September 28, 2004

Mr. Kenneth Putnam, Chairman
BWR Owners Group
Nuclear Management Company
Duane Arnold Energy Center
3277 DAEC Rd.
Palo, IA 52324

SUBJECT: 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 OFFSITE POWER FROM LARGE BREAK LOCA" (TAC NO. MC3042)

Dear Mr. Putnam:

By letter dated April 6, 2004, the BWROG submitted for NRC staff review LTR NEDO-33148, "Separation of Loss of Offsite Power from Large Break LOCA." By letter dated July 20, 2004, the staff accepted your submittal for review. Prior to this acceptance, the staff held a telephone conference with Mr. Tony Browning of your staff on June 30, 2004, to review the schedule of milestones and estimated review costs. During this conference call, both parties also agreed that, as part of the staff's review of LTR NEDO 33148, the following references would also be reviewed for comments:

- EPRI Report 1009110, Revision 1, "The Probability and Consequences of Double Sequencing Nuclear Power Plant Safety Loads," dated October 2003.

- EPRI Report 1007966, "Double Sequencing Analysis for BWRs: the Probability and Consequences of Double Sequencing Nuclear Power Plant Safety Loads, Considerations Specific to Boiling Water Plants," dated October 2003.

The NRC staff has performed a review of the electrical aspects of double sequencing, as addressed in these EPRI reports. Enclosed are the staff's comments. As discussed during our June 30, 2004, conference call, it is requested that these comments are forwarded to EPRI for resolution.

In addition, non-electrical issues that are addressed in the reports (e.g., water-hammer, delay times on fuel clad temperatures, and potential impact on core damage frequency) will be reviewed and addressed in separate correspondence. Please contact me at (301) 415-8450 if you have any questions.

Sincerely,

/RA/

Bo Pham, Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 691

Enclosures: 1. NRC Comments on EPRI Report 1009110
2. NRC Comments on EPRI Report 1007966

cc w/encls: See next page

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COMMENTS REGARDING ELECTRICAL ASPECTS

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ELECTRIC POWER RESEARCH INSTITUTE REPORT 1009110, REVISION 1

"THE PROBABILITY AND CONSEQUENCES OF

DOUBLE SEQUENCING NUCLEAR POWER PLANT SAFETY LOADS" REVISION 1

The NRC staff has performed a review of the electrical aspects of double sequencing, as addressed in the Electric Power Research Institute (EPRI) Report 1009110, Revision 1, "The Probability and Consequences of Double Sequencing Nuclear Power Plant Safety Loads," dated October 2003.

1. 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.

2. 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.

3. 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.

4. 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).

5. 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.

6. 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).

7. 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 a vulnerability was identified at Indian Point 3 in an 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.

8. Page7-6 – 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.

9. 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.

10. Page7-6 – 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 ratings 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 or 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 Chapter 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.

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 discuss 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 acknowledgment 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.

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.

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.

11. <u>Page 7-6 – Table 7-1, Item 5 and its associated Note 4</u>

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

12. <u>Page 7-6 – Table 7-1, Item 8 and its associated Note 7</u>

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

13. <u>Page 7-6 – Table 7-1, Item 9 and its associated Note 8</u>

This item evaluates 480V load control center protective relaying. Comment 8 above applies to the time-overcurrent protective relaying associated with the 480V motors powered from the load centers.

14. <u>Page 7-6 – Table 7-1, Item 10 and its associated Note 9</u>

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

15. Page 7-6 – Table 7-1, Item 11 and its associated Note

This item evaluates 480V load control 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.

16. Page 7-7 – Table 7-1, Item 12 and its associated Note 4

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

17. 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.

18. Page 7-7 – Table 7-1, Item 14 and its associated Notes 10 & 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.

19. 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 reenergization 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 reenergization will not blow the fuse.

20. 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.

21. 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 event 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 "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.

Increasing 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.

COMMENTS REGARDING ELECTRICAL ASPECTS

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ELECTRIC POWER RESEARCH INSTITUTE REPORT 1007966

"DOUBLE SEQUENCING ANALYSIS FOR BWRs: THE PROBABILITY AND

CONSEQUENCES OF DOUBLE SEQUENCING NUCLEAR POWER

PLANT SAFETY LOADS, CONSIDERATIONS SPECIFIC TO BOILING WATER PLANTS"

The NRC staff has performed a review of the electrical aspects of double sequencing, as addressed in Electric Power Research Institute (EPRI) Report 1007966, "Double Sequencing Analysis for BWRs: The Probability and Consequences of Double Sequencing Nuclear Power Plant Safety Loads, Considerations Specific to Boiling Water Plants," dated October 2003.

1. 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.

2. Page 7-3 – Discussion in Section 7.4 on BWR/6 diesel generator driven high pressure core spray (HPCS)

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.