ELECTRIC POWER RESEARCH INSTITUTE

Industry Support for NRC Issues of Loss of Off-Site Power (LOOP) and Grid Stability

Responses to NRC Request for Additional Information

1013581

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Technical Update, September 2006

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ABSTRACT

The NRC Staff provided comments on the BWR Owners' Group (BWROG) submittal of April 6, 2004 relating to the Electric Power Research Institute (EPRI) Technical Reports 1009110, Revision 1 and 1007966 on the double sequencing issue. This technical brief provides the responses that were developed by EPRI and reviewed by the BWROG.

CONTENTS

1 **INTRODUCTION 1-1**

2 **RESPONSES TO NRC COMMENTS ON EPRI TECHNICAL REPORTS 1009110 AND 1007966 .... 2-1**

EPRI Technical Report 1009110 2-1
Page 7-2 – Item 8 2-1
Page 7-3 – Sentence Immediately Following Item 10 2-2
Page 7-3 – Partial Paragraph Immediately Following Above Sentence 2-2
Page 7-3 – Last Bullet on Page 2-3
Page 7-4 – Second Bullet on Page 2-4
Page 7-5 – First Three Bullets on Page 2-5
Page 7-6 – Table 7-1, Item 1 and Its Associated Note 1 2-6
Page 7-6 – Table 7-1, Item 2 and Its Associated Note 2 2-6
Page 7-6 – Table 7-1, Item 3 and Its Associated Note 3 2-7
Page 7-6 – Table 7-1, Item 4 and Its Associated Note 4 2-7
Page 7-6 – Table 1, Item 5 and Its Associated Note 4 2-11
Page 7-6 – Table 7-1, Item 8 and Its Associated Note 7 2-11
Page 7-6 –Table 7-2, Item 10 and Its Associated Note 9 2-11
Page 7-6 – Table 7-2, Item 10 and Its Associated Note 9 2-11
Page 7-6 – Table 7-1, Item 11 and Its Associated Note 2-11
Page 7-7 – Table 7-1, Item 12 and Its Associated Note 4 2-12
Page 7-7 – Table 7-1, Item 13 2-12
Page 7-7 – Table 7-1, Item 14 and Its Associated Notes 10 and 11 2-12
Page 7-7 – Table 7-1, Item 17 and Its Associated Note 13 2-12
Page 7-7 – Table 7-1, Item 18 and Its Associated Note 14 2-13
Page 9-2 – Recommendation 5 2-13
EPRI Technical Report 1007966 2-15
General 2-15
Page 7-3 – Discussion in Section 7.4 2-15

1
INTRODUCTION

In the referenced letter[11] the NRC Staff provided comments on the BWR Owners' Group (BWROG) submittal of April 6, 2004 relating to the Electric Power Research Institute (EPRI) Technical Reports 1009110, Revision 1 and 1007966 on the double sequencing issue. The NRC provided a very thorough review effort completed by the NRC staff. The attached responses were developed by EPRI and reviewed by the BWROG.

These EPRI reports are the culmination of a project to establish a common and more comprehensive understanding of the double sequencing issue. Previously documented information on double sequencing is fragmented among many industry documents spanning a decade. The EPRI reports are intended to be 'living documents' that could be improved with additional experience and understanding of the double sequencing issue.

To that end, and in recognition that many of the NRC staff's comments can add substantially to the quality and completeness of the documents, EPRI intends to revise the two (2) technical reports. The planned treatment of some comments is described in detail in this technical update; in other cases our response simply acknowledges the need to expand the report discussions in areas affected by the comments.

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[1] *Resolution of NRC Staff Comments on Electric Power Research Institute (EPRI) Double Sequencing Reports Related to Boiling Water Reactor Owners Group (BWROG) Licensing Topical Report (LTR) NEDO-33148*, "Separation of Loss of Off-Site Power from Large Break LOCA" (TAC No. MC3042)

2 RESPONSES TO NRC COMMENTS ON EPRI TECHNICAL REPORTS 1009110 AND 1007966

**RESPONSES TO NRC COMMENTS ON
EPRI TECHNICAL REPORTS 1009110, REVISION 1 AND 1007966
REGARDING THE ISSUE OF DOUBLE SEQUENCING
NUCLEAR PLANT SAFETY LOADS**

EPRI Technical Report 1009110

Page 7-2 – Item 8

With regard to the grid operator's plans and expectations for system performance following the trip of a nuclear unit, it is useful to understand that: the minimum switchyard voltage required by a nuclear plant that has no voltage regulating capability (such as auto tap changing transformers or static VAR compensators) is generally more limiting than the minimum voltage required to prevent a grid voltage collapse. The transmission system operator, therefore, cannot be relied upon to control a plant's post-trip switchyard voltage to the level that is necessary for the nuclear plant, unless the transmission operator has been made aware of the nuclear plant's requirements, and arrangements have been negotiated to control the switchyard voltage to that level, post-trip.

Response:

We concur with this comment. Note that Item 8 is one of ten "considerations that bear on the estimation of a value for the probability-of-occurrence of a double sequencing event.

