March 17, 2005

MEMORANDUM TO: Charles E. Ader, Director
Division of Risk Analysis and Applications
Office of Nuclear Regulatory Research

FROM: Farouk Eltawila, Director ***/RA/***
Division of Systems Analysis and Regulatory Effectiveness
Office of Nuclear Regulatory Research

SUBJECT: REQUEST FOR REVIEW OF DRAFT REPORT, "EVALUATION OF LOSS OF OFFSITE POWER EVENTS AT NUCLEAR POWER PLANTS: 1986-2003"

In your memorandum of October 29, 2004, you requested our review and comments on the subject report. We reviewed a revised version of the report that was issued for public comment on December 6, 2004, (ML043380290). We revised a draft of this memorandum after a meeting with your staff. The comments below were also reviewed by John Kauffman, a former nuclear power plant (NPP) Shift Supervisor and Senior Reactor Operator, for the reasonableness of our views on plant operations. We are pleased to be given the opportunity to provide the comments that follow for your consideration.

Background

As background for our comments, the draft report provides a statistical analyses of 141 loss of offsite power (LOOP) events from 1986-2003, including 72 shutdown LOOPs, 59 LOOPs while the reactor was critical and tripped, and 10 LOOPs while the reactor was critical and did not trip. The draft LOOP study develops LOOP frequency and duration statistics and fits this data to a distribution that provides a "probability of exceedance," i.e. the probability of not recovering from a LOOP longer than a given duration. The LOOP data are grouped by plant, switchyard, grid, severe weather, and extremely severe weather. The switchyard group includes LOOPs due to plant startup transformer failures, transmission network problems, switchyard problems, and consequential LOOPs. The report analyzes and formats the LOOP data for the next step, analyses of the station blackout (SBO) risk.

An SBO is the complete loss of ac electric power to the essential and nonessential switchgear buses concurrent with turbine trip and unavailability of the onsite emergency ac power system. Implementation of the NRC's SBO rule resulted in most nuclear power plants (NPPs) having an SBO coping capability of at least four hours to a ensure safety of plant equipment and allow time to restore ac power. The report provides three offsite power restoration times: the switchyard restoration, the potential safety bus restoration, and actual safety bus restoration. Historically, the NRC has used the potential safety bus restoration time for SBO risk to account for the fact that under non-SBO conditions licensees may delay restoration of offsite power to

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the safety buses when the EDGs are running because of other higher priorities related to the LOOP event. The report estimates potential safety bus restoration times in 113 of the 141 events by adding one minute to the switchyard restoration time to account for the time it takes to connect the switchyard to the safety buses during an SBO. The report develops the potential safety bus restoration concept by: (1) assuming that an urgency to restore power exists because of a potential accident conditions, the power restored to the switchyard is of usable quality, no extensive diagnostics or repair are required, faults have been cleared, and the operator actions needed involve routine verification and switching; (2) obtaining the consensus of engineers with previous operator experience; and (3) observing that it actually took the operator one minute to backfeed power from the switchyard to the safety bus in 8 cases.

Comments

1. The "potential" safety bus restoration times, i.e. estimates of the time to restore power under SBO conditions (which are less than the actual times it took to restore power to a safety bus during a LOOP) need to consider the operational and technical challenges faced by the operator for an SBO. The report provides a sensitivity analyses using the actual safety bus restoration times which are longer.

Experience shows that in at least 50 percent of the LOOPs involving a reactor trip, the choice of the potential safety bus restoration time may not always be the best estimate. We suggest revising the report to show the actual time is just as conceivable based on: (1) the reactor operation and priorities during an SBO; (2) that although faults may isolated quickly, the collateral damage may prevent use of the equipment; (3) operator actions may be quick and involve routine verification and switching, however, operations need much more time to make unit cross-ties available, implement temporary modifications, or wait for the arrival of support staff to diagnose problems during off hours, and (4) although some experience shows it could take as little as one minute under ideal conditions to back power from the switchyard to the safety bus, other experience shows it takes more than one-minute (and up to 861 minutes). We suggest the report be revised to conclude that there is truly a range of possible restoration times bounded by the potential safety bus restoration time and the actual safety bus restoration time. The supporting experience follows and in some cases we provided additional suggestions.

