backup variables (i.e., Category 2) of Type C and a few variables of Type D have been similarly included. All radiation monitoring signals have been provided to the SPDS. These include process radiation monitors (e.g., steam lines), liquid and gaseous effluent radiation monitors, and area monitors (References 6, 8, and 13).

Because of the integration of the SPDS function with the ERF computer system at Vogtle, in fact, every Vogtle Reg. Guide 1.97 variable is accessible on the SPDS monitors through the man-machine interface.

4.0 SPDS DISPLAY HIERARCHY

The Vogtle SPDS is comprised of CRT monitors with user keyboards strategically located in the control room, technical support center, and emergency operations facility. The versatility of CRT monitoring, coupled with sophisticated man-machine interfaces and the near-instantaneous raw data processing capabilities of the associated computer system, has enabled the design of a sophisticated and powerful monitoring system.

A very brief description of the data presentation is helpful here to place into context the manner in which the SPDS parameters are monitored. For the purpose of this report, suffice it to note that the man-machine interface has been carefully thought out so that accessibility of the information and linkages among the displays are straightforward and rapidly accomplishable.

A display providing a summary status of all CSFs and the PERMS is continually displayed in the control room (assured by system interlock).

4.1 Top-Level Display

The top-level display is the essence of the Vogtle SPDS. It presents the status of all six critical safety functions, radiation monitoring system, status of plant engineered safeguard features, and current values of approximately 50 specific parameters (the "top-level parameters").

The top-level display has the following features:

(1) user selectable in either of two formats, where the top-level parameters are displayed either graphically or digitally;

(2) incorporates color coding of alarm severity;

(3) includes pattern recognition and other human engineered characteristics; and

(4) automatic audible alarm in the control room for abnormal status of any CSF or PERMS.

4.2 Second-Level Displays

Second-level displays provide the details of the statuses summarized at the top level for the six critical safety functions plus the radiation monitoring system (Section 2.0). These consist of

(1) six separate CSFST displays showing the current logic path, each of which includes a summary status of the companion CSFSTs and the plant effluent radiation monitoring system, and

(2) an effluent radiation monitoring display that provides a map and status of radiation levels in all plant areas and includes a summary status of the six critical functions.

4.3 Third-Level Displays

Third-level displays provide the most detailed information to elaborate on data summarized on the top- and mid-level displays. These enable the operator to focus in on the origins of any off-normal status indications that he may have been alerted to on higher level displays.

Information available at the third level includes

(1) time-base trends for preselected parameters in the system,

(2) digital values and graphics for core-exit temperatures in a variety of formats,

(3) locus of recent primary system operation relative to the saturation conditon,

(4) pressure-temperature operational limits map showing the locus of recent reactor coolant conditions,

(5) containment isolation valve status,

(6) current values for parameters driving each of the CSFSTs, and

(7) current values for parameters driving the radiation indications for each of the plant areas on the effluent radiation monitoring mid-level display.

4.4 Miscellaneous Operator-Aid Displays

A number of displays are available as additional aids to the operators and system user. Although not intended specifically for SPDS use, the integration of the computer systems and data bases has resulted in their accessibility by all users. This is a significant enhancement to the usefulness of the SPDS.

Noteworthy among these aids are the following:

(1) an extensive number of plant schematics, flow diagrams, and process and instrumentation diagrams (P&IDs), utilizing color coding and graphic enhancements to denote component operation and alarm status;

(2) alphanumeric presentation of all plant variables on the system input list, either individually or in pre-set groups, including all Plant Vogtle Reg. Guide 1.97 variables not part of the SPDS;

(3) descriptions of all calculated points, i.e., new data points generated by computer processing of specific sensor inputs,

including input sensor identification and the processing algorithms; and

(4) time-based trends of every parameter in the system.

5.0 SPDS PARAMETERS

Itemized below are those parameters that are explicitly shown on the Vogtle top-level SPDS display. A brief explanation and justification ties each of these to the selection bases described in Section 3.0.

(1) Neutron flux:

(a) Reg. Guide 1.97 Type B variable (see definitions of variable types, Section 3.0),

(b) key variable for monitoring Westinghouse Owner's Group (WOG) reactivity CSFST,

(c) determine if plant is in subcritical condition, and

(d) diagnosis of positive reactivity insertion.

(2) Startup rate:

(a) key variable for monitoring WOG reactivity CSFST,

(b) determine if plant is in subcritical condition, and

(c) diagnosis of positive reactivity insertion.

(3) Cooldown rate:

(a) key variable for monitoring WOG RCS integrity CSFST,

(b) detection of pressurized thermal shock condition, and

(c) maintenance of proper relationship between temperature and pressure.

(4) RCS subcooling:

(a) Reg. Guide 1.97 Types A and B variable,

(b) key variable for monitoring WOG core cooling CSFST,

(c) determine that a subcooled condition exists in the reactor cooling system (RCS), and

(d) verification of adequate RCS subcooling margin.

