Draft Report

Regulatory Effectiveness of the Station Blackout Rule

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ABSTRACT

The Nuclear Regulatory Commission's Office of Nuclear Regulatory Research is reviewing selected regulations, starting with the station blackout (SBO) rule, to determine if the requirements are achieving the desired outcomes. This initiative is part of an evolving program to make NRC activities and decisions more effective, efficient, and realistic. This report evaluates the effectiveness of the SBO rule by comparing regulatory expectations to outcomes. A set of baseline expectations was established from the SBO rule and related regulatory documents in the areas of coping capability, risk reduction, emergency diesel generator reliability, and value-impact. The report concludes that although there are opportunities to improve the clarity of SBO related regulatory documents, the SBO rule is effective and the industry and the NRC costs to implement the SBO rule were reasonable considering the outcome.

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ABBREVIATIONS

Aac	alternate ac
ACRS	Advisory Committee on Reactor Safeguards
AOT	allowed outage time
CDF	core damage frequency
CFR	*Code of Federal Regulations*
EDG	emergency diesel generator
GSI	generic safety issue
IN	information notice
INEEL	Idaho National Engineering and Environmental Laboratory (formerly INEL)
IPE	individual plant examination
LER	licensee event report
LOOP	loss of offsite power
MOOS	maintenance (and testing) out of service
NEI	Nuclear Energy Institute (formerly NUMARC and USCEA)
NRC	Nuclear Regulatory Commission, U.S.
NUMARC	Nuclear Management and Resources Council (now NEI)
PRA	probabilistic risk assessment
RCP	reactor coolant pump
RES	Nuclear Regulatory Research, Office of (NRC)
RG	regulatory guide
RY	reactor-year
SBO	station blackout
SSC	structure, system, and component
USI	Unresolved Safety Issue

EXECUTIVE SUMMARY

The Nuclear Regulatory Commission's Office of Nuclear Regulatory Research is reviewing selected regulations, starting with the station blackout (SBO) rule, to determine if the requirements are achieving the desired outcomes. This initiative is part of an evolving program to make NRC activities and decisions more effective, efficient, and realistic. As part of this program, the staff noted in SECY-97-180, "Response to Staff Requirements Memorandum of May 28, 1997, Concerning Briefing on IPE [individual plant examination] Insight Report," August 6, 1997, that the Office of Nuclear Regulatory Research activities for assessing regulatory effectiveness would determine whether additional generic action is warranted, assess whether any new generic safety issues warrant attention, and whether the individual plant examination results justify plant-specific actions.

The NRC designated SBO, which is a loss of all offsite and onsite ac power concurrent with a turbine trip, as Unresolved Safety Issue A-44 in 1980. In 1988, the Commission concluded that additional SBO regulatory requirements were justified and issued the SBO rule (10 CFR 50.63) to provide further assurance that a loss of both offsite and onsite emergency ac power systems would not adversely affect public health and safety. The SBO rule expected a reduction in the risk as a result of licensees maintaining highly reliable onsite emergency ac electric power supplies; ensuring that the plants can cope with an SBO for some period of time; developing procedures and training to restore offsite and onsite emergency ac power should either become unavailable; and making modifications necessary to meet the SBO rule requirements.

To assess the regulatory effectiveness of the SBO rule, SBO related regulatory requirements were used as a baseline for comparison to the actual outcomes. The baseline provided a set of expectations in the areas of coping capability, risk reduction, emergency diesel generator (EDG) reliability, and value-impact. The comparison showed whether the expectations were achieved. Discrepancies between expectations and outcomes prompted a review of the related regulatory documents to identify areas that need NRC staff attention.

The report's conclusion is that the SBO rule was effective, and industry and NRC costs to implement the SBO rule were reasonable considering the outcomes. In implementing the SBO rule, some plants made hardware modifications (e.g., the addition of diesel generator or gas turbine generator power supplies); and all plants generally maintained EDG reliability at 0.95 or better, and established SBO coping and recovery procedures. Consequently, the plants have gained SBO coping capability, reduced risk, increased tolerance of a loss of ac offsite or onsite power, and many plants benefitted economically from the addition of power supplies. To elaborate:

- The reduction in the estimated mean SBO core damage frequency (CDF) was approximately 3.2E-05 per reactor year, slightly better than the 2.6E-05 per reactor year expected after implementation of the SBO rule. As a result of the improvements made under the SBO rule, more plants achieved a lower SBO CDF than expected, and the plants with the greatest numbers of loss of offsite power from plant events and extremely severe weather conditions made the most improvement by providing access to an alternate ac power supply. In addition, maintaining high EDG target reliability levels provides assurance that probabilistic risk assessment/individual plant examination EDG performance assumptions are valid. With some exceptions, the observed EDG

reliability performance generally exceeds the mean reliability EDG performance assumptions in the probabilistic risk assessment/individual plant examinations, indicating that SBO CDFs are smaller and better than stated in many probabilistic risk assessment/individual plant examinations. As the SBO rule risk reduction objectives have been exceeded, further investigation of strategies for reducing SBO frequencies (as suggested in NUREG-1560, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance," December 1997) may not be needed.

- As a result of the SBO rule all plants have (1) established SBO coping and recovery procedures; (2) completed training for these procedures; (3) implemented modifications as necessary to cope with an SBO; and (4) ensured a 4- or 8-hour coping capability.

- Before the SBO rule was issued, only 11 of 78 plants surveyed had a formal EDG reliability program, 11 of 78 plants had a unit average EDG reliability less that 0.95, and 2 of 78 had a unit average EDG reliability of less that 0.90. Since the SBO rule was issued, all plants have established an EDG reliability program that has improved EDG reliability. A study shows that only 3 of 102 operating plants have a unit average EDG reliability less than 0.95 and above 0.90 considering actual performance on demand, and maintenance (and testing) out of service (MOOS) with the reactor at power. However, the analysis of EDG performance on demand indicates MOOS with the reactor at power is more than expected and can have a significant effect on the EDG reliability calculations. Increased MOOS explains why licensees appear to be having difficulty meeting a 0.975 EDG target reliability. Decreased EDG reliabilities and/or increased MOOS unavailabilities erode the risk benefits obtained from implementing the SBO rule.

- The operating experience indicates that the SBO rule has increased defense-in-depth. The SBO related hardware and procedures have been used in response to unplanned events and provided additional protection. The SBO rule provides additional defense-in-depth to compensate for potential degradation of the ac offsite power system that may result from deregulation of the electric power industry or longer than expected recovery of offsite power after extremely severe weather conditions.

- A comparison of the value-impact expectations to the outcomes indicates that the value-impact was within the expected range of reductions in public dose-per-dollar of cost. As expected, there was wide variation in plant-specific values and impacts because the SBO rule allowed flexibility. Not expected was the addition of costly power supplies, which accounted for 75 percent of the estimated industry cost impact and explains why the NRC value-impact analysis underestimated the cost by a factor of 4. However, it appears licensees justified the cost of the power supplies by counting on offsetting monetary benefits, such as more operating flexibility from increased EDG allowed outage times. Thus the value was also underestimated. The remaining 25 percent of the estimated industry cost impact appears reasonable, considering the outcomes: known coping capabilities, industry risk reduction from plant-specific procedural and hardware enhancements, and additional defense-in-depth.

A comparison of the SBO rule expectations to the corresponding outcomes indicates that no additional generic actions are warranted and that no new generic safety issues have been identified. However, consistent with adhering to Principles of Good Regulation that include

clarity (coherent and practical regulations) and reliability (regulations based on operating experience) there are opportunities to revise the regulatory documents. These revisions are consistent with the SBO technical basis (NUREG-1032); ensuring high levels of EDG reliability; maintaining the risk benefits obtained from implementing the SBO rule; providing practical guidance for reactor shutdowns with limited offsite or onsite power sources; and using operating experience in the inspection documents. The opportunities are as follows:

(1) Regulatory Guides 1.155, "Station Blackout", August 1988; RG 1.9, "Selection, Design, Qualification of Diesel-Generator Units Used as Standby (Onsite) Electric Power Systems at Nuclear Power Plants," Rev. 3, July 1993; and RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Revision 2, March 1997, which address use of the EDG reliability terms, criteria, and measurements may need to be revised in a coherent manner to: (a) clarify that MOOS with the reactor at power should be included in the reliability calculation, (b) clarify that licensees should balance increased EDG reliability against the increased EDG unavailability to maintain the RG 1.155 minimum individual EDG target reliabilities, (c) clarify that the EDG system boundary used in the reliability calculation should include the load sequencer and the bus between the EDG and the loads, and (d) establish common EDG start and load-run criteria for the guidance.

Inspection documents Temporary Instruction 2515/125, "Inspection of Implementation of Station Blackout Rule," (no date), and Inspection Procedure 62706, "Maintenance Rule," December 31, 1997, may need revision to delete use of the Nuclear Management and Resources Council (now NEI) (NUMARC) trigger values to assess compliance with the 0.95 and 0.975 EDG target reliability. The NUMARC trigger values do not provide high levels of confidence that the EDG target reliability is being met; this is inconsistent with ensuring high EDG reliability, delays corrective action, and erodes the risk benefits obtained from implementing the SBO rule.

(2) Operating events indicate that the availability of some Aac power supplies is dependent on offsite or onsite power supplies. SBO-related inspection documents may need inspection attributes to verify that the Aac sources meet NUMARC 87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Revision 1, May 1993, Appendix B, B.8, "Minimal Potential For Common Cause Failure."

(3) Regulatory Guide 1.93, "Availability of Electric Power Sources," December 1974, the basis for technical specifications in the area of ac onsite and offsite power supply availability, provides for shutdown of the reactor after extended ac power supply unavailability. Plant shutdown with one or more offsite or onsite power supplies unavailable could exacerbate the grid condition or remove redundant sources to operate decay heat removal systems, increasing the likelihood of an SBO. Additional practical guidance may minimize the likelihood of an SBO.

