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NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
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NRC REGULATORY ISSUE SUMMARY 2011-12
ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES

ADDRESSEES

All holders of, or applicants for, a power reactor operating license or construction permit under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

All holders of, and applicants for design centers and combined operating licenses under 10 CFR Part 52, "Licenses, Certificate and Approvals for Nuclear Power Plants."

INTENT

The U.S. Nuclear Regulatory Commission (NRC) is issuing this Regulatory Issue Summary (RIS) to clarify the NRC staff's technical position on existing regulatory requirements. Specifically, this RIS clarifies voltage studies necessary for Degraded Voltage Relay (second level undervoltage protection) setting bases and Transmission Network/Offsite/Station electric power system design bases for meeting the regulatory requirements specified in General Design Criteria (GDC) 17 to 10 CFR Part 50, Appendix A. For nuclear power plants that were licensed before GDC 17 applied, the updated final safety analysis report provides the applicable design criteria. This RIS does not transmit any new requirements or staff positions. No specific action or written response is required.

BACKGROUND

The events at Millstone and Arkansas Nuclear One (ANO) that led to the NRC staff's position regarding degraded voltage protection for nuclear power plant Class 1E electrical safety buses for sustained degraded transmission network (grid) voltage conditions, and expectations for voltage calculations for the plant offsite/station electric power system design respectively, are discussed below as a reminder of past operating experience.

Millstone Unit 2

Electrical grid events at the Millstone Station, in July of 1976 demonstrated that when the Class 1E buses are supplied by the offsite power system, sustained degraded voltage conditions on the grid can cause adverse effects on the operation of Class 1E loads. These degraded voltage conditions will not be detected by the Loss-of-Voltage Relays (LVRs) which are designed to detect loss of power to the bus from the offsite circuit(s). The LVR's low voltage dropout setting is generally in the range of 0.7 per unit voltage or less, with a time delay of less than 2 seconds.

As a result of further evaluation of the Millstone events, it was determined that improper voltage protection logic can also cause adverse effects on the Class 1E systems and equipment, such as spurious load shedding of Class 1E loads from the standby diesel generators and spurious separation of Class 1E systems from offsite power due to normal motor starting transients. For more information regarding this event, see Agencywide Documents Access and Management System (ADAMS) Accession No. ML093521388.

As a result of these Millstone events, the NRC requested that all licensees implement degraded voltage protection as described in a 1977 Generic Action (Multi-plant Action B-23) to ensure automatic protection of safety buses and loads. Multi-plant Action B-23 provides guidance which applies to all operating reactors at that time and plants licensed since, on how to comply with the requirements in 10 CFR Part 50, Appendix A, GDC 17. Since degradation of the offsite power system can lead to or cause the failure of redundant Class 1E safety-related electrical equipment, the NRC requested that licensees install degraded voltage protection schemes (second level of voltage protection (Degraded Voltage Relays (DVRs)) for the station electric power system) as described in NRC letters dated June 2 & 3, 1977 (Multi-plant Action B-23), "Statement of Staff Positions Relative to Emergency Power Systems for Operating Reactors," which were sent to all operating nuclear power plant licensees. As an example, see the NRC letter dated June 2, 1977, ADAMS Accession No. ML100610489, sent to the licensee for Peach Bottom Atomic Power Station. In this letter, the NRC requested that these DVR circuits satisfy the following criteria:

a) The selection of voltage and time delay setpoints shall be determined from an analysis of the voltage requirements of the safety-related loads at all station electric power system distribution levels;

   Note: Voltage requirements of all safety-related loads should be determined based on manufacturers design and operating requirements. For example, safety injection motors have starting and running voltage requirements. Motor operated valves have minimum operating voltage requirements. Motor Control Center contactors have minimum pickup and operating voltages. All voltage requirements for all safety-related loads need to be preserved by the DVR circuit(s) during all operating and accident conditions.

b) The voltage protection shall include coincidence logic to preclude spurious trips of the offsite power source;

c) The time delay selected shall be based on the following conditions:

   (1) The allowable time delay, including margin, shall not exceed the maximum time delay that is assumed in the final safety analysis report (FSAR) accident analyses;

      Note: Time delay condition (1) indicates that the DVR circuits should be designed assuming coincident sustained degraded grid voltage and accident events. Upon the onset of the coincident accident and degraded grid event, the time delay for the DVR circuit should allow for separation of the 1E buses from the offsite circuit(s) and

connection to the 1E onsite supplies in time to support safety system functions to mitigate the accident in accordance with the FSAR accident analyses.