(5) RCS wide-range pressure:

(a) Reg. Guide 1.97 Types A, B, and C variable,

(b) key variable for monitoring WOG RCS integrity CSFST,

(c) determine if plant is in a cold shutdown condition,

(d) maintenance of a proper relationship with RCS temperature,

(e) detection of potential for RCS boundary breach,

(f) verify vessel nil ductility temperature (NDT) criteria,

(g) maintenance of primary inventory subcooling,

(h) establish correct condition for residual heat removal (RHR) operation,

(i) determine whether reactor coolant pump operation should be continued, and

(j) determine whether high head safety injection should be terminated or reinitiated.

(6) Pressurizer level:

(a) Reg. Guide 1.97 Types A and B variable,

(b) key variable for monitoring WOG RCS inventory CSFST,

(c) confirmation that plant is in a cold shutdown condition,

(d) determine if safety injection should be terminated or reinitiated, and

(e) determination of adequate reactor coolant inventory.

(7) Reactor vessel water level:

(a) Reg. Guide 1.97 Types B and C variable,

(b) key variable for monitoring WOG RCS inventory and core cooling CSFSTs, and

(c) indication of a core-uncovery situation under a design-basis condition.

(8) Core-exit temperature:

(a) Reg. Guide 1.97 Types A, B, and C variable,

(b) key variable for monitoring WOG core cooling CSFST, and

(c) determine if core is being adequately cooled.

(9) Containment pressure:

(a) Reg. Guide 1.97 Types A, B, and C variable,

(b) key variable for monitoring WOG containment CSFST,

(c) backup variable for monitoring RCS integrity,

(d) determine if break is inside or outside containment,

(e) monitor conditions following break inside containment, and

(f) verify event is properly controlled.

(10) Containment hydrogen concentration:

(a) Reg. Guide 1.97 Types B and C variable,

(b) key variable for monitoring containment environment,

(c) identifying potential for containment boundary breach due to hydrogen detonation, and

(d) determination of acceptable hydrogen concentration control.

(11) Containment isolation valve status:

(a) Reg. Guide 1.97 Types B and C variable,

(b) key variable for detection of containment boundary breach, and

(c) determine accomplishment of containment isolation.

(12) Containment water level:

(a) Reg. Guide 1.97 Types A, B, and C variable,

(b) key variable for monitoring WOG containment CSFST,

(c) backup variable for determining adequate reactor coolant inventory,

(d) verify water source available for recirculation mode cooling,

(e) determination of high energy line rupture inside or outside containment, and

(f) determination of flooded conditions at instrumentation mounting locations.

(13) Condensate storage tank level:

(a) Reg. Guide 1.97 Types A and B variable and

(b) determination of adequate water supply for auxiliary feed-water pumps.

(14) Refueling water storage tank level:

(a) Reg. Guide 1.97 Type A variable,

(b) verify water source available for the emergency core cooling system and containment spray system,

(c) determination of time for initiation of cold leg recirculation following a loss of coolant accident, and

(d) event diagnosis (e.g., steam generator tube rupture).

(15) Reactor coolant pump status:

(a) key variable for monitoring WOG core cooling CSFST,

(b) aids interpretation of reactor vessel level indicating system (RVLIS) indications, and

(c) verification of proper system operation.

(16) Wide range hot leg temperature:

(a) Reg. Guide 1.97 Types A and B variable,

(b) key variable for monitoring WOG RCS integrity CSFST,

(c) backup variable for monitoring reactivity and core cooling,

(d) maintenance of adequate heat sink,

(e) maintain proper relationship with RCS pressure,

(f) verify vessel NDT criteria,

(g) maintain primary inventory subcooling,

(h) determine if plant is in cold shutdown condition,

(i) establish correct conditions for RHR operation,

(j) monitor RCS heatup/cooldown rate,

(k) determine whether safety injection should be terminated,

(l) determination of loss of reactivity control, and

(m) detection of pressurized thermal shock condition.

(17) Wide range cold leg temperature:

(a) Reg. Guide 1.97 Types A and B variable,

(b) key variable for monitoring WOG RCS integrity CSFST,

(c) backup variable for monitoring reactivity and core cooling,

(d) maintain proper relationship with RCS pressure,

(e) maintain primary inventory subcooling,

(f) verify vessel NDT criteria,

(g) determination of natural circulation conditions in conjunction with hot leg temperature, and

(h) detection of pressurized thermal shock condition.

(18) Steam generator pressure:

(a) Reg. Guide 1.97 Types A and B variable,

(b) key variable for monitoring WOG heat sink CSFST,

(c) determination of high energy, secondary line rupture,

(d) maintenance of adequate reactor heat sink, and

(e) verify that auxiliary feedwater flow to steam generator associated with rupture is isolated.

(19) Steam generator narrow range level:

(a) Reg. Guide 1.97 Types A and B variable,

(b) key variable for monitoring WOG heat sink CSFST,

(c) determination of adequate heat sink,

(d) detection of water spillage into steam lines, and

(e) determine whether safety injection should be terminated.