(4) Follow-up at 2 plants found a large difference between the unit average EDG reliability based on load-run tests and unplanned demands and the reliability calculated by the licensee based on the last 100 start and load-run tests and unplanned demands. This difference confirms a previous finding in INEL-95/0035, "Emergency Diesel Generator Power System Reliability," February 1996, that the current testing and inspection

activities (as prescribed by the NRC) may not be focusing on the dominant contributors to unreliability during actual demands. Accordingly, NRC test and inspection documents may need to be modified to better factor in the conditions and experiences gained from actual system demands.

As a lesson learned, to the extent that the NRC staff revises existing regulatory documents to be more risk-informed and performance-based, they may need to be modified to ensure consistent interpretation and use of terms, goals, criteria, and measurements.

1 INTRODUCTION

The Nuclear Regulatory Commission's (NRC's) Office of Nuclear Regulatory Research (RES) is reviewing regulations, starting with the station blackout rule (SBO), to determine if the requirements are achieving the desired outcomes. This initiative is part of an evolving program to address regulatory effectiveness to make NRC activities and decisions more effective, efficient, and realistic.

SBO can be a significant contributor to core damage frequency (CDF) and, with the consideration of containment failure, can be an important contributor to reactor risk. In 1980, the Commission designated the SBO issue as Unresolved Safety Issue (USI) A-44, "Station Blackout," to determine the need for additional safety requirements. On June 21, 1988, the NRC concluded that additional SBO safety requirements were justified and published the SBO rule in the *Federal Register* Notice 23203 (Title 10 of the *Code of Federal Regulations* Section 50.63 [10 CFR 50.63], "Loss of all alternating current power") [Ref. 1]. The amendment was intended to provide further assurance that a loss of both offsite and onsite emergency ac power systems would not adversely affect public health and safety.

In May 1997, the staff briefed the Commission on the individual plant examination (IPE) insight report, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance," NUREG-1560, December 1997 [Ref. 2]. The report concluded that SBO remains a dominant contributor to the risk of core melt at some plants, even after implementation of the SBO rule; that SBO frequencies are above 1E-05 per reactor year (RY) for many plants; and that these results warrant further investigation of strategies for reducing SBO frequencies. In a staff requirements memorandum, "Briefing on IPE Insight Report," May 28, 1997 [Ref. 3], the Commission asked the staff to provide a scope and schedule for using IPE results to assess regulatory effectiveness in resolving major safety issues. The staff responded in SECY-97-180, "Response to Staff Requirements Memorandum of May 28, 1997, Concerning Briefing on IPE Insight Report," August 6, 1997 [Ref. 4], noting that the probabilistic risk assessment (PRA) Implementation Plan was tracking activities to assess the regulatory effectiveness of major efforts to resolve safety issues, including SBO. SECY-97-180 noted that these activities would determine whether additional generic action is warranted, assess whether any new generic safety issues (GSIs) warrant attention, and whether the IPE results justify plant-specific actions.

2 BACKGROUND

2.1 Station Blackout and the Station Blackout Rule

Federal Register Notice 23203 amended the regulations to define an SBO and add the SBO rule. In 10 CFR 50.2, "Definitions," SBO is defined as the complete loss of ac electric power to the essential and nonessential electric switchgear buses in a nuclear plant (i.e., loss of the offsite electric power system concurrent with a turbine trip and unavailability of the emergency ac power system). In 10 CFR 50.63, the SBO rule requires that nuclear power plants be capable of withstanding an SBO for a specified duration and of maintaining core cooling during that period. The specified duration would be determined for each plant by comparing the individual plant design with factors that have been identified in NRC technical studies as the

main contributors to the risk of core melt resulting from an SBO. These risk factors are identified in the SBO rule as (1) the redundancy of the onsite emergency ac power sources, (2) the reliability of the onsite emergency ac power sources, (3) the frequency of loss of offsite power (LOOP), and (4) the probable time needed to restore offsite power.

The SBO rule requires licensees to propose and justify an SBO coping duration based on their ability to: (1) maintain highly reliable onsite emergency ac electric power supplies; (2) ensure that the plants can cope with an SBO for some period of time based on the probability of an SBO at the site and the capability to restore power to the site; (3) develop procedures and training to restore offsite and onsite emergency ac power should either become unavailable; and (4) if necessary, make modifications necessary to meet the SBO rule requirements. The SBO rule also requires that the staff do a regulatory assessment of each of the licensee's response to the SBO rule and notify the licensee of the staff's conclusions.

Before the SBO rule, some regulatory documents addressed SBO risk factors such as the unavailability of either offsite or onsite power sources and emergency diesel generator (EDG) reliability. Regulatory Guide (RG) 1.93, "Availability of Electric Power Sources," December 1974 [Ref. 5], provides limiting conditions for reactor unit operation if offsite or onsite power sources are unavailable. RG 1.108, "Periodic Testing of Diesel Generator Units Used as Onsite Electric Power Systems at Nuclear Power Plants," Revision 1, August 1977 [Ref. 6], expected licensees to periodically demonstrate EDG reliability by means of 69 consecutive valid tests per plant or 23 per EDG with no failures. RG 1.108 discussed that Branch Technical Position EICSB 2, "Diesel-Generator Reliability Qualification Testing," of the Standard Review Plan established an EDG reliability goal of 0.99 (at 50 percent confidence). RG 1.9 "Selection, Design, Qualification of Diesel-Generator Units Used as Standby (Onsite) Electric Power Systems at Nuclear Power Plants," Rev. 2, December 1979 [Ref. 7], calls for 300 valid start and load qualification tests with no more than three failures.

Before SBO rule was implemented, a survey was documented in NUREG/CR-4557, "A Review of Issues Related to Improving Nuclear Power Plant Diesel Generator Reliability," March 1986 [Ref. 8], that found that only 7 of 56 nuclear power plant sites had an EDG reliability program; 11 of the 56 sites kept EDG records of the demands and failures experienced by each EDG following RG 1.108; and 3 of 56 sites kept a report of each EDG's reliability. In addition, NUREG/CR-4557 reveals that 11 of 78 nuclear power plants had a unit average EDG reliability significantly below 0.95, and 2 of the 78 plants had a unit average EDG reliability below 0.90.

Appendix A, " Summary of the SBO Technical Bases and Additional Background," is summarized in the next section and gives details about the SBO regulatory documents and terms mentioned in this report.

2.2 Technical Basis for SBO Regulatory Requirements and Guidance

The SBO rule was based on several plant-specific probabilistic safety studies; operating experience; and reliability, accident sequence, and consequence analyses completed between 1975 and 1988. In 1975, WASH-1400, "Reactor Safety Study," indicated that SBO could be an important contributor to the total risk from nuclear power plant accidents. This study concluded that if an SBO persists for a time beyond the capability of the ac-independent systems to remove decay heat, core melt and containment failure could follow. In 1980, the Commission designated the SBO issue as USI A-44 and the staff completed several technical studies to

determine if any additional safety requirements were needed. NUREG-1032, “Evaluation of Station Blackout at Nuclear Power Plants,” June 1988 [Ref. 9], integrated the findings of the technical studies completed for USI A-44. NUREG-1032 presented the staff’s major technical findings for the resolution of USI A-44, and provided the basis for the SBO rule and the accompanying Regulatory Guide 1.155, “Station Blackout”, August 1988 [Ref. 10]. NUREG-1032 provided the bases for RG 1.155 by analyzing the effect of variations in various offsite and onsite ac power system designs and plant locations, EDG reliability, and SBO coping capability on the SBO CDF. RG 1.155 allows flexibility for implementing the SBO regulatory requirements plant-specific basis. Consequently, the values and impacts associated with the SBO rule were expected to vary significantly. NUREG-1109, “Regulatory/Backfit Analysis for the Resolution of Unresolved Safety Issue A-44, ‘Station Blackout,” June 1988 [Ref. 11], established risk reduction expectations, estimated industry and NRC implementation costs, and used these factors to analyze the value-impact. The public and the industry provided comments on the drafts of the SBO Rule, RG 1.155, and NUREG-1109. The industry comments resulted in significant increases in the estimates of industry costs to implement the SBO rule.

As part of the industry involvement in developing the SBO rule, the Nuclear Management and Resources Council (NUMARC) (now NEI) submitted NUMARC 87-00, “Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors,” November 1987 [Ref. 12], as an alternative to complying with the SBO rule. In content, NUMARC 87-00 followed RG 1.155 and added prescriptive, practical guidance which was endorsed by RG 1.155.

The NRC SBO initiatives expected that the resolution of GSI 56, “Diesel Generator Reliability,” would elaborate an EDG reliability program consistent with RG 1.155. SECY-93-044, “Resolution of Generic Safety Issue B-56, Diesel Generator Reliability,” February 22, 1993 [Ref. 13], recommended that the staff incorporate (by reference or example) EDG unavailability (i.e., maintenance [and testing] out of service [MOOS]) operating experience and the NUMARC EDG reliability program (Appendix D of NUMARC 87-00, Rev. 1, “Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors,” August 1991 [Ref. 14]), into the regulatory guide and the NUMARC guideline being developed for the maintenance rule. The recommendation was implemented in RG 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” June 1993 [Ref. 15], and NUMARC 93-01, “Nuclear Energy Institute Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plant,” May 1993 [Ref. 16].

The NRC completed safety evaluations for each plant (they can be found in the NRC Public Document Room under each plant’s docket number). The NRC also completed eight pilot inspections by October 1994 using Temporary Instruction 2515/120, “Inspection of Implementation of Station Blackout Rule,“ (no date) [Ref. 17]. Inspection Procedure (IP) 62706, “Maintenance Rule,” December 31, 1997 [Ref. 18], concerns SBO-related EDG performance verifications under the maintenance rule.

3 ASSESSMENT OF THE STATION BLACKOUT RULE

The scope of the SBO rule assessment is to determine whether the SBO rule is effective and whether certain areas may need the staff's attention.

