WESTINGHOUSE REACTOR PROTECTION SYSTEM EXECUTIVE SUMMARY

This report documents an analysis of the safety-related performance of the reactor protection system (RPS) at U.S. Westinghouse commercial reactors during the period 1984 through 1995. Objectives of the study were the following: (1) to estimate RPS unavailability based on operational experience data and compare the results with models used in probabilistic risk assessments (PRAs) and individual plant examinations (IPEs), and (2) to review the operational data from an engineering perspective to determine trends and patterns and to gain additional insights into RPS performance. The Westinghouse RPS designs covered in the unavailability estimation include those with solid state protection system (SSPS) trains and Analog Series 7300 or Eagle-21 channels. The fault trees developed for these designs assumed a four-loop plant.

Westinghouse RPS operational data were collected from Licensee Event Reports as reported in the Sequence Coding and Search System and the Nuclear Plant Reliability Data System. The period covered 1984 through 1995. Data from both sources were evaluated by engineers with operational experience at nuclear power plants. Approximately 15,000 events were evaluated for applicability to this study. Those data not excluded were further characterized as to the type of RPS component, type of failure, failure detection, status of the plant during the failure, etc. Characterized data include both independent component failures and common-cause failures (CCFs) of more than one component. The CCF data were classified as outlined in the report *Common-Cause Failure Data Collection and Analysis System* (NUREG/CR-6268). Component demand counts were obtained from plant reactor trip histories and component test frequency information.

The risk-based analysis of the RPS operational data focused on obtaining failure probabilities for component independent failure and CCF events in the RPS fault tree. The level of detail of the basic events includes the following: reactor trip breakers (mechanical/electrical portion, undervoltage coil, and shunt trip coil); SSPS undervoltage driver and universal cards; and channel trip sensor/transmitters, signal processing modules, and associated bistables and relays. CCF events were modeled for all redundant, similar types of components.

Quantification of the fault tree models resulted in a mean unavailability (failure probability upon demand) of 2.2E-5 (with no credit for manual scram by the operator) for the Analog Series 7300 design. The lower 5^{th} percentile is 5.8E-6 and the upper 95^{th} percentile is 5.7E-5. Approximately 95% of the overall RPS unavailability is from CCF events. CCF of the two undervoltage driver cards (one per train) is the dominant contributor (46.1%) to RPS unavailability. Other important CCF events involve the channel bistables (11.5%), train universal cards (9.7%), channel signal processing modules (7.8%), reactor trip breakers (7.4%), and rods (5.5%). Results for the Eagle-21 RPS design are similar, with a mean unavailability of 2.0E-5.

Both the Analog Series 7300 and Eagle-21 RPS designs have a single undervoltage driver card in each of the two trains. Failure of both of these cards results in failure of RPS (unless manual scram is credited). This CCF event is the dominant contributor (almost 50%) to RPS unavailability. In 1989, a CCF event involving both driver cards occurred while the plant was shut down. The failures were caused by maintenance activities and were detected before the plant returned to power. Since then, the driver card design has been changed to minimize the chance of such maintenance activities causing such failures. Also, plant procedures for such maintenance have been improved. However, CCF of both of these cards is still predicted to be a dominant contributor to RPS unavailability.

Issues related to reactor trip breakers, arising during the early 1980s, are no longer dominant with respect to RPS unavailability. (This is true for both cases of RPS unavailabilities: without crediting operator action and crediting operator action.) Automatic actuation of the shunt trip mechanism within the reactor trip breakers and improved maintenance procedures have resulted in improved performance of these components.

The Analog Series 7300 and Eagle-21 RPS designs have comparable unavailabilities. This occurs because the Eagle-21 design considered in this report involves only the channel processing portion of the RPS. The dominant contributors to RPS unavailability result from other portions of the RPS.

The RPS fault trees were also quantified allowing credit for manual scram by the operator. The resulting mean unavailabilities are 5.5E-6 for the Analog Series 7300 design and 4.5E-6 for the Eagle-21 design. Therefore, operator action reduces the RPS unavailability by approximately 75%. This reduction is significant and occurs mainly because the manual scram signal bypasses the dominant undervoltage driver card failures. For the Analog Series 7300 design, CCF of the two reactor trip breakers is the dominant event, contributing 29.1% to the RPS unavailability. Other important CCF events involve the channel bistables (27.9%), rods (21.7%), and channel signal processing modules (18.9%). Contributors to the Eagle-21 unavailability are similar.

RPS unavailability estimates from Individual Plant Examinations (IPEs) and other sources range from approximately 1.0E-6 to 1.0E-4. Because of the lack of detailed information in the IPE submittals, it is not clear which estimates included credit for operator action. The IPE range of RPS unavailabilities covers the uncertainty ranges obtained in this study, based on the analysis of data from 1984 through 1995. However, most of these other sources estimated that the trip breaker CCF events would dominate the RPS unavailability. In this study, such events contribute less than 10% when no credit is taken for manual scram by the operator and approximately 30% if credit is taken.

The engineering analysis identified decreasing trends in component failure and CCF event counts for several RPS components. No increasing trends were identified over the period 1984 through 1995.

Finally, not many significant Westinghouse RPS CCF events were identified from the period 1984 through 1995. Therefore, current practices appear to be effective in preventing such events.