The Reviewers are correct in noting that, without prior negotiated agreements as to the pre-event voltage targets or schedule, those units without the post-trip ability to control plant bus voltage are more likely to experience a double sequencing event given identical configurations in all other respects. Note the last paragraph of Section 2.4 entitled *Causes of Double Sequencing*, wherein we state that the "initiators are more likely to occur if the grid and nuclear unit organizations are not closely coordinated both contractually and in their operations and communications protocol."

Additionally, a firm agreement as to pre-trip voltage targets goes a long way to ensuring that nuclear unit (and grid) voltage will be adequate in the post-trip period without actions on the part of the grid operator.

The closing sentence of Item 8 states "Adherence to these guidelines minimizes the likelihood of double sequencing." The guidelines are those of Generic Letter 79-36, which cannot be reasonably satisfied without installed voltage regulation equipment, large voltage margins in the plant's design or close coordination with the transmission system operators. There is a Branch Technical Position (BTP) that includes similar guidelines for the more modern nuclear units to which the BTPs applied.

Based on the above, we propose to make no change to the document as a result of this comment. It is our intent that the users of the document consider all items listed in this section in arriving at their own estimation of the probability of occurrence of a double sequencing event at their nuclear unit(s). Clearly, a "loose" interface with the grid operators will, for nuclear units without the benefit of automatic voltage regulating capability, contribute to a higher likelihood of occurrence of a double sequencing event.

Page 7-3 – Sentence Immediately Following Item 10

"Best estimate LOOP [loss of offsite power] frequency" is not the important parameter for LOCAs [loss-of-coolant-accidents]. The important parameter for LOCAs is "conditional LOOP probability given a LOCA." This is the parameter that should be determined for LOCA initiators including degraded voltage situations.

Response:

We concur that the use of the term "best estimate" is inappropriate and plan to change the affected sentence to read "The above guidelines should assist the user in determining the probability of occurrence of a degraded voltage-induced LOOP."

It is our intention to more definitively identify double sequencing as an event that can only occur subsequent to a safeguards system actuation whether that actuation is real or spurious. In this regard, the probability of occurrence of a double sequencing event will always be preconditioned by a safeguards actuation. Thus, the term "double sequencing" has no meaning as a potentially limiting condition except when coupled with a safeguards actuation. While a spurious actuation followed by a double sequencing condition will not be the most limiting event since it will be far more time forgiving relative to operator response, it will, none-the-less, expose safeguards equipment to the operational anomalies that accompany the double sequence condition.

We will revise section 7-1 wherein the term "best estimate" is used in a few instances to eliminate the word "best".

Page 7-3 – Partial Paragraph Immediately Following Above Sentence

With regard to the statement, "While a LOOP is not likely to cause a LOCA," it is noted that a LOOP that results in a full-load rejection of a nuclear plant's turbine generator has some potential to cause a LOCA due to stuck-open safety or relief valves.

Response:

We concur with this comment and will revise the sentence to read, "While a LOOP is not likely to cause a LOCA having greater significance than a post-trip stuck open safety or relief valve, a LOCA may under some circumstances result in a LOOP."

TMI lessons learned and changes incorporated thereafter have vastly improved the operators' ability to detect and effectively mitigate the impact of a stuck valve scenario. None-the-less, this clarification of our statement helps to ensure that the evaluation of the impact of double sequencing on "stuck open valve" isolation equipment (mainly MOVs) is not overlooked.

Page 7-3 – Last Bullet on Page

With regard to the sentence that reads, "The delay in tripping the turbine is nominally about 30 seconds, however the reverse power relays usually operate considerably sooner and trip the generator." The beginning of that sentence should read, "The delay in tripping the generator is …" Also, it is our understanding that Westinghouse plants and some other pressurized water reactors (PWRs) utilize 30 second time delays only and do not necessarily utilize reverse power relays to trip the generator and transfer loads (reactor coolant pump shaft seizure event credit).

Response:

This comment, in part, corrects our reference to the "turbine" when it should have stated the "generator". We will make this correction.

Regarding the 30 seconds time delay in tripping of the generator when mechanical and/or electrical faults are not present in the turbine generator lineup, we note that there may not be a consistent position across the PWR spectrum on this issue. A 30 second delay in tripping will cause the main generator with attached turbine to motor for several seconds. This is an undesirable condition that, at the very least, is to be minimized in terms of its frequency of occurrence. In the case of some units, protective relays, usually of the reverse power type, operate in parallel with the 30-second timer. Depending on the time setting selected for these relays, they may or may not operate faster than the 30-second timer, which, in some cases, may be caused to start timing by the detection of a reverse power condition by a separate relay.

Our discussions with Westinghouse experts revealed that their reasons for avoiding an immediate trip of the generator when conditions permit relates to the departure from nucleate boiling (DNB) advantage of maintaining forced (versus coastdown) flow from the reactor coolant pumps for at least a few seconds for a reactor trip following a Steam Generator Tube Rupture (SGTR) event.