3.1 Method for Assessing Regulatory Effectiveness of the Station Blackout Rule

For the purposes of this assessment, the regulatory documents present expectations (desired outcomes) in terms of specific objectives, requirements, and guidance. The regulatory documents are considered effective if the expectations are being achieved. Discrepancies between expectations and outcomes prompted a review of the related regulatory documents to identify areas that may need attention. This assessment focuses on the SBO rule and related SBO regulatory documents and does not address plant-specific issues.

To assess the regulatory effectiveness of the SBO rule, the expectations as defined by SBO regulatory requirements were used as a baseline for comparison to the actual outcomes. The baseline was established from objective measures stated in the SBO rule, RG 1.155, 53 FR 23203, and NUREG-1109 in the areas of coping capability, risk reduction, EDG reliability, and value-impact. The value-impact assessment was used to determine if the NRC costs and industry costs to implement the SBO rule were reasonable.

Plant-specific data on the actual SBO rule outcomes relative to the expectations for SBO coping capability, selected EDG target reliability, and modifications are shown in Appendix B, "Plant-Specific SBO Information by Reactor Type and Operating Status." The data were collected only from publicly available sources such as licensee PRA/IPEs dated from November 30, 1991 to July 27, 1994, as recorded in the NRC PRA/IPE databases; licensee event reports (LERs); and NRC/licensee correspondence, particularly that related to the SBO rule safety evaluations. When using the above PRA/IPEs it should be recognized that their data do not always reflect the current design or operating performance of safety systems.

Completed NRC system risk and reliability studies that analyzed the dominant SBO risk factors were also a source of data to measure outcomes. INEL-95/0035, "Emergency Diesel Generator Power System Reliability," February 1996 [Ref. 19], presents an analysis of the reliability of some of EDG power systems at U.S. nuclear plants during the period 1987–1993 and includes SBO insights relative to risk and EDG reliability. INEL-95/0035 is being updated to reflect the operating experience through 1998 for 100 percent of the industry and is presently going through internal comment process as "Reliability Study Update: Emergency Diesel Generator Power System, 1987–1988 (DRAFT)," December 1999 [Ref. 20] (INEL-95/0035 DRAFT update). Both Idaho National Engineering and Environmental Laboratory (formerly INEL) (INEEL) reports were used. In NUREG/CR-5496, "Evaluation of Loss of Offsite Power Events at Nuclear Power Plants: 1980–1996," November 1998 [Ref. 21], the NRC contractor has analyzed LOOP events at U.S. nuclear plants from 1980–1996 to determine their likelihood and duration. Appendix B also contains a tabulation of the NUREG-1032 and NUREG/CR-5496 data on plant-specific LOOP events and notes LOOP events that had recovery times 4 hours or longer.

3.2 Comparison of Expectations and Outcomes

Table 1, “Summary of Station Blackout Rule Expectations and Outcomes,” summarizes the SBO rule (and related regulatory guidance and industry guidelines) in the areas of coping capability, risk reduction, EDG reliability, and value-impact.

Table 1 Summary of Station Blackout Rule Expectations and Outcomes

Station Blackout Rule Expectations		Actual Outcomes	Observations
Area	**Expected Result**		
Minimum Acceptable Coping Capability	100 plants will analyze and select a 2-, 4-, 8-, and 16-hour coping capability. 100 plants will develop procedures and training. 39 plants complete modifications.	All plants have 4- or 8-hour coping capability. 108 plants developed procedures, completed training. 72 plants completed modifications.	Expectations exceeded.
Industry-Wide Risk Reduction in Mean SBO CDF	2.6E-05/RY	3.2E-05/RY	Expectations exceeded. Overall risk reduced. Most vulnerable plants completed initiatives to attain low SBO CDF. RG 1.93 actions to shut down with unavailable power supplies not practical.
EDG Reliability	RG 1.155 plant individual target EDG reliability of 0.95 or 0.975, assuming EDG unavailability due to MOOS while the reactor is in a power or non-power status is negligible.	Overall industry unit average unit EDG reliability is generally better than 0.95 however, the EDG 0.975 EDG reliability target appears to be difficult to achieve considering MOOS while the reactor is at power. MOOS while the reactor is at power is not negligible SBO regulatory documents contain multiple EDG performance bases and expectations.	Individual EDG reliabilities not publically available; used unit average EDG reliability- based safety system demands. Observed EDG performance generally exceeds PRA/IPE EDG performance assumptions; additional SBO CDF reductions possible. However, MOOS and failure to meet EDG target reliability could erode risk benefits from the SBO rule. There are opportunities to clarify the regulatory guidance
Value-Impact	2400 person-rem averted per $M. Expected range was 700 to 5000 person-rem/$M. Based on averting 145K person-rem at a total cost of $61.5M.	775 person-rem averted per $M. Based on averting 145,000 person-rem at a total cost of $187M.	Outcome was near the low end of the expected range. The total costs were underestimated by a factor of 3 due to additions of power supplies.

3.2.1 Risk Reduction

In NUREG-1109, the staff estimated that on an industry wide basis the implementation of the SBO rule would result in an industry risk reduction of 2.6E-05 per RY. This expectation is based on a mean SBO CDF before and after the SBO rule of 4.2E-05 per RY and 1.6E-05 per RY, respectively. In addition, as indicated in NUREG-1109, the staff expected that more plants would be in lower SBO CDF ranges after implementation of the SBO rule. The expected range changes are shown in Table 2, “The Number of Plant Units in Station Blackout Core Damage Frequency Ranges Before and After Station Blackout Rule Implementation” which compares the

number of plants in each SBO CDF range before and expected after SBO rule implementation. These data were obtained from NUREG-1109, which estimated a plant's SBO CDF before SBO rule implementation from plant-specific dominant risk factor characteristics identified in NUREG-1032 assuming that all plants could cope with an SBO for at least 2 hours, various plant-specific NRC and licensee PRA/IPEs, and other data available around the 1985 time-frame. Information from Appendix B was used in Table 2 to show the actual outcome as changes in the SBO CDF range numbers after implementation of the SBO rule.

Table 2 The Number of Plant Units in Station Blackout Core Damage Frequency Ranges Before and After Station Blackout Rule Implementation

Parameter	Number of Plants in SBO CDF Range (E-05 per reactor-year)											
SBO CDF Range	< 0.5	0.5 .99	1.0 1.49	1.5 1.99	2.0 2.49	2.5 2.99	3.0 3.49	3.5 3.99	4.0 4.49	4.5 4.99	5.0 9.99	10 35
Before SBO rule Implementation (Estimated)	5	13	14	7	13	4	9	5	4	3	13	10
Expected After SBO rule Implementation	23	23	14	9	6	5	6	5	4	0	5	0
Actual Outcome After SBO rule Implementation	46	22	13	17	1	3	1	3	0	1	1	0

On the basis of the SBO CDF data for all plants in Appendix B, the mean SBO CDF associated with SBO rule implementation is 1.0E-05 per RY. Therefore, the reduction in the estimated mean SBO CDF was approximately 3.2E-05 per RY, slightly better than the 2.6E-05 per RY expected. Comparison of the range numbers of the expected to the actual outcome after SBO implementation in Table 2 shows more plants have lower SBO CDFs and fewer plants have higher CDFs than expected. The actual outcome is even more favorable when compared to the corresponding SBO CDF range values before SBO rule implementation.

Appendix C, "Comparison of Selected SBO Characteristics," was prepared from the data in Appendix B to facilitate comparisons and analyses of SBO characteristics. The comparison of the actual LOOP initiating frequencies while at power from 1968 to 1996 (obtained from NUREG-1032 and NUREG/CR-5496) to the values used in the PRA/IPEs shows that the PRA/IPE LOOP initiating frequencies may have been underestimated by more than a factor of 2–39 for eight plants. Analysis of Appendix C also indicates that the SBO rule was effective in addressing the plants most vulnerable to extremely severe weather and plant-centered LOOPs. In addition, the 15 of the 21 plants that have the greatest vulnerability to a plant-centered LOOP (a LOOP initiating frequency greater than 1.0E-01 per RY) have access to an alternate ac (Aac) power supply, and 19 of the 21 plants have insignificant SBO CDFs with an order of magnitude of 1.0E-06 or smaller. Last, the 8 operating plants that have the highest expected frequency of extremely severe weather frequency (Category 5) and the 10 plants that have an 8-hour coping time have an Aac power supply.

Table 3, “Probabilistic Risk Assessment/Individual Plant Examination Sensitivity Analyses,” was prepared from information in plant-specific PRA/IPE sensitivity analyses to show the effect of typical SBO rule modifications on the overall risk. Table 3 lists the modifications due to the SBO rule addressed in the PRA/IPE sensitivity analysis and the corresponding risk reduction associated with the modification as a percentage of the total plant CDF. Table 3 indicates that the overall risk (i.e., the risk from SBO and other initiators) dropped for plants that made major SBO rule modifications, such as adding a power supply, or even simple SBO rule procedural changes (e.g., shedding dc loads).