(a) It is conceivable that given the pressure of an SBO, a potential safety bus restoration time may in some cases be justified. However, it is also conceivable that during an SBO, that the actual safety bus restoration time is just as valid as the NPP operator may not have control over recovery due to weather or grid conditions (about one-third of the LOOPs involving a reactor trip). In addition, recovery during an SBO may take longer than a LOOP as there are more operating tasks to delegate to the available staff. Typical tasks during an SBO include diagnosis of EDG failure and its recovery, battery load shedding; making alternate electric feeds from the switchyard or unit cross-ties available, and starting alternate ac power supplies; and communicating with the plant Technical Support Center (TSC), Operational Support Center (OSC), and NRC Operations Center. Although there has never been an SBO in the U.S., the operating experience indicates that as SBO conditions were approached, the LOOP lasted longer more than 50 percent of the time, i.e. we looked back to 1996 and found that for the subset of LOOPs involving a reactor trip and the loss of one EDG, three of the five LOOPs lasted longer more than the four hour SBO coping capability of most NPPs.

(b) The shorter estimates of potential safety bus restoration time do not provide a general window of time for reactor operation. Following a reactor trip with an SBO the operators must first stabilize the reactor (e.g. in a pressurized water reactor, isolate the reactor coolant system and verify turbine driven auxiliary feedwater has been established), enter emergency procedures for the event, and reach the point in the procedure where attempts to restore power are first initiated (estimate 15 minutes). In addition, the operators must among other things, address reactor problems and get ready to close circuit breakers (estimate at least another 15 minutes). We suggest accounting for reactor operation time by providing a 30 minute window of time for reactor operation in the current estimates of the safety bus restoration times under SBO conditions.

c) Licensee Event Report (LERs) and other event information provide some of the practicalities of NPP operation that need to be considered in the development of realistic power restoration times as indicated below. These selected instances add to the view that the actual times are equally as valid as the potential times. A detailed review of other study events would likely yield additional, similar insights.

> In LER 414199600, a transformer fault occurred on Unit 2 resulting in a LOOP. At the time of the LOOP, EDG B was unavailable as a result of maintenance. A detailed sequence of events in an NRC inspection report (IR 50-413/96-03) shows the operators entered procedures for a Reactor Trip or Safety Injection (SI) immediately, a Reactor Trip Response within a 2 minutes of the LOOP, and re-entered the Reactor Trip or SI emergency procedures about 8 minutes into the LOOP, and entered procedures for the Loss of Reactor or Secondary Coolant 26 minutes into the event. In the next 30 minutes, SI was terminated, letdown re-established, and the OSC and TSC were made operational. In parallel with the stabilizing the reactor, other teams were working to restore EDG B to service, diagnose the LOOP, and restore offsite power. About 60 minutes into the event, operations decided restoring offsite power through Unit 2 equipment was not an option and decided to use the Unit 1 cross tie. Power was available from the switchyard through Unit 1 just by closing two circuit breakers; however load shedding was required before using the cross-tie and about 180 minutes into the event all but one circuit breaker was closed. The LER and the inspection report indicate that a procedure deficiency slowed the operators down and offsite power was first restored about 330 minutes into the event. The draft report assumes switchyard power was available in 120 minutes and potential safety bus restoration time one minute later. In contrast, the experience shows power was always available in the switchyard but reactor operation, problem diagnosis, returning the EDG to service, switching and load shedding, and recognition of a procedural error resulted is 330 minutes passing before power was actually restored to a safety bus; we suggest using 330 minutes in the analyses.
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> In LER 3241989009 power was available in the switchyard. However, the bus duct on the secondary side of the Unit 2 station auxiliary transformer was faulted and did not allow the use of the Unit 1 cross tie. The fault was cleared as assumed in the study; however the fault damage left the equipment needed unusable. Plant personnel decided to bypass the problem by backfeeding offsite power from the switchyard, through the main and auxiliary transformers by manually isolating the main generator. It took approximately 6.5 hours to removal the links and this appears to be a very ambitious effort given these links are typically in the isolated phase bus several feet above the ground floor, accessible after bolted covers are removed, and held in place with several dozen bolts in each of the three

phases. The draft report assumes a potential safety bus restoration time of 90 minutes. Had there been an SBO, this area of the plant would have been in the dark and link removal performed with flashlights. We suggest using 6.5 hours rather than 90 minutes while recognizing that 6.5 hours maybe non-conservative.

LER 2701992004 involved two LOOPs; the draft report only considers one. After initially recovering offsite power in 57 minutes, recovery actions 35 minutes later resulted in a second LOOP. It then took another 115 minutes to diagnose the problem and recover. The LOOPs occurred between 21:00 and 22:00 hours when most of the support staff are home. The plant procedures did not address this event, the electrical system at this plant is complicated, and recovery of power was largely dependent the arrival of a key engineer from home. In the past, this was counted as one LOOP lasting 207 minutes since the NRC SBO analyses does not consider the effects of a double LOOP scenario on the hardware (RCP seals, etc). We suggest using 207 minutes in the analyses.

Some LERS not used in this study have identified problems with SBO procedures or NPP SBO related design weaknesses that have existed for several years; had there been an SBO recovery would not have been as expected and most likely required more time. For example, in LER 3351998007 the licensee discovered during an SBO recovery exercise that one of the methods to restore electrical power could not be performed as the procedure was written.