(2) The time delay shall override the effect of expected short duration grid disturbances, preserving availability of the offsite power source(s); and

(3) The allowable time duration of a degraded voltage condition at all distribution system levels shall not result in failure of safety-related systems or components;

d) The voltage monitors (or DVRs as defined above) shall automatically initiate the disconnection of offsite power source(s) whenever the voltage and time delay limits have been exceeded; and

e) The voltage monitors (DVRs) shall be designed to satisfy the requirements of IEEE Standard 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations"; and

f) The Technical Specifications shall include limiting conditions for operation, surveillance requirements, trip setpoints with minimum and maximum limits, and allowable values for second-level voltage protection DVRs.

The NRC incorporated the staff positions to meet GDC-17 requirements in Multi-plant Action B-23 into Branch Technical Position (BTP) of the Standard Review Plan (SRP/NUREG-0800), PSB-1, Revision 0, "Adequacy of Station Electric Distribution System Voltages," dated July 1981 (ADAMS Accession No. ML052350520), which was updated later becoming BTP 8-6 of the SRP, Revision 3, "Adequacy of Station Electric Distribution System Voltages," dated March 2007 (ADAMS Accession No. ML070710478). In addition, the SRP provides a design approach, consistent with the original Multi-plant Action B-23, with respect to the selection of the time delay for the DVR circuit.

Arkansas Nuclear One

Another degraded voltage event, in September of 1978, at ANO station demonstrated that degraded voltage conditions could exist on the Class 1E buses even with normal transmission network (grid) voltages, due to deficiencies in equipment between the grid and the Class 1E buses (Offsite/Station electric power system design) or by the starting transients experienced during certain accident events not originally considered in the sizing (design) of these circuits. Information Notice No. 79-04, "Degradation of Engineered Safety Features," (ADAMS Accession No. ML031180118) provides additional information regarding this event.

The NRC staff issued Generic Letter 79-36, August 8, 1979, "Adequacy of Station Electric Distribution Systems voltages" (ADAMS Legacy No. 7908230155), expanding its generic review of the adequacy of electric power systems for operating nuclear power plants. Specifically, the NRC requested that all licensees review the electric power systems at each of their nuclear power plants to determine analytically if, assuming all onsite sources of AC power are not available, the offsite power system and the station electric power system is of sufficient capacity and capability to automatically start as well as run all required safety-related loads.

Recent Inspection Findings

Despite lessons learned from past events, and the generic communications on degraded voltage protection and adequate station voltages, NRC inspectors have identified incorrect implementation of degraded voltage protection schemes by the licensees at various plants during inspections. Specifically, the existing degraded voltage setpoints at some plants were not adequate to protect the safety-related components during degraded voltage conditions for accident and non-accident conditions. In some cases, the voltage conditions were too low to power the safety-related equipment but high enough to prevent transferring of safety loads to the standby power source. In addition, the time delays provided for the degraded voltage protection relays were not consistent with the accident analysis assumptions for those plants. Although the licensees analyses were site-specific, the NRC staff is concerned that other licensees might not have adequately implemented the staff positions and guidance issued previously to address the adequacy of station electrical distribution system voltages. Examples of inspection findings recently identified by the inspectors include the following:

DC Cook Units 1 and 2

During the safety system design and performance capability biennial baseline inspection (NRC Inspection Report No. 50-315/03-07(DRS); 50-316/03-07(DRS)) (ADAMS Accession No. ML032260201) at the DC Cook Nuclear Power Plant, in July of 2003, NRC inspectors identified that the degraded voltage protection scheme was bypassed whenever the 4160V buses were not being supplied through the reserve auxiliary transformers. This resulted in a lack of automatic degraded voltage protection during normal operation and for the first 30 seconds of an accident when engineered safety feature loads were being sequenced onto the safety buses. This condition did not meet the staff position described in BTP PSB-1 and the electrical scheme is contrary to the design criteria for degraded voltage protection stated in an NRC letter to the licensee (a version of a letter sent to all licensees) dated June 3, 1977. This issue was reviewed by the NRR technical staff under Task Interface Agreement (TIA) 2004-02, and the staff concluded that the degraded voltage protection design at DC Cook was inadequate and as such should be modified to include degraded voltage protection during normal operation as well (ADAMS Accession No. ML043480350). Because the NRC staff had approved DC Cook's degraded voltage protection design in 1980, the staff's 2005 determination that the design was inadequate constituted a change in position and was subject to a backfit analysis. By letter dated November 9, 2005 (ADAMS Accession No. ML050680057), the NRC imposed a facility-specific compliance backfit on DC Cook Nuclear Plant, Units 1 and 2 to bring the facility into compliance with its license, the rules and orders of the Commission, and the licensee's written commitments. The licensee implemented a plant modification to the degraded voltage relaying circuit to make it functional during normal operation (see ADAMS Accession No. ML060530405) addressing the backfit issue.

Fermi Unit 2

In May of 2008, NRC inspectors determined that the time delay settings of the degraded voltage relays for both divisions I and II of the Class 1E electrical distribution system were inadequate. The time delays could impact the emergency core cooling system (ECCS) injection timing requirements of the licensee's 10 CFR 50.46 loss-of-coolant accident (LOCA) analysis during a degraded voltage condition. The licensee's degraded voltage protection scheme could result in the voltage being too low to adequately power the ECCS equipment but high enough to prevent the emergency diesel generators from connecting to the safety-related buses in a timely manner. This issue was reviewed by the NRR technical staff under TIA 2007-03 (ADAMS Accession No. ML080420435). The staff determined that the current degraded voltage protection scheme was inadequate as the time delay relay settings for the degraded voltage relays for both divisions could impact the emergency core cooling system injection timing requirements. Additionally, for a short period of time under degraded voltage conditions, voltage could be too low for the proper operation of safety-related motors but high enough to prevent emergency diesel generator start. Because the NRC staff had approved Fermi's degraded voltage protection design in 1981, the staff's 2008 determination that the design was inadequate constituted a change in position and was subject to a backfit analysis. The staff determined that the provisions of 10 CFR 50.109 (a) (4) were applicable, and that a modification was necessary to bring the facility into compliance with the rules and orders of the Commission. See NRC Inspection Report 05000341/2008008 (ADAMS Accession No. ML081720585) for additional details. The NRC approved the plant modification in License Amendment No.183 (ADAMS Accession No. ML102770382).

Peach Bottom Atomic Power Station Units 2 and 3

Exelon did not use the safety-related degraded grid relay trip setpoint specified in the Technical Specifications (TS) as a design input in calculations to ensure adequate voltage was available to all safety-related components required to respond to a design basis LOCA. Instead, Exelon used the results from a Voltage Regulation Study to establish the voltage level for system operability. The study credited the use of non-safety-related equipment (load tap changers) to raise the voltage level. This allowed higher voltages to be used in the design calculations for components than would be allowed by the TS setpoint. The NRR technical staff reviewed the issue in TIA 2009-07 (ADAMS Accession No. ML102710178). The staff concluded that the licensee must demonstrate that the existing degraded voltage trip setpoints, including allowable values and time delays shown in the licensees TS Table 3.3.8.1, are adequate to protect and provide the required minimum voltage to all safety-related equipment. Since the load tap changers are not safety-related and are subject to operational limitations and credible failures, they cannot be relied on to establish degraded voltage relay setpoints and time delay input for design basis calculations. For additional details, see NRC Inspection Report 05000277/2010004 and 05000278/2010004 (ADAMS Accession No. ML103140643). The licensee subsequently issued Licensee Event Report 2-10-04 (ADAMS Accession No. ML103280505) based on the determination that certain plant equipment could be degraded as a result of lower voltages that could exist during a postulated design basis loss-of-coolant event coupled with certain degraded voltage conditions.