Table 3 Probabilistic Risk Assessment/ Individual Plant Examination Sensitivity Analyses

Description of Modification	**Effect on Overall Risk (Percent Reduction of Plant CDF)**
Adding EDGs	
Calvert Cliffs (one safety and one nonsafety EDG)	24
Turkey Point (two safety EDGs)	20
Adding safety EDG	
Diablo Canyon	14–18
Add nonsafety EDG for site	
Arkansas Nuclear 1	23–36
Arkansas Nuclear 2	43–47
Procedural	
Arkansas Nuclear 1: EDG service water supply valve open	7
Monticello: Depressurize during SBO	17
Monticello: Battery load shed	17
Credit of combustion turbine generator	
Fermi	10
Extend battery life from 2 to 4 hours	
Arkansas Nuclear 1	16
Improve reliability of onsite gas turbine generator	
Point Beach	13
AC cross-tie	
Fermi	49
AC cross-connect and automatic depressurization system	
Monticello	38

Previous Assessment of the Effect of the Station Blackout Rule on Core Damage Frequencies

The NRC staff evaluated the impact of the SBO rule on CDFs in NUREG-1560. NUREG-1560 concluded that SBO remained a dominant contributor to risk at many plants, even after implementation of the SBO rule, SBO frequencies exceed 1E-05 per RY for many plants, and that the results warrant further investigation of strategies for reducing SBO frequencies. NUREG-1560 provides SBO risk perspectives based on comparing the SBO CDFs for the 56 plants whose PRA/IPEs addressed the impacts of the SBO rule to the SBO CDFs for 51 plants where the impact of the SBO rule on SBO CDF was not known or credited, or was assumed in the PRA/IPEs to have no impact. NUREG-1560 observed that (1) the average reported reduction in total CDF is consistent with the average reduction in SBO CDF from the backfit analysis of the SBO rule; (2) the average SBO CDF for all plant units considered in the evaluation is comparable to a "typical" estimate in an evaluation of SBO accidents at nuclear plants; and (3) the large variability in the SBO CDF results for the plant units evaluated is also consistent with the variability in the SBO CDF results from other SBO studies.

Generic Safety Issue 23 "Reactor Coolant Pump Seal Failure"

In the memorandum "Closeout of Generic Safety Issue 23, Reactor Coolant Pump Seal Failure, November 8, 1999, the staff also reviewed SBO coping analyses using reactor coolant pump (RCP) seal leakage rates from their research. The staff concluded that no additional cost-beneficial generic requirements should be proposed in part because implementation of the SBO rule has added alternate power sources and reduced the likelihood of an RCP seal LOCA.

Plant Shutdown With Power Supply Unavailability May Increase the Likelihood of an SBO

RG 1.93, "Availability of Electric Power Sources," December 1974 [Ref. 22], provides for the nuclear unit to shut down after extended unavailability of either the offsite power source or emergency onsite power sources, and is the basis for technical specifications in this area. Plant shutdown with the one or more offsite or onsite power supplies unavailable could exacerbate the grid condition or remove redundant sources to operate decay heat removal systems. The extended unavailability of one or more offsite or onsite power supplies should prompt an alternate approach, such as assuring the immediate availability of coping systems, reducing power, or assuring availability of adequate electric grid reserves.

Assessment

The SBO rule was effective in achieving the desired reduction in the SBO CDF. The reduction in the estimated mean SBO CDF was approximately 3.2E-05 per RY, slightly better than the 2.6E-05 per RY expected. The SBO rule caused meaningful reductions in the risk at many plants. Also, more plants have lower CDFs and fewer plants have higher CDFs than expected. As a result of the SBO rule, the plants with the most LOOPs from plant events and extremely severe weather improved the most. Consequently, these plants have relatively low SBO CDFs. However, the mean LOOP initiating frequencies of eight plants used in the PRA/IPE analysis may have been underestimated by factors of 2–39 in comparison to the actual number of plant LOOPs experienced. In addition, RG 1.93, which addresses plant shutdown after extended unavailability of offsite and onsite power supplies, potentially increases the likelihood of an SBO.

3.2.2 Emergency Diesel Generator Reliability

Emergency Diesel Generator Performance

After implementation of the SBO rule, all licensees committed to establish an EDG reliability program and to maintain a minimum individual EDG target reliability of 0.95 or 0.975. Accordingly, all licensees have committed to an information and data collection system to monitor the achieved reliability levels and compare them to the target values. In addition, all licensees have monitored EDG unavailability since 1989.

INEL-95/0035 and the INEL-95/0035 DRAFT update investigated the performance of EDG trains on demand. The INEL-95/0035 DRAFT update was used in this assessment even though it contains preliminary results. However, the INEL-95/0035 DRAFT, has more data on the time period since the implementation of SBO rule and better illustrates the EDG reliability outcome of SBO implementation.

INEL-95/0035 and the INEL-95/0035 DRAFT compare the EDG train performance on demand to the RG 1.155 EDG target reliability expectations. These comparisons are somewhat unequal. The INEEL studies compare the unit average EDG reliability based on performance of its "safety mission" (a loss of voltage to the safety buses that results in both a start and a load-run) to the RG 1.155 0.95 and 0.975 individual EDG reliabilities. Licensees generally calculated RG 1.155 individual EDG reliability using data from plant-specific valid starts and load-runs over different time interval. The INEEL studies calculated a unit average EDG reliability using (a)12 years of test and unplanned demand data that simulate the safety mission and (b) Bayes' empirical methods, which allow consideration of the plant-specific and industry data to establish new estimates of the mean reliability and its uncertainty bounds. Nevertheless, the INEEL comparison is valid. Since the 0.95 or 0.975 individual EDG reliability is the target, demonstrations of the EDG's ability to perform their safety mission over several years should result in unit average EDG reliabilities of 0.95 or 0.975 or higher; lower would indicate the individual EDG reliabilities are not consistent with RG 1.155.

The INEEL reports evaluated the validity of the RG 1.155 (Section B) assumption that so long as the EDG unavailability due to MOOS is not excessive, the maximum specified EDG reliabilities of 0.95 and 0.975 would result in an acceptable overall reliability for the emergency power system. INEEL evaluated only the EDG MOOS with the reactor at power as it has higher risk due to the possibility of a demand while the EDG is unavailable and the reactor is at power. Appendix A explains MOOS in detail.

The following insights were obtained from the INEEL analyses of EDG safety performance:

(1) The INEL-95/0035 DRAFT update indicates that the 58 plants that committed to a 0.95 minimum EDG target reliability achieved a unit average EDG reliability of 0.945 to 0.989, with and without consideration of MOOS with the reactor at power; INEL-95/0035 EDG reliabilities are similar ranging from 0.934 to 0.99.

(2) INEEL studies indicate that the plants that committed to a 0.975 minimum individual EDG target reliability are having difficulty achieving a 0.975 unit average EDG target reliability. With MOOS while the reactor unit is at power, the INEL-95/0035 DRAFT update indicates only 8 of the 44 operating plants that committed to a 0.975 minimum EDG

reliability achieved a unit average EDG reliability above 0.975; plant reliabilities ranged from 0.917 to 0.98. INEL 95/0035 EDG reliabilities are similar: none of the 19 plants considered achieved a unit average EDG reliability of 0.975. Without MOOS, the INEL-95/0035 DRAFT update indicates that approximately 36 of the 44 plants that committed to a 0.975 minimum EDG reliability had a 0.975 or higher unit average EDG train reliability; INEL 95/0035 differs: 18 of the 19 plants considered had a 0.975 or better unit average EDG reliability.

Under RG 1.155 licensees, could select the 0.975 EDG target reliability to achieve shorter coping durations to avoid modifications. In addition, the plants with the least independence and redundancy in onsite emergency power supplies for safe shutdown equipment had to select the 0.975 minimum EDG target reliability to achieve a lower SBO CDF. Consequently, failure to meet the 0.975 EDG target reliability could significantly erode these risk reductions. The effect of a 0.025 decrease in EDG reliability on the SBO CDF was evaluated using Table 4, “Estimated Increase in The SBO CDF Due to a Decrease in EDG Reliability From 0.975 to 0.95." Table 4 was developed from NUREG-1032, Table C.4, “Tabulated estimated values of total core damage frequency for SBO accidents as a function of EDG configuration, EDG reliability, offsite power cluster, and ability to cope” assuming the coping duration was constant. NUREG-1032 grouped each plant’s offisite power system into one of five offsite power clusters based on its susceptibility to grid and weather conditions. Table 4 illustrates that a 0.025 decrease in EDG reliability could increase the SBO CDF by 1.0 E-05 per RY or more in plants in the offsite power clusters 2–5 (about 60 plants). Increases in the SBO CDF of 1.0 E-05 per RY or more erode the 3.2 E-05 per RY risk reduction obtained from implementing the SBO rule.

Table 4 Estimated Increase in the Station Blackout Core Damage Frequency Due to a Decrease in Emergency Diesel Generator Reliability From 0.975 to 0.95

Emergency ac power system configuration	Coping duration	Offsite power cluster				
		1	2	3	4	5
1/2	4 8	<E-05 <E-05	1.1E-05 <E-05	2.6E-05 <E-05	6.6E-05 1.7E-05	1.4E-04 5.1E-05
2/3	4 8	<E-05 <E-05	3.2E-05 1.1E-05	8.0E-05 2.0E-05	0.3E-04 4.5E-05	4.5E-04 1.3E-04
2/4	4 8	<E-05 <E-05	<E-05 <E-05	<E-05 <E-05	1.3E-05 <E-05	4.8E-05 <E-05

(3) The INEEL studies indicate that MOOS has a significant effect on the reliability calculation. Table 5, “Effects of MOOS While the Reactor is at Power on EDG Reliability,” was prepared from data in the INEL-95/0035 DRAFT update. Table 5 indicates that consideration of MOOS while the reactor is at power lowers the unit average EDG train reliabilities for the 0.95 and 0.975 groups by 0.034 and 0.012, respectively. INEL-95/0035 gives similar results.

Table 5 Effects of Maintenance Out of Service While the Reactor is at Power on Emergency Diesel Generator Reliability

EDG target reliability	Mean industry unit average EDG reliability		
	without MOOS	with MOOS	decrease in reliability
0.95	0.985	0.954	0.034
0.975	0.978	0.967	0.012

NUREG/CR-5994, "Emergency Diesel Generator: Maintenance and Failure Unavailability, and Their Risk Impacts," October 1994 [Ref. 23], analyzed the effects of MOOS increases on the CDFs for five plants. The data indicate that when MOOS increases from 0.007 (assumed in RG 1.155 Section B) to 0.02, the plant CDF may increase by less than 1.0E-06, which is insignificant; however, an increase in MOOS to 0.04 may cause increases in plant CDF of more than 1.0E-05 and could offset the risk reduction obtained by implementing of the SBO rule.