Documentation was provided by Westinghouse indicating a minimum requirement for 2 seconds retention of forced reactor coolant flow in the case of the KORI units (3 and 4) following a SGTR event-induced unit trip. This event is most limiting as it relates to the need for a short period of forced coolant flow following the reactor and turbine trip.

We agree that the reverse power trip of the main generator has been stated with too high a degree of certainty in our report since there are variations on this trip scheme across the industry. We will likely revise the affected sentence to read "The delay in tripping the turbine is nominally set at 30 seconds; however, there are a variation of design arrangements across the PWR spectrum. For this reason, we will amend the document such that licensees choosing to use the guidance contained herein receive a clear message that they need to understand their specific unit designs.

We note that the last sentence in the section commented on already stresses the usefulness of understanding the extent of trip delay and we remain convinced that having that knowledge will help to more fully understand the manner in which the double sequencing event would evolve. This generator trip timing discussion is of more significance to those units that normally power their safeguards buses from the unit auxiliary transformer and have either an installed generator breaker or utilize a high-speed transfer actuation to switch to their preferred offsite power source. At issue here is the likely timing of occurrence of a degraded voltage condition that leads to a double sequencing event, since it is highly unlikely that a degraded voltage condition will occur and persist when loads are powered from the main generator-connected unit auxiliary transformer.

Page 7-4 – Second Bullet on Page

With regard to the sentence that reads, "High-speed transfer schemes have historically functioned very reliably," NRC report AEOD/E-93-02 and EPRI Advanced Light Water Reactor [ALWR] Requirements Document for the ALWR Evolutionary Plant, Chapter 11, indicate that high speed transfer schemes have not functioned very reliably.

Response:

We concur that from some aspects and on a statistical level, high-speed transfer schemes can be shown to "have not functioned very reliably." However, for events at domestic nuclear units resulting in either a full or partial loss of offsite power, high-speed transfer schemes have not been a large contributor to these losses. EPRI Technical Report 1002987, entitled *Losses of Off-Site Power at U.S. Nuclear Power Plants Through 2001* was reviewed to arrive at this conclusion. EPRI's document lists some 149 full or partial loss of power events occurring between the years 1990 and 2001. Of these, five (5) events can be shown to have at their root, a failure of a high-speed transfer scheme. Some of these are due to now corrected design or system operating errors. Another four (4) events can be remotely tied to high-speed transfer scheme operation. These events generally resulted in proper scheme operation to prevent a transfer to offsite power for reasons quite apart from failures within the transfer schemes.

Conservatively counting all nine (9) events as high-speed transfer failure-initiated events, one arrives at a 6% contribution to all loss of offsite power events (during the period studied) being caused by high-speed transfer schemes. This is not to be confused with a 6% failure rate for high-speed transfer schemes since the many times that they operate correctly are not reported in a manner that can be readily retrieved. We recognize that not all nuclear units use a high-speed transfer of safeguards buses since several are normally powered from their startup auxiliary transformers while others utilize a generator breaker that allows the unit auxiliary transformers to remain energized even if the main generator is not operating. For this reason, the contribution of high-speed transfer schemes to LOOP events is only roughly estimated here.

We note that significant improvements have been made in maintenance practices driven by both internal industry initiatives and NRC actions (like the Maintenance Rule). These improvements serve to render historical high speed transfer failure data useful in only a very conservative sense. Additionally, and as noted above, some failures served to reveal defective transfer actuation scheme designs which were then fixed and most likely made known to the entire industry to investigate via the now available Operating Experience-related processes.

The important point being made in the report is that high-speed transfers, when they occur, do so sufficiently fast as to cause no undue stress on the equipment being transferred. Therefore, to the double sequencing issue, high-speed transfer reliability is a rather moot point, as it does not represent a worst case. A failure of the transfer would, in the case of most domestic nuclear units, result in safeguards loads being powered by the onsite emergency generators.

Since our statement can be misinterpreted in a non-conservative manner, we propose to change the wording in the report from "High-speed transfer schemes have historically functioned very reliably." To "High-speed transfer schemes have not historically been a major contributor to loss of offsite power events nor have they been demonstrated to unduly stress transferred loads."

Page 7-5 – First Three Bullets on Page

The assumptions of these three bullets is that as long as the duration of safety system deenergization is small compared to the capabilities of the batteries (1-hour useful discharge life), double, triple, or even quadruple sequencing would not affect the batteries capability. The margin that is believed to exist on the batteries is not as large as assumed here. The first one-minute loading on batteries that is due to load sequencing is almost always limiting. The battery voltages during this period are pulled down very close to the minimum required voltages of the loads due to current inrushes of loads like circuit breaker charging motors. Although the battery may have one or more hours capacity at much lower current demands, a substantial amount of capacity does not have to be discharged before it cannot meet the limiting load sequencing requirement. The battery may not be capable of providing two, three, or four load sequencing repetitions if the charger is not available due to low input voltage or late sequencing on the emergency diesel generator (EDG).