Palo Verde Nuclear Generating Station Units 1, 2, and 3

In July of 2009, an NRC inspection team questioned the calculations that demonstrate adequate voltage to safety-related loads during worst case loading conditions and the adequacy of a time delay of 35 seconds for transfer of safety buses to the onsite power supplies should an actual degraded voltage condition occur. The licensee's calculation assumed a voltage above the degraded bus setpoint to demonstrate adequate voltage at the terminals of the safety-related loads rather than the degraded voltage dropout setpoint value. The licensee maintains that a degraded voltage condition concurrent with a design basis accident is not credible. See NRC Inspection Report 05000528; -529; and -530/2009008, ADAMS Accession No. ML093240524 regarding the inspection finding. The NRR technical staff reviewed the issue in TIA 2010-05 (ADAMS Accession No. ML102800340). The staff concluded that the licensee's calculation must demonstrate that the trip setpoint adequately protects the Class 1E equipment powered by the safety-related bus from a potentially damaging degraded voltage condition, and the time delay to transfer from a degraded offsite source to the standby power source to support the emergency core cooling equipment operation must be consistent with accident analysis time assumptions, as recommended by BTP PSB-1 (NUREG 0800).

SUMMARY OF ISSUES

Because the NRC continues to identify inspection findings associated with degraded voltage, the NRC is providing clarifying information on two issues related to the need for two sets of calculations for the design of the electric power systems of a nuclear power plant and its interface with the transmission network as defined in GDC 17. The two issues are (1) Degraded Voltage Relaying Design Calculations, and (2) Offsite/Station Electric Power System Design Calculations.

(1) The Degraded Voltage Relaying Design Calculations establish the necessary settings of the DVRs to ensure that all safety-related components are provided adequate voltage based on the design of the plant power distribution system (and the offsite circuits), including the design of the Class 1E distribution system in the plant and its most limiting operating configuration(s).

(2) The Offsite/Station Electric Power System Design Calculations specify the voltage operating parameters of the plant electrical distribution system based on the transmission network (grid) operating parameters. This interface calculation establishes operating voltage bands for all plant electrical buses, which ensures that all plant safety-related components and systems have proper voltage for starting and running in all operational configurations (expected operational and accident line-ups and conditions). Therefore, based on normal grid operation (including (grid) post-contingency), the degraded voltage relays will not operate, maintaining the offsite power supply to the plant electrical distribution system.

(1) Degraded Voltage Relaying Design Calculations

Proper design of a degraded voltage relaying scheme is needed to ensure that safety-related systems are supplied with adequate voltages. The purpose of the NRC-developed BTP PSB-1 (revised later to become BTP 8-6) is to provide additional guidance to supplement the 1977 Generic Action (Multi-plant Action B-23) and the SRP and to provide some design details of a

DVR circuit that satisfies the regulatory requirements (there may be other designs that satisfy the requirements). The DVR design should protect (ensure voltage requirements are met) Class 1E safety-related buses and components from sustained degraded voltage conditions on the offsite power system coincident with an accident as well as during non-accident conditions. The Class 1E buses should separate from the offsite power system within a few seconds (or immediately if the design philosophy recommended in BTP PSB-1 is followed) if an accident occurs coincident with sustained degraded voltage conditions. During normal plant operation, the Class 1E safety-related buses should automatically separate from the power supply within a short interval if sustained degraded voltage conditions are detected. The time delay chosen should be optimized to ensure that permanently connected Class 1E loads are not damaged under sustained degraded voltage conditions (such as a sustained degraded voltage below the DVR voltage setting(s) for the duration of the time delay setting).

DVR Setting Design Calculations

Licensee voltage calculations should provide the basis for their DVR settings, ensuring safety-related equipment is supplied with adequate voltage (dependent on equipment manufacturers design requirements), based on bounding conditions for the most limiting safety-related load (in terms of voltage) in the plant.