(4) The INEL-95/0035 DRAFT update indicates that three of 102 operating plants have a unit average EDG reliability less than 0.95 without MOOS. Follow-up at 2 of the 3 plants found that the unit average EDG reliability was 0.99 or higher based on the last 100 EDG start and load-run tests and/or unplanned demands; this is 0.05–0.07 more than corresponding INEEL plant-specific values, which are based only on load-run tests and unplanned demands that simulate the EDG safety mission. This finding may indicate that plant start testing is not identifying the causes of EDG unreliability during demands that simulate the EDG safety mission. This confirms an INEL 95/0035 finding based on a review of LERs, that the current testing and inspection activities may be missing the dominant contributors to unreliability during actual demands and may need to be modified to better consider the conditions and experiences gained from actual system demands.

(5) The INEEL-95/0035 DRAFT indicates that many licensees could demonstrate additional reductions in the plant SBO CDF from improved EDG performance. In addition maintaining high EDG reliability levels provides assurance that the PRA/IPE EDG performance assumptions are valid. Each INEEL study has a figure similar to Figure 1, "Preliminary Plant-Specific EDG Unit Average EDG Unreliability Compared to the Unreliability Estimates Using the PRA/IPE EDG Performance Assumptions" which shows EDG unreliability for 44 plants grouped by 24, 8, and 6 hour mission time. Figure 1 indicates (a) that 0.05 and 0.025 unreliabilities (which correspond to the 0.95 and 0.975). RG 1.155 EDG reliability targets are generally in the upper end of the PRA/IPE EDG uncertainty interval and (b) that except for a few cases, the mean PRA/IPE EDG unreliability values are higher than the corresponding values calculated from the operating experience.

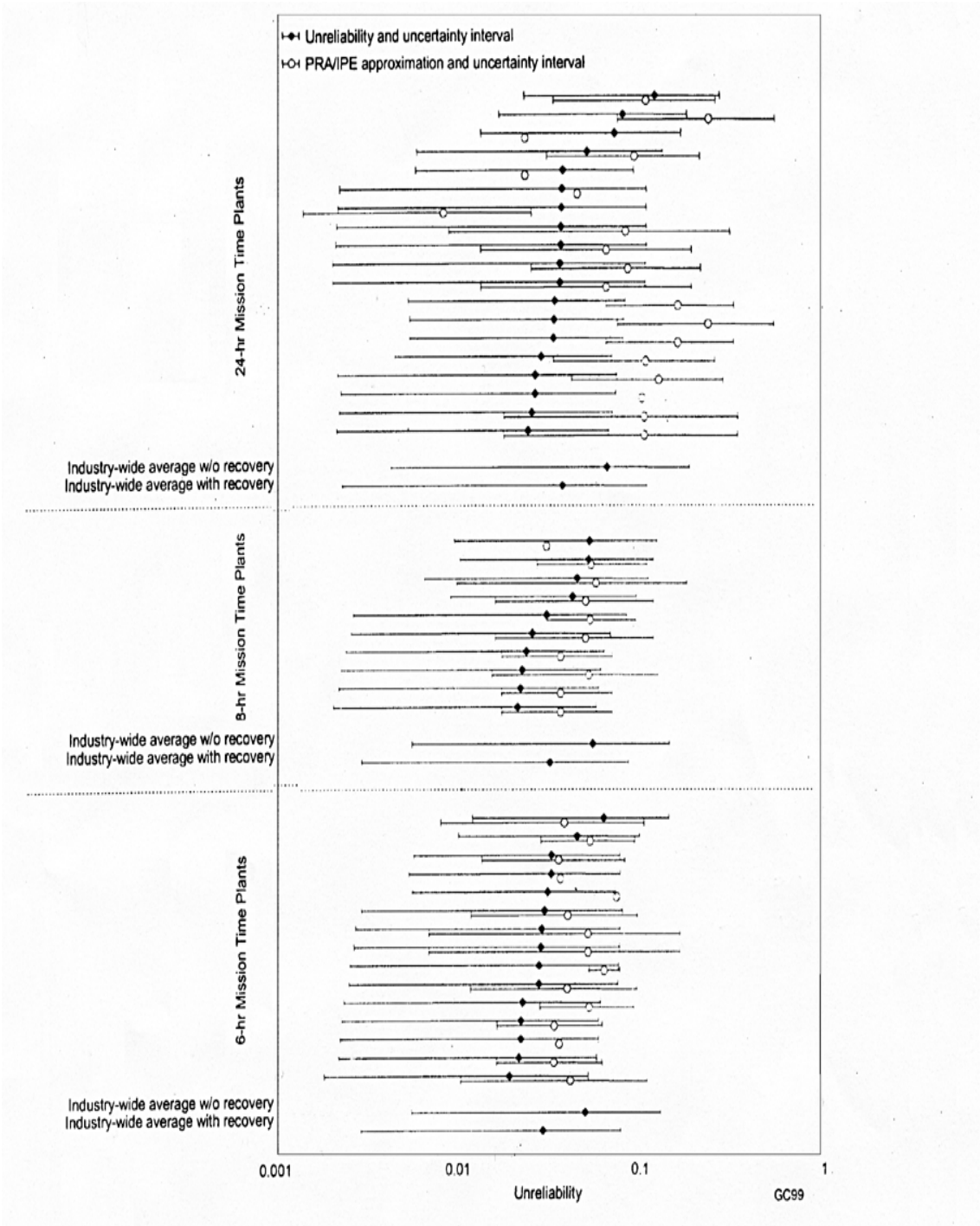

Figure 1 "Preliminary unit average emergency diesel generator unreliability compared to the unreliability estimates using the probabilistic risk assessment/individual plant examination emergency diesel generator performance assumptions."

Summary of EDG Performance Bases

A review of EDG performance bases found that the SBO rule, the resolution of GSI-56 in conjunction with the SBO rule and the maintenance rule, and inspection procedures, resulted in multiple EDG performance bases. These are summarized below. Appendix A provides background information on the regulatory documents discussed below.

1) RG 1.155, Section C.1.2 expects licensees to establish a reliability program to maintain a minimum individual EDG target reliability of 0.95 or 0.975. RG 1.155, Section B assumes that as long as MOOS (regardless of the reactor power status) is not excessive, the maximum EDG failure rates for each EDG could result in an acceptable overall reliability for the emergency power system configuration. RG 1.155, Section C.1.1 expects EDG reliability to be determined using the NSAC-108 definition of reliability as the product of the starts and load-run reliabilities excluding MOOS, and the NSAC-108 definitions of valid start and load-runs. RG 1.155, Section C endorses NUMARC 87-00, November 1987, as acceptable alternative guidance. NUMARC 87-00, Section 6.0 also requires the monitoring of the unit average individual EDG unavailability in comparison to an industry average.

(2) Under RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Rev. 2, March 1997 [Ref. 24], licensees can select the RG 1.155 0.95 or 0.975 individual EDG target reliability as either a goal or a performance criterion (Section B, "Emergency Diesel Generators"); or they can select IPE unavailability values compared to the industry values as a goal or performance criterion (Section B), or maintenance preventable functional failures as the sole performance criterion (Section 1.4). RG 1.160, Section B also discusses the balancing of reliability and unavailability under (a)(3) of the maintenance rule. In addition, RG 1.160 Rev. 2 endorses NUMARC 93-01, "Nuclear Energy Institute Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plant," April 1996 [Ref. 25], which allows licensees to use PRA/IPE numerical assumptions about EDG reliability performance as goals or performance criteria under the maintenance rule (NUMARC 93-01, paragraph 9.3.2.).

(3) RG 1.9, Rev. 3 provides that onsite emergency power supplies be selected with sufficient capacity, be qualified, and have the necessary reliability and availability for SBO and design basis accidents. RG 1.9, Rev. 3, Section 2.2 gives definitions of valid EDG starts and load-runs and delineates the ac onsite emergency power equipment and system boundary used to count failures.

(4) SBO rule and maintenance rule inspection documents provide EDG performance bases.

Inspection documents TI 2515/120, Section 2515/120-040 and IP 62706, Section 3.05, December 31, 1997 use the NUMARC 87-00, Rev. 1, Appendix D trigger values (NUMARC trigger values) for assessing compliance with the RG 1.155 minimum individual EDG target reliabilities of 0.95 and 0.975. Appendix D "EDG Trigger Values," provides background information.

EDG Performance Bases Not Always Clear

Since licensees appear to be having difficulty maintaining the 0.975 minimum target reliability and since there are multiple EDG performance bases, the SBO related regulatory documents on EDG reliability were compared to the SBO technical basis (NUREG-1032), and to each other, to assure they could be readily understood and easily applied to achieving high EDG reliability. The comparison found inconsistent use of EDG performance terms, criteria, and measurements:

(1) The NUREG-1032 EDG equipment and system boundary used to count failures included the load sequencer and the bus between the EDG and the loads. RG 1.155 does not specify the EDG boundary. The RG 1.9 Rev. 3, Section 2.2, EDG system boundary does not include the load sequencer and the bus between the EDG and the loads. The INEL-95/0035 and INEL-95/0035 DRAFT update data indicate that load sequencer failures have caused EDGs to fail after unplanned demands; plant calculations of EDG reliability may be inflated if these failures are not considered.

(2) The NUREG-1032 and RG 1.155 criteria for determining valid start and load-run demands to use in the EDG reliability calculations apply only to actual test or unplanned demands. The corresponding criteria in RG 1.9, Rev. 3, Section 2.2 differ, counting "conditional failures" identified in the course of maintenance that could have caused start or load-run failures.