Response:

The one-minute load peak period of a nuclear unit's battery loading profile is a conservative modeling technique used to envelope the numerous very short demands on the batteries during the first moments of a worst case battery loading event. These demands, like multiple and only slightly time separated breaker operations (and subsequent operating spring recharging operations) are spread out over a time period assumed to not exceed one minute in duration. We concur that a station battery's size is oftentimes dictated by the voltage drop experienced during this short duration of peak loading, but also realize that it is the reapplication of this one minute load at the tail end of the Station Blackout (SBO) coping period (when the battery is significantly discharged) that is often most limiting. A double sequencing event without a SBO event (by definition, there will not be a SBO event) will not remove meaningful capacity from a battery even when assuming that the battery charger makes no contribution to the supply of DC System demand. We estimate that a second one-minute peak in the early seconds or minutes of an event will not be voltage limiting either, as insignificant battery capacity has been expended at that point and far fewer breakers will require tripping. We refer to those breakers that upon a LOOP event, serve to remove from safeguards buses, all non-essential post-LOCA loading.

None-the-less, we concur that the document should not serve to relieve the users of the requirement to determine that the above is or is not the case for their unit(s), and will revise our notes, accordingly. The words "triple or even quadruple" will be removed since they have no relevance to the double sequencing issue and serve to project a sense of overconfidence relative to the ability to generically address this DC System issue. Also, while most but not all nuclear units have a 125 VDC system, some units employ a different voltage level. We will acknowledge this detail in our revised discussion.

We note that for BWRs, the more significant DC bus loading in terms of impact on the battery is that of the DC MOVs used in the design.

Your Comment No. 6 is is closely tied to comments numbers 9 and 14. Accordingly, our responses to these refer to the above response.

Page 7-6 – Table 7-1, Item 1 and Its Associated Note 1

This item evaluates 4kv motor and control switchgear buses and breakers from a loading duty cycle perspective, but that is not the limiting case for double sequencing. An evaluation should be performed of the circuit breaker (CB) anti-pump logic and load sequencing logic for the double sequencing scenario. Actuation of CB anti-pump logic due to double sequencing can result in a trip and lockout of CBs feeding safety equipment. CB anti-pump logic designs that re-charge CB closing springs following a trip of the CB are especially vulnerable, but all CB anti-pump designs are vulnerable to some degree. Such vulnerability was identified at Indian Point 3 in April 5, 1994, letter to the NRC. NUREG/CR-6538 provides additional background on CB anti-pump logic vulnerabilities during double sequencing.

Load sequencing logic that is not specifically designed for double sequencing can result in overloading emergency diesel generators (EDGs) due to failure to load shed previously sequenced loads during double sequencing, paralleling the EDG out-of-phase with motor residual voltages, and/or it can simply result in lockup of the sequencer. Additional information on these load sequencing vulnerabilities can be found in NRC Information Notice 92-53, "Potential Failure of Emergency Diesel Generators Due to Excessive Rate of Loading," and NUREG/CR-6538.

Response:

We concur with the breaker anti-pumping comment and will revise the document to ensure that the user is aware of the need to complete a unit-specific review of that circuit's design and ability to function properly during a double sequencing evolution.

Regarding the load sequencing logic comment, a properly designed load sequencer must have the ability to function correctly in the long-term post-LOCA during which period a LOOP has always been deemed credible. A design that allows an emergency diesel generator (EDG) to become overloaded and/or damage itself and/or its loads due to an out-of-synchronization breaker closure is inappropriate and requires correction. A sequencer design that works properly in the long-term post-LOCA should work equally properly in the near-term post-LOCA. None-the-less, our revisions will include references to NUREG-6538 and the related NRC Issue 171 since these can be helpful to users of the double sequencing documents.

Page 7-6 – Table 7-1, Item 2 and Its Associated Note 2

This item evaluates 4kV protective relaying. It only evaluates electro-mechanical induction disk time-overcurrent relaying. IEEE Standard 741-1997 identifies solid state overload (SSO) relays with thermal memory capability that have been used on the motors of motor-operated valves (MOVs). If these relays are also used on 4 kV motors, it provides a greater potential that the relay will trip during double sequencing because the relay is not completely reset back to zero following the first start of the motor. This is the case for any motor-current overload protective device that utilizes a thermal memory capability, e.g., thermal overload (TOL) protective devices in motor starters.

Response:

We concur that our Note 2 explanation using induction disk type time-overcurrent relays as the example too narrowly focuses on one relay type and does so without consideration for load inertia. The document will be revised accordingly, likely recommending that licensees review limiting cases. Motor overload protection is intended to mimic as closely as reasonably practical, the motor being protected and to do so with a degree of non-conservative motor protective margin (i.e., the motor needs to be in a sustained overloaded or locked rotor condition to cause the protection to operate). Thus, both load inertia and the thermal overload protection memory feature require consideration. We note that overload protective device thermal memory is one element involved in more closely mimicking motor performance in that a motor is similarly unable to immediately cool down following its deenergization.