(20) Steam generator wide range level:

(a) Reg. Guide 1.97 Types A and B variable,

(b) determiantion of adequate heat sink, and

(c) safety injection for secondary breaks outside containment.

(21) Auxiliary feedwater flow:

(a) Reg. Guide 1.97 Types A and B variable,

(b) key variable for monitoring WOG heat sink CSFST,

(c) determine if sufficient flow exists to maintain heat sink, and

(d) safety injection termination.

(22) Steam generator steam flow:

(a) Reg. Guide 1.97 Type D variable (verification of proper system operation),

(b) maintenance of adequate heat sink during power operation, and

(c) detection of secondary plant transients during power operation.

(23) Feedwater flow:

(a) Reg. Guide 1.97 Type D variable,

(b) determine if sufficient flow exists to maintain adequate heat sink during power operation, and

(c) detection of secondary plant transients during power operation.

(24) Main steam radiation:

(a) Reg. Guide 1.97 Types A, B, and E variable,

(b) backup variable for monitoring RCS integrity, and

(c) detection of radioactive release to system.

(25) Reactor Trip

(26) Turbine Trip

(27) Safety Injection Signal

(28) Containment Isolation Signal

(29) Loss of Off-Site Power

Parameters 25-29 are key Reg. Guide 1.97 Type D variables for verifying automatic actuation of safety systems.

The parameters above are provided for each reactor coolant loop, where appropriate. Where multiple sensors are present, the parameters represent calculated parameters based on specific processing of the individual sensors. In addition, certain processed parameters, such as maximum core-exit temperature, are generated from the plant sensors.

The radiation monitoring family of SPDS displays is comprised of the parameters identified below.

(1) Area monitors:

(a) control room,

(b) radiochemistry laboratory,

(c) sampling room,

(d) fuel-handling building,

(e) large parts decontamination station,

(f) small parts decontamination station,

(g) hot instrument decontamination station, and

(h) technical support center - CRT room and work area.

(2) Containment building:

(a) vent effluent particulates, iodine, and radioactive gases;

(b) atmosphere process air particulate;

(c) operating level area - high and low ranges;

(d) access hatch area; and

(e) in-core instrument room area.

(3) Gaseous monitors:

(a) waste gas process system radioactive gases;

(b) plant vent air particulates, iodine, and radioactive gases;

(c) solid waste building effluent - particulates, iodine, and radioactive gases;

(d) volumetric reduction room air - particulates, iodine, and radioactive gases;

(e) waste gas process effluent radioactive gases;

(f) waste gas decay tank effluent radioactive gases;

(g) waste gas comp. area vent radioactive gases;

(h) fuel handling building effluent radioactive gases;

(i) cubicle air - particulates and radioactive gases;

(j) control room air intake process radioactive gases; and

(k) technical support center vent radioactive gases.

(4) Liquid monitors:

(a) boron recycle process,

(b) component cooling water process,

(c) nuclear service cooling water process,

(d) auxiliary steam condensate return,

(e) auxiliary component cooling water,

(f) chemical and volume control system letdown,

(g) turbine building drain,

(h) control building sump discharge, and

(i) waste liquid effluent.

(5) Steam generators:

(a) sample liquid process,

(b) blowdown liquid process,

(c) steam lines, and

(d) condenser air ejector.

6.0 SUMMARY

In response to NRC requirements, the Georgia Power Co. has identified six critical safety functions plus a radiation monitoring system upon which to build the SPDS at the Alvin W. Vogtle nuclear generating station. A minimum and sufficient parameter set was selected to characterize these safety functions. The methodology required to process these parameters so as to determine the statuses of the safety functions was established.

The Vogtle SPDS takes full advantage of the exhaustive, methodical approach followed by the Westinghouse Owner's Group in identifying the critical safety functions, choosing the most concise parameter set for each of the safety functions, and establishing the processing methodology (logic tree construction, parameter decision values, and function restoration hierarchy). Georgia Power Co. has augmented the Owner's Group post-accident monitoring critical safety functions by providing processing for non-reactor-trip operational modes as well.

The Vogtle station will complement the Owner's Group critical safety functions with a comprehensive plant effluents radiation monitoring system. An additional set of parameters, chosen for their unique value in determining plant conditions, has been selected for continuous display along with the statuses of the critical safety functions and radiation monitoring system on the top-level display.

While the SPDS parameters alluded to provide for a system that fully satisfies the NRC requirements, the integration of the SPDS with the ERF computer system and data base at Vogtle greatly enhances the usefulness of the SPDS. Alarm conditions monitored on the SPDS can be investigated by operations and technical staff using the same monitors and man-machine interfaces. This permits a rapid interrogation, location, and timely diagnosis of abnormal plant operation.

Georgia Power Co. has carefully selected SPDS parameters to continuously monitor safety status of the Vogtle Plant. These parameters are sufficient to assess the plant safety status for a wide range of events, which include symptoms of severe accidents.

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