(3) RG 1.160, Rev. 2 guidance gives licensees the option of monitoring EDG performance using different criteria than the RG 1.155 EDG target reliabilities. Under RG 1.160, Rev. 2, licensees may chose PRA/IPE unavailability, PRA/IPE reliability, or maintenance preventable functional failures. Licensees must balance reliability and unavailability, however it is not clear that licensees should balance the improvement in EDG reliability against the resulting increase in EDG unavailability (MOOS); otherwise the balanced reliabilities could be non-conservative with respect to the RG 1.155 minimum individual EDG target reliabilities. In addition, PRA/IPE reliability and unavailability are represented by a range of values, and some of the values are non-conservative with respect to the RG 1.155 minimum individual EDG target reliabilities. As already shown, a 0.025 decrease in EDG reliability or a 0.04 increase in EDG unavailability results in increases in the SBO CDF that offset the risk reductions obtained from implementing the SBO rule.

(4) TI 2515/120, IP 62706, and some licensees are using the NUMARC EDG trigger values for demonstrating achievement of the 0.95 and 0.975 minimum individual target reliability. However, the NRC intended that the NUMARC trigger values not be used for this purpose. The Advisory Committee on Reactor Safeguards (ACRS) convinced the staff that the NUMARC trigger values provided low statistical confidence that high levels of EDG reliability would be achieved. Others expressed the view that allowing EDG reliability performance to degrade to these levels provides high statistical confidence that the EDG target reliability is not being met however, waiting to attain these levels delays potentially needed corrective actions. Statistics similar to those used by these two perspectives are shown In Appendix D. In a letter to the ACRS dated October 29, 1993 [Ref. 26], the Executive Director of Operations informed the ACRS that the staff agreed that conformance of individual EDGs with trigger values cannot be taken, in any statistical fashion, to mean that the EDG has demonstrated achievement of the licensee's commitments to 0.95 or 0.975. The letter stated that Note 3 was added to RG 1.160, June 1993 to emphasize this fact. In addition, the staff has not endorsed

NUMARC 87-00, Rev. 1. Past and present revisions of RG 1.160 (Section C) state that NUMARC 93-01 (which references NUMARC 87-00, Rev. 1, and uses the trigger values in Section 12.2.4) references other documents, but NRC's endorsement of NUMARC 93-01 should not be considered an endorsement of the referenced documents. The NRC staff intended that this be interpreted to mean NUMARC 87-00, Rev. 1, was not endorsed.

However, wording in past revisions of RG 1.160 could lead to the conclusion that the NUMARC reference documents do not apply to the EDGs and may explain how licensees and the NRC inspection documents adopted the NUMARC trigger values. For example, RG 1.160, June 1993, Section C also states that the example in NUMARC 93-01, Section 12.2.4, describes an acceptable method to establish EDG performance criteria and/or goals and subsequently monitor EDG performance. As another example RG 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," Rev.1, January 1995 [Ref. 27], Section B states that the EDGs are required to be handled under (a)(1) and (a)(2) of the maintenance rule as described in NUMARC 93-01.

Assessment

Before implementation of the SBO rule, only 11 of 78 plants surveyed had formal EDG reliability programs; 11 of 78 plants had a unit average EDG reliability less than 0.95; and 2 of 78 plants had a unit average EDG reliability of less that 0.90. Since implementing the SBO rule, all plants have established an EDG reliability program and an improved EDG reliability. Considering actual safety performance and maintenance and test out of service (MOOS) with the reactor at power, only 3 of 102 operating plants have a unit average EDG reliability below 0.95 and above 0.90. However, analysis indicates MOOS with the reactor at power significantly affects the reliability calculation based on safety performance and explains why licensees are having difficulty meeting the 0.975 EDG target reliability. Decreases in reliability and/or increases in MOOS unavailability erode the risk benefits of implementing of the SBO rule.

There are opportunities to revise the RG 1.155, RG 1.9, and RG 1.160 which inconsistently use EDG reliability terms, criteria, and measurements. These RGs may need to be revised to: (a) clarify that MOOS with the reactor at power should be included in the reliability calculation to ensure high levels of EDG reliability (b) clarify that licensees should balance increased EDG reliability against the increased EDG unavailability to maintain the RG 1.155 minimum individual EDG target reliabilities and the risk levels achieved from implementing the SBO rule, (c) clarify that the EDG system boundary used in the reliability calculation should include the load sequencer and the bus between the EDG and the loads to be consistent with the SBO technical basis (NUREG-1032), and (d) establish common EDG start and load-run criteria.

Inspection documents Temporary Instruction 2515/125 (no date) and IP 62706 may need revision to delete use the NUMARC trigger values to assess compliance with the 0.95 and 0.975 EDG target reliability. Statistically the NUMARC trigger values do not provide high levels of confidence that the EDG target reliability is being met; this inconsistent with ensuring high EDG reliability, delays corrective action, and erodes the risk benefits obtained from implementing the SBO rule.

Follow-up at two plants in the 0.975 EDG reliability group that had less than 0.95 unit average EDG reliability based on load-run tests and unplanned demonstrations of its safety mission found the unit average EDG reliability based on the last 100 valid start and load-run tests and

unplanned demands was 0.05–0.07 higher; this confirms a previous finding in INEL-95/0035 that the current testing and inspection activities may be missing the dominant contributors to EDG unreliability during actual demands and may need to be modified to better consider the conditions and experience gained from actual system demands.

3.2.3 Minimum Acceptable Coping Capability, Plant Procedures, Training, and Modifications

In NUREG-1109, the staff expected that 100 plants would (1) be able to show a minimum acceptable coping capability of 2, 4, 8, or 16 hours based on plant-specific characteristics; (2) complete an analysis of the plant's ability to cope with an SBO for the selected duration; (3) develop SBO-related procedures; (4) complete training on these procedures; and (5) complete modifications necessary to cope. The SBO rule was flexible allowing for a wide range of coping capabilities, so plants with an already low risk from SBO could select short coping times and would need few, if any, modifications. Plants with higher risk could select longer coping times and would possibly need modifications to cope. Thirty-nine plants were expected to complete hardware modifications.

Appendix E, "Station Blackout Rule Activity and Modification Summary," was prepared to show the expected number of plants completing analyses, procedure development and training, various types of modifications in the licensee's response to the SBO rule, the estimated costs of the modifications, and the outcomes. The costs are discussed in Section 3.2.4, "Value-Impact Analysis."

The outcome was that 108 plants selected a minimum SBO coping capability of 4 or 8 hours, completed the coping analysis, developed procedures, completed training, and 72 plants completed modifications. Not credited was the fact that some plants may have developed adequate procedures and completed training before the SBO rule in response to Generic Letter 81-04, "Emergency Procedures and Training for Station Blackout Events," February 25, 1981.

<u>Assessment</u>

The SBO rule expectations were met in the areas of coping analysis, procedure development and training, and modifications. The scope and number of modifications to achieve specified coping durations exceeded the expectations and may explain why risk reductions were greater than expected.

3.2.4 Value-Impact Analysis

A comparison of value-impact expectations and outcomes was derived from NUREG-1109. The value-impact analysis in NUREG-1109 estimated the expected value based on the public dose reduction associated with the SBO rule. The impacts were based on estimates of industry and NRC costs to implement the SBO rule. As explained in Appendix A under "Public and Industry Comment," the industry costs were provided by the industry. The ratio of the value to the impact was also derived as an indication of the cost effectiveness of the SBO rule. Each of these matters is discussed below.

Table 6, "Station Blackout Rule Value-Impact Summary," was prepared from Appendix E to compare the expected impact, value, and value-impact ratio to the corresponding outcomes. Appendix E used the expected values and impacts from NUREG-1109. The outcomes were

estimated using either the values and impacts from NUREG-1109 or from information submitted to the NRC by the licensees. The cost of an additional EDG at Davis Besse was $9.07M. This value was taken as a representative amount for the addition of power supplies and used in the cost estimates shown below.

Table 6 Station Blackout Rule Value-Impact Summary

Value Impact Factors	Expected ($)	Outcome ($)
Impact-NRC and Industry Implementation Cost		
Best estimate		
Miscellaneous SBO modifications	60M	63M
NRC implementation	1.5	2.0M
19 additional power supplies	0	174M
TOTAL	61.5M	237M
Monetary savings attributed to adding additional power supplies for operating flexibility		-50M
TOTAL		187M
Estimated range		
Total	43M–95M	350K–20M
Plant-specific	350K–4M	–
Estimated Value		
Public dose reduction in person-rem	145,000	145,000
Value-Impact Ratio (person-rem averted/$million)		
Best estimate	2400	775
Range	700–5000	–

In NUREG-1109, the staff used information supplied by the industry to estimate that the industry would spend approximately $60 million (M). NUREG -1109 estimated that the NRC would spend approximately $1.5M to implement the SBO rule. The total estimated SBO rule implementation cost of $61.5M was a best estimate with a low of $43M and a high of $95M. In NUREG-1109, the staff recognized that there would be wide variation in plant-specific costs, ranging from $0.35M for plants that needed only procedural changes to $4M if all the anticipated modifications were completed. The outcome in terms of actual SBO rule costs was about $237M, which exceeded expectations by about a factor of 4. The discrepancy is attributable to the addition of 19 power supplies at an estimated cost of approximately $174M. These additions, although consistent with the SBO rule, were also motivated by monetary benefits from operating flexibility because these power supplies. So the NRC also underestimated the value and it may be conservative to ascribe all these costs to the SBO rule.

The NRC estimated that the added power supplies added an estimated $50M in value from more operating flexibility from increased allowed outage times (AOTs). For example, Davis-Besse obtained NRC approval to change its technical specifications to increase the AOT for its EDGs from 3 to 7 days to gain flexibility in performing EDG maintenance while the reactor is at power. In submitting this change to the NRC, Davis-Besse noted that its SBO diesel generator

installation would save $5.25M over the remaining plant life, including $3.15M for increased flexibility in performing maintenance on its safety EDGs and $2.1M in replacement power costs. North Anna increased its EDG AOT from 3 to 14 days by crediting the non-Class 1E SBO EDGs. Other licensees increased their EDG AOT by documenting excess EDG redundancy or Aac power supply connections from their SBO analyses. RES estimated that 10 reactor units besides Davis-Besse benefitted $50M from increased EDG AOT to gain operating flexibility.