Also related to the above as well as your comments 18 and 20, and a topic that we need to address in a future document revision, is the manner in which short duty cycle rated motors like those used to power ac-powered MOVs are protected. The thermal overload selection process for these results in the specification of a device that can not support continuous operation of the short duty cycle rated motors, since the motors would not be protected against too long a run if that were not the case. Thus, a motor requiring 10 amperes of running current might have a thermal overload device rated at 7 amperes. Note that the ampere values used represent a roughly estimated example case presented only to make our point here.

Page 7-6 – Table 7-1, Item 3 and Its Associated Note 3

This item evaluates 4kV 125Vdc control power. Note 3 concludes that control power for the metal-clad 4kV switchgear at most, if not all units, is supplied by a 125Vdc battery system and is therefore not subject to the effects of double sequencing. Comments 6 and 7 above apply.

Response:

Our responses to Comments 6 and 7 above relative to the 125 Vdc systems also apply to this comment.

Page 7-6 – Table 7-1, Item 4 and Its Associated Note 4

a. *This item evaluates 4kV pump induction motors, however, Note 4 states that the discussion is also applicable to motors of other sizes and voltage rating since the 4kV large motor case is bounding and thus applicable to Items 5, 11, 12 and 16 in the listing of evaluated components. The 4kV pump induction motor case does not necessarily bound Items 5, 12, and 16; this is actually implied in Table 7-1 itself. The table lists the "Level of Impact" for Item 4 (the 4kV pump motor case) as "None," whereas Items 5, 12, and 16 are listed as "Negligible." The reason for the difference in Items 5 and 12 is likely due to the fact they are fan motors, rather than a pump motor like Item 4. Fans have a much higher moment of inertia than the typical pump; and, as a result, they take much longer to come up to full speed.This means there is more motor heat-up during the start and potentially less margin between motor torque capability and the fan load torque requirement.*

This concept is described in the Note 4 discussion of PWR reactor coolant pump high inertia flywheel loads that are not subject to double sequencing, but is not discussed for the high inertia safety-related fan motors that are subject to double sequencing. Neither Tables 7-3 nor 7-4 under Note 4 provide any data on fan motors. This information should be provided as well as an evaluation of the effects of double sequencing on the fan motors. It is noted that Recommendation 1 in Chapters 9 and Key Recommendation 2 in Chapter 1 both recommend that fans be more thoroughly reviewed by plant engineering motor specialists. Fans and their motors, however, should be specifically evaluated in this EPRI report, rather than leaving it to the individual plants, since they may be the most limiting electrical motors under double sequencing conditions.

Response:

Regarding motor/load inertia and the impact of double starts on motor integrity, we concur that our document needs to evaluate a few fan-loaded motors at a minimum. Our recommendation that users evaluate bounding fan load cases will likely remain, however, as it may not be possible for the BWROG to identify a bounding typical case. It is appropriate to provide a sampling of results, however, and we will strive to obtain the necessary detailed information from the owners of the pilot units studied or from a BWR plant if a more limiting case is identified there.

b. *Note 4 discusses Section MG1-20.43 of NEMA MG1 Standard, entitled "Number of Starts." It states that properly specified and designed motors for nuclear power plants satisfy the specified conditions for applied voltage. What the Note misses and does not discus is the good likelihood that the double sequencing of the motors will be due to actuation of the degraded voltage relays due to inadequate switchyard voltages as a result of the loss of the plant's generator MVAR support to the grid. Under these conditions, the applied voltage is not adequate. The first start of the motors will be a prolonged start under degraded voltage conditions with substantial preheating of the motor during the start. The second start of the motors on the EDGs could also be considered somewhat of a degraded start under the NRC Regulatory Guide (RG) 1.9, "Selection, Design, Qualification, and Testing of Emergency Diesel Generator Units Used as Class 1E Onsite Electric Power Systems at Nuclear Power Plants," specified minimum voltage of 75 percent and frequency of 95 percent. Section MG1-20.45 of the NEMA MG1 standard specifies an applied voltage of plus or minus 10 percent of rated voltage, with rated frequency. Under the degraded voltage condition discussed, the applied voltage will not meet the minimum specified voltage in MG1-20.45; and as a result will not meet the requirements in MG1-20.43 for two starts in succession. This should be discussed in Note 4. It is noted that in Section 2.3, page 2-3 of the report, there appears to be no acknowledgement that switchyard voltage could drop immediately following the trip of the plant's generator due to the loss of the generator's MVAR support to the grid. This should be addressed in Section 2.3.*

Response:

Regarding the potential that the first start of critical motors will be attempted with a degraded voltage (less than 90% of motor rating) applied, we will add discussion advising users to evaluate a bounding case using the minimum voltage which could persist for the duration of their second level undervoltage relay time delay. We note that safety related motors for the pilot units were specified for purchase with an ability to start loads with a minimum of 80% (and in some cases, 70%) of rated voltage applied. Our document revisions will provide advice to licensees to consider any better than standards-specified capability that they may have built into the nuclear units.

Judgment will need to be exercised in this area, realizing that hypothetically, a worst case could be defined as one having the lowest level of voltage without protection (the first level undervoltage relay setting) for the maximum time duration (the time delay setting for the second level undervoltage relay).