The draft shows the analysts were certain that it one minute time to back power from the switchyard to the safety bus based in part on eight events. However, the report also shows an equal number of events where the analysts were certain it took more than one minute to back power from the switchyard to the safety bus (64, 24, 4, 60, 40, 861, 30, 60 minutes).

(d) The draft report assumes that power is always of sufficient quality. This is an unverifiable assumption, particularly for events involving the grid and weather. The offsite power must be of sufficient quality for the equipment to work. If the voltage or frequency are not within plant or grid protective relay setpoints, restoration will not work. The actual restoration times should be used for weather and grid events unless the quality the offsite power supply (magnitude of the voltage and frequency) can be confirmed.

The draft report analyses of the switchyard and potential bus restoration times from the August 14, 2003, blackout consider that the grid voltage and frequency were stable and of sufficient quality to work based on inputs that judged the grid to be stable sooner than times stated in the LERs and logs where the NPP operators thought grid was stable. The grid and NPP operators judgements during an event are likely to be the same had there been an SBO and should be used for the analyses. Our staffs have been meeting to develop a sequence of events of the power restoration for the August 14, 2003 blackout from based on times we obtained from the New York Independent System Operator (NYISO) detailed account of the recovery several months after the event, the NRC LERs, a Region I log of information reported during the event, and times your staff obtained from information Region I gathered after the event. We suggest that post event judgements about when the grid was stable enough to connect to the safety buses, after several hours of investigation and in the absence of voltage and frequency data, should not be given preference over load dispatchers or nuclear plant operator decisions based on their training, experience, and evaluation of the voltage and frequency at the time of the event.

(e) As a detailed comment, the draft report averaged the recovery times at NMP 1 & 2 and Fitzpatrick for the August 14, 2003 event based on all three sites having a common 115kV offsite power supply. Electrical diagrams in the Final Safety Analyses Reports show that the NMP2 offsite power is supplied by two 115kV lines from two 115/345 kV transformers in the nearby 345kV Scriba switchyard) i.e not the same 115kV system that supplies NMP1 and Fitzpatrick. In addition, the draft report deleted a 1902 minutes LOOP data point from the analyses as an outlier when it should have received special attention (see Comment 3). We suggest the exceedance curves and other analyses be revised to include this event.

2. Although the shutdown and critical LOOP data is statistically the same, a LOOP while at power is very different from a LOOP while shutdown in terms of electrical hardware alignment of electrical loads and the dynamic response. The data sets are not homogeneous from an engineering and operational perspective and should not be combined for statistical uses. Inclusion of the shutdown data minimizes the probability of exceedance of the LOOPs while critical and is a key factor in analyzing SBO risk.

Based on statistical analyses, the draft report separates the LOOP frequency data for shutdown and critical operations, and combines the LOOP durations and probability of exceedance data for shutdown and critical operations. 10CFR 50 describes a SBO as a turbine trip (power operation) and progressing to a safe condition when shutdown. Specifically, 10 CFR 50.2 “Definitions” state that “Station blackout means the complete loss of ac electric power to the essential and nonessential switchgear buses in a nuclear power plant (i.e loss of offsite electric power system concurrent with turbine trip and unavailability of the onsite emergency ac power system).” In addition, 10CFR50.2 states that “safe shutdown for station blackout means bringing the plant to those shutdown conditions specified in plant technical specifications as Hot Standby or Hot Shutdown, as appropriate.” We suggest that the exceedance curves be revised to reflect only the LOOP data during critical operations.

Also, a LOOP at power reduces the generation available to the grid up to approximately 1300 megawatts (mW) per unit lost, depending on the size of the plant, whereas a LOOP during shutdown increases the power available to the grid by 30–50 mW, the shutdown load.

3. The raw data that shows in 11 of the 59 LOOPs with a reactor trip (19 percent), the potential safety bus restoration time was in excess of four hours , i.e 278, 297, 297, 380, 385, 388, 454, 1428, 1902, 7921, 7921 minutes. Had there been an SBO, it follows that offsite power was not and could not have been recovered within the SBO coping capability of most plants in these events and recovery of power solely dependent the recovery of an EDGs. If the actual bus restoration time is considered, 23 of 59 LOOPs (38 percent) were not restored in 4 hours. In comparison there were 5 of 60 LOOPs (8 percent) longer than 4 hours in NUREG-1032 (the SBO rule technical bases which evaluates data from 1969–1985). We suggest the report conclusions discuss the significance of entire distribution of LOOPs with the reactor critical and evaluate the potential impact of a long LOOPs in sensitivity studies in the analyses of SBO risk.

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