It also appears that the addition of a power supply resulted in significant plant-specific risk reductions. Turkey Point added two EDGs and cross-ties reducing the risk of an SBO after a LOOP from 7.6E-04 to 2.9E-06 per RY. Table 3 indicates that adding power supplies to the Calvert Cliffs, Diablo Canyon, and Arkansas Nuclear One PRA/IPEs resulted in risk reductions ranging from 14 to 47 percent.

In NUREG -1109, the staff expected that the SBO rule would add value by averting 145,000 person-rem from an accident; the estimates ranged from 216,500 person-rem to 65,000 person-rem. The expected reduction in person-rem was calculated by multiplying the reduction in CDF per RY from an SBO by the remaining life of the plant (assumed to be 25 years) and the estimated public dose based on the highest source term at a site from an accident. The total reduction in person-rem for each plant was summed and divided by 10 to account for a smaller source term for an SBO at a 50-mile radius. The 145,000 person-rem derived in NUREG-1109 appears to be realistic, and may be low since the weighted population dose factor for the five NUREG-1150 power reactors ranges from 166,000 to 2,000,000 person-rem within 50 miles of the plant (NUREG/BR-0184, “Regulatory Analysis Technical Evaluation Handbook,” February 1997).

In NUREG-1109, the staff calculated a value-impact ratio of 2,400 person-rem per $M based on averting 145,000 person-rem at a cost of $61.5M with a range of 700 person-rem per $M to 5,000 person-rem per $M. The outcome was a value-impact ratio of 611 person-rem per $M based on an estimated impact of $237M. However, some plants received approximately $50M in monetary benefit from increased EDG AOT, reducing the impact to $187M, which makes the value-impact ratio approximately 775 person-rem per $M. This is within the expected range.

Previous Assessment of the Cost Effectiveness of the SBO Rule

The staff also evaluated the industry’s average cost per person-rem averted in satisfying the SBO requirements in SECY 97-180, “Response to Staff Requirements Memorandum of May 28, 1997, Concerning Briefing on IPE Insight Report,” August 6, 1997. The staff used a different methodology and concluded that, on average, the SBO rule averted a person rem at a cost of $4,750 (211 person-rem per $M); and that this cost is likely too high because it does not give full credit for other sizable economic benefits and it is skewed by a few plants whose SBO cost exceeded $10M. Most reactors incurred SBO costs of less than $1M. A supporting calculation suggested that about 70 percent of the reactors incurred costs of less than $1000 per person-rem averted (1000 person-rem per $M), and 75 percent incurred costs of less than $2000 per person-rem averted (500 person-rem per $M).

Assessment

Comparing of the expected value-impact to the actual value-impact indicates that the actual value impact was within the expected range of reduction in public dose per dollar of cost. However, the NRC staff did not anticipate that so many licensees would install additional safety-

related and nonsafety-related power sources which accounted for 75 percent of the estimated industry cost. So the staff underestimated the expected ("best estimate") cost by a factor of approximately 4. However, it appears licensees justified the cost of the added power supplies based on offsetting monetary benefits, such as more operating flexibility from increased EDG AOT. So the NRC also underestimated the value. Disregarding the costs of the power supplies, the costs of meeting the SBO rule requirements were reasonable since plants have added SBO coping and recovery procedures, and have established EDG reliability programs to maintain EDG target reliability levels. Further, the SBO rule focused NRC and industry resources on an area known to be important to the overall risk of an operating nuclear power plant, and the SBO rule analysis helps to maintain an acceptable level of safety at operating nuclear power plants.

The industry and NRC costs to implement the SBO rule were reasonable, considering the outcomes. As expected there was wide variation in plant-specific values and impacts because the SBO rule provided flexibility; plants with higher risk needed longer coping times and possibly more modifications, and plants with an already low risk from SBO needed shorter times to cope and fewer modifications.

3.2.5 Insights From Operating Experience Reviews

Performance during operating events provides a additional means to assess the effectiveness of regulatory requirements and guidance. The following are some operating experience insights.

<u>Modifications Due to the Station Blackout Rule</u>

Plant modifications and procedures due to the SBO rule have been relied upon to provide protection during operating events. For example, in the original emergency power system design for Turkey Point Units 3 and 4, the two units shared two 2850-kW safety-related EDGs and five onsite nonsafety-related EDGs that could be connected to the reactor unit emergency power system through a nonsafety-related switchgear. As a result of the SBO rule, the licensee added two 3095-kW safety-related EDGs. A March 1993 report, "Effect of Hurricane Andrew on the Turkey Point Nuclear Generating Sation from August 20–30, 1992," indicates that the five onsite nonsafety-related EDGs were unavailable because of water damage to the nonsafety-related switchgear; the total load on the four safety-related EDGs was approximately 3400 kW, and about 3.5 days into the storm, one of the two original 2850-kW EDGs tripped and was restarted in 2.5 hours. Had the two safety-related 3095-kW EDGs not been added as a result of the SBO rule, the load on the only remaining 2850-kW EDG would have exceeded the EDG rating by 19 percent and most likely the EDG would have failed unless unloaded quickly by the operators, leaving no ac power for 2.5 hours.

<u>Offsite Power System Deregulation</u>

In SECY 99-129, "Effects Of Electric Power Industry Deregulation on Electric Grid Reliability and Reactor Safety," May 11, 1999 [Ref. 28], the staff states that the risk significance of potential grid unreliability due to deregulation is likely to be minimal, although individual plants might have an increase in the total plant CDF if grid performance degrades as a result of deregulation of the electric utility industry. Grid degradation would increase the risk of an SBO, but the SBO rule provides additional defense in depth by requiring plants to cope with an SBO for a specified duration.

Dominant SBO Risk Factor Trends

The main factors affecting the likelihood of SBO accidents at nuclear plants are (1) EDG reliability and redundancy, (2) the LOOP frequency, and (3) the time to restore offsite power following its loss.

Neither INEL-95/0035 (with data from 1987–1993) nor INEEL DRAFT update (with data from 1987–1998) found any trend in EDG train performance by year.

Table 7, “Dominant Station Blackout Risk Factor Trends — Offsite Power System,” was prepared to compare the offsite power trends in NUREG-1032 (based on 1968–1985 operating experience) to the corresponding offsite power values in NUREG/CR-5496 (based on 1980–1996 operating experience). The results show overall improvement in LOOP frequency and duration. An exception is the increasing duration of grid-related LOOP events. This is being addressed by SECY 99-129.

The number of LOOPs of 4 or more hours prompted RES to calculate the probability of failing to recover from LOOP. Table 8, “Analysis of Loss of Offsite Power Event Recovery 1968–1996," was prepared by counting the number of plant-, grid-, and weather-related LOOPs in NUREG-1032 and NUREG/CR-5496 and calculating the probability of failing to recover from the LOOP in each of the corresponding recovery time intervals in Table 8. Table 8 indicates that there is a higher probability of nonrecovery from weather-related LOOPs within 4 hours than from plant- or grid-centered LOOPs. The data show there is a 47-percent chance of nonrecovery from a weather-related LOOP within 4 hours and an 18-percent chance of nonrecovery within 8 and 16 hours. The corresponding values from plant- and grid-related LOOPs are significantly lower, 0.05 and 0.06 in 4 hours and 0.0 and 0.0 in 8 hours. Table 8 also shows the NUREG-1032 “enhanced” or expected probabilities of non-recovery for plants with recovery procedures and at least one power source. Comparing the weather-related enhanced probability of nonrecovery to the corresponding calculated probability of non-recovery indicates the enhanced levels have not been achieved.

Table 7 Dominant Station Blackout Risk Factor Trends — Offsite Power System

Source of LOOP Data	**NUREG-1032 (1968–1985 LOOP operating experience)**	**NUREG/CR-5496 (1980–1996 LOOP operating experience)**
Plant-related LOOP		
Mean frequency	0.087	0.04
Median time to restore	18 minutes	20 minutes
LOOPs > 4 hours	0	4
Grid-related LOOP		
Mean frequency (occurrence per year)	0.018	0.0019
Median time to restore	36 minutes	140 minutes
LOOPs > 4 hours	1 (due to severe weather)	0
Weather-related LOOP		
Mean frequency	0.009	0.0066
Median time to restore	4.5 hours	1.2–2.4hours
LOOPs > 4 hours	4	5

Table 8 Analysis of Loss of Offsite Power Event Recovery 1968–1996

Number of LOOP Events and Probability of Recovery	Cumulative Recovery Time in Minutes								
	0 30	0 60	0 120	0 180	0 240	0 480	0 960	0 > 961	Total
Plant LOOP events	46	58	71	71	71	75			75
P (nonrecovery)	0.39	0.23	0.05	0.05	0.05	0 (in 388 min)			
Weather LOOP events	4	4	6	6	9	14	14	17	17
P (nonrecovery)	0.76	0.76	0.65	0.65	0.47	0.18	0.18	0 (in 7950 min)	
Enhanced P (nonrecovery)	0.65	0.40	0.25	.01	0.05	0.02			
Grid LOOP events	7	9	11	15	17	18			18
P (recovery) P (nonrecovery)	0.61	0.5	0.39	0.17	0.06	0 (in 388 min)			

Appendix F, “Operating Events,” Table F-1, “Losses of Offsite Power Since 1990 Having Recovery Times of 4 Hours or Longer,” summarizes six plant-centered and three weather-related LOOP from 1990 (when the SBO rule was implemented) to 1998. The LOOPs occurred while the reactor unit was running and it took 4 or more hours to recover offsite power. Three of the events closely followed an SBO resulting in a LOOP and the unavailability or technical inoperability of one EDG. Analysis of the plant events found communication and procedural weaknesses in that delayed recovery. These weaknesses were subsequently corrected and recovery from future losses of offsite power should significantly improve. Analysis of weather events shows that it could take up to 4.5 days to recover offsite power in a hurricane, 28 hours after a tornado, and approximately 8 hours after ice accumulation or contamination from salt sprays. Provisions for these types of events are addressed in NUMARC 87-00, Rev.1 which requires actions for achieving enhanced coping capability under hurricane and tornado conditions. Key features of NUMARC 87-00, Rev. 1, are (1) actions to be taken in the 24-hour period before anticipated arrival of the hurricane and (2) a commitment to be in a safe shutdown condition 2 hours before the hurricane arrives. Another key feature to mitigate hurricanes and tornados was the addition of Aac power supplies at the plants that have the most vulnerability to extremely severe weather conditions.