> Note**:** All voltage requirements for the safety-related equipment must be preserved by the DVR circuit(s). For example, safety injection motors have starting and running voltage requirements. Motor operated valves have minimum operating voltage requirements. Motor Control Center contactors have minimum pickup and operating voltages. All voltage requirements for all safety-related loads need to be preserved during all operating and accident conditions.

These voltage calculations should model offsite circuits and the plant electrical distribution system, including the plant safety-related electrical distribution system, such that the limiting voltage at the bus monitored by the DVR can be calculated in terms of the voltage at the terminals of the most limiting safety-related component in the plant in all required operating conditions (such as starting and running). These models should include all plant equipment (including non-safety-related) that can affect voltage supplied to the safety-related equipment. As a minimum, the model should utilize loads on the plant distribution system consistent with the specific transient or accident being analyzed. These models would allow calculation of voltages at terminals of all safety-related equipment with the voltage at the DVR monitored bus at the DVR dropout setting, providing the necessary design basis for the DVR voltage settings. In this manner, the DVR circuit ensures adequate voltage (starting and running) to all safety-related equipment. Voltage-time settings for DVRs should be selected so as to avoid inadvertent separation of safety buses from the offsite power system during unit startup, normal operation (including motor starting), and shutdown.

These DVRs should disconnect the Class 1E buses from any power source other than the emergency diesel generators (onsite sources) if the degraded voltage condition exists for a time interval that could prevent the Class 1E safety-related loads from achieving their safety function.

Note: Upon the onset of the coincident accident and degraded grid event, the time delay for the DVR circuit must allow for separation of the 1E buses from the offsite circuit(s) and connection to the 1E onsite supplies in time to support safety system functions to mitigate the accident in accordance with the FSAR accident analyses.

The DVRs should also prevent prolonged operation of Class 1E safety-related loads at degraded voltage, which could result in equipment damage.

The operation of voltage correcting equipment, external to the 1E distribution system, should not be assumed for DVR setpoint analyses.

(2) Offsite/Station Electric Power System Design Calculations

The offsite power source is the preferred source of power to safely shut down the plant during design basis accidents, abnormal operational occurrence, and reactor trips. The licensee's voltage calculations should provide the basis for proper operation of the plant safety-related electrical distribution system, when supplied from the offsite circuit(s) (from the transmission network). These calculations should demonstrate that the voltage requirements (both starting and running voltages) of all plant safety-related systems and components are satisfied based on operation of the transmission system (including the bounding transmission system single contingency in terms of voltage drop) and the plant onsite electric power system during all operating configurations of transmission network and plant systems. In addition, during accident conditions, the nuclear unit generator trip (transmission system single contingency) and associated transmission system voltage drop should be factored into the accident case voltage calculations since unit trip occurs as a result of the accident. In this way, all safety-related systems and components will function as designed with proper starting and running voltages during all plant conditions and the DVRs will not actuate (separating the transmission network supply). The following are guidelines for voltage drop calculations derived from Generic Letter 79-36, which have been supplemented to add clarifying information. They do not represent new NRC staff positions.

Guidelines for voltage drop calculations

a) The plant voltage analysis, while supplied from the transmission network, should be based on the operating voltage range of the transmission network connection. This transmission owner/operator supplied voltage range should address all transmission network and plant system operating configurations and should also include voltage drop due to the bounding worst case transmission system contingency (transmission system contingencies include trip of the nuclear power plant). The unit trip grid contingency voltage drop value should be used in the accident cases in accordance with the plant accident analyses since a unit trip occurs with an accident.

b) Separate analyses should be performed assuming the power source to the safety buses is (1) the unit auxiliary transformer; (2) the startup transformer; and (3) other available connections (e.g., from all available connections) to the offsite network one by one assuming the need for electric power is initiated by (1) an anticipated transient such as a unit trip (e.g., anticipated operational occurrence), or (2) an accident, whichever presents the bounding load demand on the power source.