From a probabilistic standpoint, however, it is highly unlikely that this will be the case. With the very small degraded voltage-to-operating voltage margins that exist at most nuclear units, the most likely degraded voltage scenario is one wherein voltage falls only marginally below the second level undervoltage relay setpoint. Just as likely, following large motor starts, bus voltage might return to a level above the setpoint but not sufficiently above that level to reset the dropped out voltage detection device(s). When small margins are involved, such issues as relay drop-out-to-pickup ratios become an issue. Your comment reveals the need for more discussion in our document in this area. Our revisions will seek to provide guidance as to a means for calculating a degree of voltage degradation that is both conservative and reasonable.

We do not agree that emergency diesel generator (EDG) starts of motors should be viewed as degraded, even though allowed momentary voltage and frequency swings are significantly outside of NEMA MG 1 limits. Experience shows EDGs to be excellent suppliers of stand-alone power for the starting of motors. This is due to the use of automatic voltage regulators and dynamic governors that serve to rapidly restore voltage and frequency to the set targets. For that reason, unless we identify evidence to the contrary, we will continue to consider the second start of equipment to be under normal power supply conditions.

Regarding the lack of mention in Section 2.3 "that switchyard voltage could drop immediately following the trip of the plant's generator due to the loss of the generator's MVAR support to the grid", we note that an immediate drop, while likely, would not represent a worst case since the second level undervoltage relay timers would likely start immediately as opposed to being delayed in their start, a condition which we believe does represent the worst case. We do agree that a worst case for one condition (an untimely interruption in coolant injection flow) may not be a worst case for another condition (like the first start of motors occurring with a degraded voltage). The vast number of combinations and permutations for event development makes the use of judgment in some areas unavoidable. We will include some discussion on this subject in both Section 2.3 and when specifically addressing motor starts.

c. On page 7-9 of the report, Note 4 states that motors are nominally designed for a life of from 20 to 40 years and, in many applications have, with reasonable preventive maintenance, lasted significantly longer than the design life. Note 4 should acknowledge that the majority of plants will be operating for 60 years under license renewal and address the consequences of this on motor design life.

Response:

We concur with your comment and note that individual nuclear unit owners will always have the responsibility for evaluating the impact of life extension initiatives on their equipment using available guidance such as this double sequencing document. We will revise the report to acknowledge the likelihood of most plants operating for 60 years and provide some of the generic reasons why motors may be acceptable for life extension given their relatively mild service environment, low number of starts, routine preventive maintenance etc.

d. *On page 7-11, Note 4 references Table 7-3 data from Millstone and states that sizeable safety margins are evident between the inertia the motors could accelerate to rated speed and the inertia of the actual plant loads. Are the actual plant load inertias provided in Table 7-3, the inertia with the pump discharge valves initially in the closed or open position? During double sequencing, the first pump start will typically be with the pump discharge valves in the closed position resulting in low load inertia; but during the second pump start the valves will likely be in the fully open position resulting in high load inertia. This issue was identified during an Advisory Committee on Reactor Safeguards (ACRS) hearing on delayed LOOP, and the ACRS indicated that the design of the pumps generally only provide for starting of the pump against a closed discharge valve.*

Response:

You are correct in alluding to the fact that the motor's output capacity (torque) will, in part, be consumed by accelerating and moving the pumped (or compressed) media if a valve (or damper) is open, and flow allowed. Regarding safety margins between load and motor torque requirements and capability, respectively and the issue of pump starts with discharge valves in the wrong position, we note that a properly designed pump motor start control circuit includes interlocks to preclude starts under incorrect discharge valve lineups when valve position is important.

A Service Water Pump (SWP) at one of the pilot units is a good example for discussion and will be considered for inclusion in the report. In this case, SWP motor starts are supervised by valve position; i.e., the start circuit is not satisfied without the valves first returning to their required position. A shutdown of the motor whether manually or by way of a LOOP-induced trip, is followed by automatic valve repositioning prior to its restart permissive being satisfied.

Finally, while we agree that load inertia is a factor that affects acceleration time, it is the BWROG's position that "built-in" inertia (like that presented by the mass and diameter of a large fan blade set) represents the greatest opposition to acceleration during the lowest motor torque capability rotational speed region. We note that the load, air in this example case, presents a resistance to acceleration (inertia) that is not in any respect directly proportional to fan speed, but rather, is considerably less than directly proportional. In fact, as the motor and fan approach operational (rated) speed, the induction motor finds itself with its greatest operational torque capability since it is in the "pull-in" torque region of the associated torque versus rpm curve. While we believe that this consideration markedly reduces any concern related to "load" induced inertia, we will none-the-less speak to this point in our revisions to the document(s).

Page 7-6 – Table 1, Item 5 and Its Associated Note 4

This item evaluates 4kV fan motors. Comment 10a above applies.

Response:

Our response to Comment 10a applies to this comment as well.

Page 7-6 – Table 7-1, Item 8 and Its Associated Note 7

This item evaluates 480V load center switchgear and breakers. Comment 7 above applies to 480V breakers that are load sequenced.

Response:

Our response to Comment 7 applies to the comment as well.