Potential SBO Alternate ac Power Source Unavailability

Appendix F, Table F-2, “Station Blackout Challenges,” was prepared from a review of the 1990–1998 operating experience. The review found one event (LER 335/98-007) that identified inadequate SBO recovery procedures during a simulator exercise in 1998 that could have complicated recovery from an SBO. Four events (LER 346/98-006, 247/98-007 and two events in Information Notice [IN] 97-21 [Ref. 29]) identified the potential unavailability during an SBO event of an Aac power source (added as a result of the SBO rule). The latter is a concern since the unavailability of the Aac power supply during an SBO could lead to core damage. IN 97-21 described the dependencies of the Aac support system batteries and ac auxiliary power. LER 247/98-007 reported that the SBO Aac power source output circuit breakers were not capable of being closed onto a de-energized bus during an SBO. The licensee reported that the

cause of the problem was insufficient comprehensive testing. LER 346/98-006 reported that a tornado resulted in a LOOP and the technical inoperability of one EDG; and offsite power was restored in 28 hours. An NRC analysis of the tornado event noted that a nonessential bus supplies power to the auxiliaries of the Aac, and if not powered, the batteries would deplete in approximately 28 hours. If the EDGs failed to start or run in the first 8 hours of the 28-hour event, the SBO-DG might have been unavailable likely leading to core damage.

Assessment

Implementation of the SBO rule has strengthened additional defense in depth. As demonstrated at Turkey Point, the SBO rule modifications and procedures have been relied upon to mitigate the consequences of, and provide protection during LOOP events. The SBO rule provides defense in depth if deregulation of the electric utility industry or changing offsite power system trends effect the SBO risk.

There is a lower probability of recovering within the SBO coping time for extremely severe weather LOOP events than from other types of LOOPs. The SBO rule has resulted in industry requirements (that have been endorsed by the NRC) that can be taken before extremely severe weather conditions to mitigate the potential consequences of such an event and the addition of Aac power supplies at the plants that have the most vulnerability to extremely severe weather conditions.

Subsequent to issuing an IN 97-21, an event revealed that the availability of an Aac power supply system was limited by dependencies on offsite or onsite power supplies and that this situation could lead to core melt.

4 CONCLUSIONS

The report's conclusion is that the SBO rule was effective, and industry and NRC costs to implement the SBO rule were reasonable considering the outcomes. In implementing the SBO rule, some plants made hardware modifications (e.g., the addition of diesel generator or gas turbine generator power supplies); and all plants generally maintained EDG reliability at 0.95 or better, and established SBO coping and recovery procedures. Consequently, the plants have gained SBO coping capability, reduced risk, increased tolerance of a loss of ac offsite or onsite power, and many plants benefitted economically from the addition of power supplies. To elaborate:

- The reduction in the estimated mean SBO core damage frequency (CDF) was approximately 3.2E-05 per reactor year, slightly better than the 2.6E-05 per reactor year expected after implementation of the SBO rule. As a result of the improvements made under the SBO rule, more plants achieved a lower SBO CDF than expected, and the plants with the greatest numbers of loss of offsite power from plant events and extremely severe weather conditions made the most improvement by providing access to an alternate ac power supply. In addition, maintaining high EDG target reliability levels provides assurance that probabilistic risk assessment/individual plant examination EDG performance assumptions are valid. With some exceptions, the observed EDG reliability performance generally exceeds the mean reliability EDG performance assumptions in the probabilistic risk assessment/individual plant examinations, indicating that SBO CDFs are smaller and better than stated in many probabilistic risk assessment/individual plant

examinations. As the SBO rule risk reduction objectives have been exceeded, further investigation of strategies for reducing SBO frequencies (as suggested in NUREG-1560, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance," December 1997) may not be needed.

- As a result of the SBO rule all plants have (1) established SBO coping and recovery procedures; (2) completed training for these procedures; (3) implemented modifications as necessary to cope with an SBO; and (4) ensured a 4- or 8-hour coping capability.

- Before the SBO rule was issued, only 11 of 78 plants surveyed had a formal EDG reliability program, 11 of 78 plants had a unit average EDG reliability less that 0.95, and 2 of 78 had a unit average EDG reliability of less that 0.90. Since the SBO rule was issued, all plants have established an EDG reliability program that has improved EDG reliability. A study shows that only 3 of 102 operating plants have a unit average EDG reliability less than 0.95 and above 0.90 considering actual performance on demand, and maintenance (and testing) out of service (MOOS) with the reactor at power. However, the analysis of EDG performance on demand indicates MOOS with the reactor at power is more than expected and can have a significant effect on the EDG reliability calculations. Increased MOOS explains why licensees appear to be having difficulty meeting a 0.975 EDG target reliability. Decreased EDG reliabilities and/or increased MOOS unavailabilities erode the risk benefits obtained from implementing the SBO rule.

- The operating experience indicates that the SBO rule has increased defense-in-depth. The SBO related hardware and procedures have been used in response to unplanned events and provided additional protection. The SBO rule provides additional defense-in-depth to compensate for potential degradation of the ac offsite power system that may result from deregulation of the electric power industry or longer than expected recovery of offsite power after extremely severe weather conditions.

- A comparison of the value-impact expectations to the outcomes indicates that the value-impact was within the expected range of reductions in public dose-per-dollar of cost. As expected, there was wide variation in plant-specific values and impacts because the SBO rule allowed flexibility. Not expected was the addition of costly power supplies, which accounted for 75 percent of the estimated industry cost impact and explains why the NRC value-impact analysis underestimated the cost by a factor of 4. However, it appears licensees justified the cost of the power supplies by counting on offsetting monetary benefits, such as more operating flexibility from increased EDG allowed outage times. Thus the value was also underestimated. The remaining 25 percent of the estimated industry cost impact appears reasonable, considering the outcomes: known coping capabilities, industry risk reduction from plant-specific procedural and hardware enhancements, and additional defense-in-depth.

A comparison of the SBO rule expectations to the corresponding outcomes indicates that no additional generic actions are warranted and that no new generic safety issues have been identified. However, consistent with adhering to Principles of Good Regulation that include clarity (coherent and practical regulations) and reliability (regulations based on operating experience) there are opportunities to revise the regulatory documents. These revisions are consistent with the SBO technical basis (NUREG-1032); ensuring high levels of EDG reliability; maintaining the risk benefits obtained from implementing the SBO rule; providing practical

guidance for reactor shutdowns with limited offsite or onsite power sources; and using operating experience in the inspection documents. The opportunities are as follows:

(1) Regulatory Guides 1.155, “Station Blackout”, August 1988; RG 1.9, “Selection, Design, Qualification of Diesel-Generator Units Used as Standby (Onsite) Electric Power Systems at Nuclear Power Plants,” Rev. 3, July 1993; and RG 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,” Revision 2, March 1997, which address use of the EDG reliability terms, criteria, and measurements may need to be revised in a coherent manner to: (a) clarify that MOOS with the reactor at power should be included in the reliability calculation, (b) clarify that licensees should balance increased EDG reliability against the increased EDG unavailability to maintain the RG 1.155 minimum individual EDG target reliabilities, (c) clarify that the EDG system boundary used in the reliability calculation should include the load sequencer and the bus between the EDG and the loads, and (d) establish common EDG start and load-run criteria for the guidance.
Inspection documents Temporary Instruction 2515/125, "Inspection of Implementation of Station Blackout Rule,” (no date), and Inspection Procedure 62706, “Maintenance Rule,” December 31, 1997, may need revision to delete use of the Nuclear Management and Resources Council (now NEI) (NUMARC) trigger values to assess compliance with the 0.95 and 0.975 EDG target reliability. The NUMARC trigger values do not provide high levels of confidence that the EDG target reliability is being met; this is inconsistent with ensuring high EDG reliability, delays corrective action, and erodes the risk benefits obtained from implementing the SBO rule.

(2) Operating events indicate that the availability of some Aac power supplies is dependent on offsite or onsite power supplies. SBO-related inspection documents may need inspection attributes to verify that the Aac sources meet NUMARC 87-00, “Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors,” Revision 1, May 1993, Appendix B, B.8, “Minimal Potential For Common Cause Failure.”

(3) Regulatory Guide 1.93, “Availability of Electric Power Sources,” December 1974, the basis for technical specifications in the area of ac onsite and offsite power supply availability, provides for shutdown of the reactor after extended ac power supply unavailability. Plant shutdown with one or more offsite or onsite power supplies unavailable could exacerbate the grid condition or remove redundant sources to operate decay heat removal systems, increasing the likelihood of an SBO. Additional practical guidance may minimize the likelihood of an SBO.

(4) Follow-up at 2 plants found a large difference between the unit average EDG reliability based on load-run tests and unplanned demands and the reliability calculated by the licensee based on the last 100 start and load-run tests and unplanned demands. This difference confirms a previous finding in INEL-95/0035, “Emergency Diesel Generator Power System Reliability,” February 1996, that the current testing and inspection activities (as prescribed by the NRC) may not be focusing on the dominant contributors to unreliability during actual demands. Accordingly, NRC test and inspection documents may need to be modified to better factor in the conditions and experiences gained from actual system demands.

As a lesson learned, to the extent that the NRC staff revises existing regulatory documents to be more risk-informed and performance-based, they may need to be modified to ensure consistent interpretation and use of terms, goals, criteria, and measurements.

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