c) For multi-unit stations, a separate analysis should be performed for each unit assuming (1) an accident in the unit being analyzed and simultaneous shutdown and cooldown of all other units at the station in accordance with the plant's licensing basis; or (2) an anticipated transient (anticipated operational occurrence/GDC 17) in the unit being analyzed (e.g., unit trip) and simultaneous shutdown and cooldown of all other units at that station, whichever presents the largest load situation.

d) All actions that the electric power system is designed to automatically initiate or control should be assumed to occur as designed (e.g., automatic bulk or sequential loading or automatic transfers of bulk loads from one transformer to another, automatic starts of components, operation of automatic voltage controlling equipment such as capacitor bank switching or load tap changers). All non-safety-related plant auxiliary loads should be included, as applicable, in the plant loading studies since their operation can affect voltage to safety-related equipment.

e) Manual load shedding should not be assumed.

f) For each event analyzed, the maximum load necessitated by the event and the mode of operation of the unit at the time of the event should be assumed in addition to all loads caused by expected automatic actions and manual actions permitted by administrative procedures.

g) The voltage analysis should include documentation for each condition analyzed, of the voltage at the input and output of each transformer and at each intermediate bus between the connection of the offsite circuit(s) and the terminals of each safety-related load.

h) The calculated voltages at the terminals of each safety-related load should be compared with the required voltage range for normal operation and starting of that load calculated in Item a) above. Any identified inadequacies of calculated voltage should require immediate remedial action.

i) For each case evaluated, the calculated voltages on each safety bus should demonstrate adequate voltage at the safety bus and down to the component level.

j) To provide assurance that actions taken to assure adequate voltage levels for safety-related loads do not result in excessive voltages, assuming the maximum expected value of voltage at the connection to the offsite circuit(s), a determination should be made of the maximum voltage expected at the terminals of all safety-related equipment and their starting circuits (if applicable). If this voltage exceeds the maximum voltage rating of any safety-related equipment, immediate remedial action should be taken.

k) Analysis documentation should include a statement of the assumptions for each case analyzed.

BACKFIT DISCUSSION

The NRC has evaluated this RIS against the criteria of 10 CFR Section 50.109, 10 CFR Part 50, Appendix A, GDC 17, NRC Letter dated June 2, 1977 "Statement of Staff Positions Relative to Emergency Power Systems for Operating Reactors," BTP-1 and later BTP 8-6 (both of NUREG 0800) and Generic Letter 79-36, and has determined that it does not represent a backfit. Specifically, NRC Staff technical positions outlined in this RIS are consistent with the aforementioned regulations and generic communications, while providing more detailed discussion concerning the necessary voltage calculations supporting DVR settings based only on voltage requirements of Class 1E components and the Class 1E distribution system design. Under section 50.109, a backfit can be defined as a proposed action that is a modification of the procedures required to operate a facility and may result from the imposition of a regulatory staff position that is either new or different from a previously applicable staff position.

FEDERAL REGISTER NOTIFICATION

Although this RIS is informational and does not represent a departure from the current regulatory requirements, a notice of opportunity for public comment on this RIS was published in the Federal Register (76 FR 2924) on January 18, 2011, for 30 days. On February 23, 2011, a Notice was published in the Federal Register extending the comment period for additional 30 days to March 19, 2011, based on the request from Nuclear Energy Institute (ADAMS Accession No. ML110330025). There were fourteen organizations/individuals provided comments, which were considered before issuance of this RIS. Each of the comments were documented and responded to by NRC staff and are available in ADAMS at Accession No. ML112371830. This response supersedes the information provided earlier in ADAMS at Accession No. ML1116006590.

This RIS does not represent a departure from current regulatory requirements.

CONGRESSIONAL REVIEW ACT

This RIS is not a rule as designated by the Congressional Review Act (5 U.S.C. §§ 801-886) and, therefore, is not subject to the Act.

PAPERWORK REDUCTION ACT STATEMENT

This RIS does not contain any information collections and, therefore, is not subject to the requirements of the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.).

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This RIS requires no specific action or written response. If you have any questions, please contact the technical contact listed below or the appropriate regional office.

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