Page 7-6 –Table 7-2, Item 10 and Its Associated Note 9

This item evaluates 480V load control center switchgear and breakers. Comment 7 above applies to 480V breakers that are load sequenced.

Response:

Our response to Comment 7 applies to this comment as well.

Page 7-6 – Table 7-2, Item 10 and Its Associated Note 9

This item evaluates 125Vdc control power for 480V load control centers. Comment 6 above applies.

Response:

Our response to Comment 6 applies to this comment as well.

Page 7-6 – Table 7-1, Item 11 and Its Associated Note

This item evaluates 480V load center powered pump motors. The number of the note associated with it appears to be in error. The staff believes Note 4 was intended. Comments 10a, b, c, and d above apply.

Response:

Your comment has caused us to realize that the equipment numbers in the Table are not appropriately indexed to the notes. In addition to correcting this overall condition, we will also correct the note numbering error that you have identified when we revise the document. Our responses to Comments 10a, b and c apply to this comment as well.

Page 7-7 – Table 7-1, Item 12 and Its Associated Note 4

This item evaluates 480V load center powered fan motors. Comment 10a above applies.

Response:

Our response to Comment 10a applies to this comment.

Page 7-7 – Table 7-1, Item 13

This item evaluates 480V motor control centers molded case circuit breakers. No note is associated with this item, but it appears Note 10 was intended to apply.

Response:

We will correct this omission.

Page 7-7 – Table 7-1, Item 14 and Its Associated Notes 10 and 11

This item evaluates 480V motor control center protective relaying. It appears that only Note 11 applies to this item and Note 10 was intended to apply to Item 13. Note 11 states that double sequencing will not cause improper operation of thermal overload protectors if these relays are set in accordance with standard industry practice. The staff does not believe this is necessarily true, particularly if the double sequencing is due to degraded voltage. Comment 10b above discusses the degraded voltage scenario. The double sequencing, in combination with the prolonged inrush current during the first degraded voltage start, could cause actuation of thermal overload protectors due to the excessive pre-heating of the thermal element during the first start. Comment 8 above also applies.

Response:

We will correct the notation error. The document will be expanded to cover this issue and the potential need for unit-specific sensitivity checks of bounding motor/load thermal overload combinations. Our response to Comment 8 is closely related to this comment.

Page 7-7 – Table 7-1, Item 17 and Its Associated Note 13

This item evaluates 480V MOV reversing and non-reversing contactors. The associated Note 13 addresses the high continuous inrush current that can flow to the coils of motor starters during a sustained degraded voltage condition. It describes fuse blowing experiment results at Millstone that found properly sized fuses remained intact with inrush current flowing from 40 to 60 seconds. Degraded voltage relay time delays have typically been chosen to be short enough to preclude the fuses from blowing, but did not consider the second additional short re-energization and inrush that would occur during double sequencing initiated by a degraded voltage condition. Degraded voltage relays, particularly those with longer time delays, should be evaluated to ensure the second re-energization will not blow the fuse.

Response:

We concur with your observation that most second level undervoltage time delays have been selected to be sufficiently short to avoid the potential for blowing control circuit fuses due to the sustained inrush current demand of a starter contactor that has insufficient voltage to pick up. However, lacking assurance that this is the case across the industry, we will add a reminder that fuse sizing criteria and second level undervoltage time delay need to be evaluated on a unit-specific bounding case basis.

We do not, in general, agree that the second contactor pickup demand has the potential to blow the fuse even if only minor fuse opening margin remains after the first attempt. This is due to the fact that a contactor, when energized with acceptable voltage (which it will have on the second position change demand) changes state in a matter of a few electrical cycles, at most. A second pickup demand occurring simultaneous to a voltage dip caused by a large motor start would, at most, expose the contactor and fuse to a few second period of inrush current. We will discuss the need to consider this potential in our revisions to the document.

Page 7-7 – Table 7-1, Item 18 and Its Associated Note 14

This item evaluates short duty cycle (15 minute) motors. The associated Note 14 states that even in the most severe applications, several strokes from one position to the other can be completed without violating the 15-minute criteria. The Note does not address double sequencing that is initiated by a degraded voltage. In this scenario, the MOV motor inrush and operating cycle during the first degraded voltage start can be excessively long since the motor torque is a direct function of the applied V^2*. During the second sequence, if the MOV has not fully cycled, there will be a second motor inrush. This could potentially trip the motor overload protection and should be evaluated. Comment 18 above also applies.*

Response:

This comment and comments 12d and 18 relate to the type of motors used to power Motor Operated Valves (MOVs). We agree with your observation relative to prolonged starts and the potential to trip the thermal overload. Our report will be modified to note that for nuclear units wherein the thermal overloads are not bypassed either full time or upon occurrence of an accident event per NRC guidance, a review of a bounding case will be necessary to determine if the thermal overload is appropriately sized.

Page 9-2 – Recommendation 5

This recommendation provides guidance on how probabilistic risk assessment organizations can use the EPRI report and any input from their safety analysis personnel to determine if there is a need to update probabilistic safety analysis models to include double sequencing. It indicates that increasing the failure probability of the diesel generators and the grid-related LOOP initiating frequency are two approaches to modeling the risk impact of double sequencing in plant-specific probabilistic risk assessment (PRA) models, and those can easily be implemented in the nuclear plant equipment out-of-service computer program. The staff does not agree with this view and would reject an analysis that used only these approaches.

NUREG/CR-6538, "Evaluation of LOCA with Delayed LOOP and LOOP With Delayed LOCA Accident Scenarios," found that in 1997 nuclear plant individual plant evaluations (IPEs) do not model nor do they discuss LOCA with consequential or delayed LOOP. Increasing grid-related LOOP initiating event frequencies in plant-specific PRAs or EOOS programs would therefore provide no insight into the risk impact of double sequencing scenarios, but would only indicate the risk impact of station blackout scenarios which are typically the events LOOP frequencies are used for. In fact, LOOP initiating event frequency is not the parameter of interest in double sequencing scenarios (see Comment 2, above). Conditional probability of LOOP given a LOCA, or consequential LOOP for short, is the parameter of interest. This is supported by the discussion in Section 1.1 of the EPRI report under the topic of "Probability of Double Sequencing at Domestic Nuclear Power Plants." A comprehensive discussion of consequential LOOP can also be found in Appendix G of a July 31, 2002, NRC Office of Research memorandum located in the NRC Agencywide Documents Access and Management System (ADAMS) at Accession No. ML022120661.

Increasingly the failure probability of the diesel generators, which is the second proposed approach, is only a portion of the vulnerability of double sequencing scenarios. A PRA should consider the other equipment vulnerabilities addressed in the EPRI report as amended by the totality of these NRC comments. If the vulnerabilities do not make the particular safety equipment unavailable altogether, the analysis should consider how the equipment failure rates would increase under the double sequencing scenario conditions and stresses.

Response:

There are many points for discussion relative to this comment. Regarding the approaches to PRA adjustment that we suggested, we concur that, if it cannot be shown that double sequencing will not increase the likelihood of failure of accident mitigation equipment, these approaches are not the right ones. Our view of this matter is that minor additional degradation related to equipment exposure to infrequent and perhaps, one-time conditions cannot be quantified and might very well be undetectable as to its impact on equipment reliability. We believe that the revisions to this document occurring as a result of your comments have the potential to change the NRC's outlook as to the acceptability of the proposed PRA approach. It is also possible that our work involved in revising the document as a result of your comments will result in a change to our proposed approach.

It is key, however, that licensees be able to confidently establish that a double sequencing event will not invalidate compliance with the single failure criterion for a common mode condition; i.e., double sequencing. In most cases, redundant and independent equipment divisions are identically designed and constructed. As an example, if a double sequencing event causes a properly sized and in proper condition fuse to blow in the MCC control circuit of a Train A critical MOV control circuit due to the inability of its starter contactor to pickup, then it is logical that it will blow the fuse in the Train B MOV circuit as well. Your reviewers say it well in the last paragraph of this comment wherein they state that "If the vulnerabilities do not make the particular safety equipment **unavailable altogether** [emphasis added], the analysis should consider how the equipment failure rates would increase under the double sequencing scenario conditions and stresses." Redundant divisions' being "unavailable altogether" is a condition that would be unacceptable and is the key consideration for evaluation when addressing the double sequencing issue. Minor accelerated aging type of degradation to properly maintained equipment for a potential one-time event is not the substantive double sequencing issue.

Regarding the issue of "conditional probability" and as noted earlier in our responses, we will refrain from using that terminology since a double sequencing event can only occur if there is a safeguards actuation and otherwise has no meaning.

EPRI Technical Report 1007966

General

The comments provided for EPRI Report 1009110, Revision 1, "The Probability and Consequences of Double Sequencing Nuclear Power Plant Safety Loads," apply equally to this report and boiling water reactors (BWRs) in general, since the electrical equipment in BWRs is not substantially different from pressurized water reactor designs.

Response:

We agree that, with minor exception, the NRC's comments on the more comprehensive *1009110, Revision 1* report are equally applicable to BWRs. An example of one exception is the discussion of the 30-second time delayed trip of the main generator in PWR plants included in your Comment 4.

We note that, while much of the basic equipment is similar if not identical, and has no way of knowing if it is installed in a PWR or a BWR, the BWR design inherently requires a much smaller subset of equipment to operate to migigate the consequences of the entire range of design basis accidents.

Page 7-3 – Discussion in Section 7.4

In this discussion it is indicated that BWR/6 designs have additional margin and are less affected by double sequencing because they have a dedicated diesel generator for the HPCS system. It is not clear if these conclusions recognize that the HPCS is normally powered from offsite power and is powered from its diesel only when offsite power is lost. It is therefore subject to energization and reenergization similar to double sequencing. There is also at least one BWR/6 plant that has a short sequence of an HPCS pump and a cooling water pump on the HPCS diesel generator, which would make it even a bit more like the double sequencing designs.

Response:

We will research this comment and revise the document as appropriate.

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