Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

CNL-18-077

June 18, 2018

10 CFR 50.90

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Browns Ferry Nuclear Plant, Units 1, 2, and 3
Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68
NRC Docket Nos. 50-259, 50-260, and 50-296

Sequoyah Nuclear Plant, Units 1 and 2
Renewed Facility Operating License Nos. DPR-77 and DPR-79
NRC Docket Nos. 50-327 and 50-328

Watts Bar Nuclear Plant, Units 1 and 2
Facility Operating License Nos. NPF-90 and NPF-96
NRC Docket Nos. 50-390 and 50-391

Subject: **Response to Browns Ferry Nuclear Plant, Units 1, 2, and 3 (TS-512); Sequoyah Nuclear Plant, Units 1 and 2 (TS-17-03); and Watts Bar Nuclear Plant, Units 1 and 2 (TS-17-20) - Request for Additional Information Related to License Amendment Request to Incorporate New Technical Specification for Unbalanced Voltage Relays**

References:

1. TVA Letter to NRC, CNL-17-034, "Application to Modify the Technical Specifications for the Browns Ferry Nuclear Plant (TS-512), Sequoyah Nuclear Plant (TS-17-03) and Watts Bar Nuclear Plant (TS-17-20) to Resolve the Open Phase Issue Identified in NRC Bulletin 2012-01, 'Design Vulnerability in Electrical Power System,' " dated November 17, 2017 (ML17324A349)

2. NRC Letter to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3; Sequoyah Nuclear Plant, Units 1 and 2; and Watts Bar Nuclear Plant, Units 1 and 2 - Request for Additional Information Related to License Amendment Request to Incorporate New Technical Specification for Unbalanced Voltage Relays (EPID L-2017-LLA-0030)," dated May 21, 2018 (ML18115A379)

In Reference 1, Tennessee Valley Authority (TVA) submitted a License Amendment Request (LAR) to the Nuclear Regulatory Commission (NRC) to propose adding a new level of protection, "Unbalanced Voltage" to the Technical Specifications (TS) for the loss of power (LOP) instrumentation.

In Reference 2, the NRC transmitted a request for additional information (RAI) and requested that TVA respond by June 18, 2018. Enclosure 1 to this letter contains the TVA response to the NRC Instrumentation and Control Branch (EICB) RAI. Enclosure 2 to this letter contains the TVA response to the NRC Electrical Engineering Operating Reactor Branch (EEOB) RAI. Enclosure 3 contains an example of the level of detail of the anticipated UFSAR mark-ups for information only in response to EEOB-RAI-8 (Enclosure 2).

Consistent with the standards set forth in 10 CFR 50.92(c), TVA has determined that the additional information, as provided in this letter, does not affect the no significant hazards determination associated with the request provided in Reference 1.

There are no new regulatory commitments associated with this submittal. Please address any questions regarding this request to Edward Schrull at (423) 751-3850.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 18th day of June 2018.

Respectfully,

E. K. Henderson
Director, Nuclear Regulatory Affairs

Enclosures:
1. TVA Response to EICB Branch NRC RAI
2. TVA Response to EEOB Branch NRC RAI
3. Proposed Level of Detail for UFSAR Markups (for information only)

cc (Enclosures):

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant
NRC Senior Resident Inspector - Sequoyah Nuclear Plant
NRC Senior Resident Inspector - Watts Bar Nuclear Plant
NRC Project Manager – Browns Ferry Nuclear Plant
NRC Project Manager – Sequoyah Nuclear Plant
NRC Project Manager – Watts Bar Nuclear Plant
State Health Officer, Alabama Department of Public Health
Director, Division of Radiological Health - Tennessee State Department of Environment and Conservation

Enclosure 1
TVA Response to EICB Branch RAI

<u>NRC BACKGROUND</u>

By application dated November 17, 2017 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17324A349), Tennessee Valley Authority (TVA, the licensee) submitted a request for an amendment to Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68 for the Browns Ferry Nuclear Plant, Units 1, 2, and 3; Renewed Facility Operating License Nos. DPR-77 and DPR-79 for the Sequoyah Nuclear Plant, Units 1 and 2; and Facility Operating License Nos. NPF-90 and NPF-96 for the Watts Bar Nuclear Plant, Units 1 and 2. This license amendment request (LAR) proposed addition of a new level of protection, "Unbalanced Voltage" to the Technical Specifications (TSs) for the loss of power instrumentation. TVA stated that the proposed change provides protection against potentially adverse unbalanced voltage conditions in offsite power sources. In addition, this LAR addresses potential concerns with open phase conditions in U.S. Nuclear Regulatory Commission (NRC) Bulletin 2012-01, "Design Vulnerability in Electric Power System," dated July 27, 2012 (ADAMS Accession No. ML12074A115).

The NRC staff from the Office of Nuclear Reactor Regulation, Division of Engineering, Instrumentation and Controls Branch (EICB) reviewed the information provided by TVA and determined that additional information as discussed below is needed to complete its review.

<u>EICB RAI-1</u>

In the LAR, the licensee proposed to add Function 3, "4.16kV Shutdown Board Undervoltage (Unbalance Voltage Relay)," into Browns Ferry TS Table 3.3.8.1-1, "Loss of Power Instrumentation." Provide the Nominal Trip Setpoints (Permissive Alarm, Low, and High Unbalanced Voltage Relay) for the Function 3. The NRC staff needs this information to verify that the requirements of Section 50.36(c)(2) of Title 10 of Code of Federal Regulations are being met regarding the selection of the setpoints and allowable values for "Unbalanced Voltage."

<u>TVA Response to EICB-RAI-1</u>

The Browns Ferry Nuclear Plant (BFN) Unbalanced Voltage Relay (UVR) setpoints and accuracy were determined in a calculation that utilized TVA's setpoint and scaling procedure NPG-SPP-06.7, Revision 3, "Instrument Setpoint, Scaling and Calibration Program" and Branch Technical Instruction BTI-EEB-TI-28, R009, "Setpoint Calculations." The following table contains the BFN nominal setpoints for the UVR relays.

BFN UVR	Voltage Setpoint	Time Delay Setpoint
Permissive Alarm	1.34 volts (V)	2.60 seconds
Low	3.23 V	7.86 seconds
High	19.50 V	3.18 seconds

The BFN nominal setpoints for the UVR relays ensure that the requirements of 10 CFR 50.36(c)(2) are met.

Enclosure 2
TVA Response to EEOB Branch RAI

NRC BACKGROUND

By application dated November 17, 2017 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17324A349), Tennessee Valley Authority (TVA, the licensee) submitted a request for an amendment to Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68 for the Browns Ferry Nuclear Plant (BFN) Units 1, 2, and 3; Renewed Facility Operating License Nos. DPR-77 and DPR-79 for the Sequoyah Nuclear Plant (SQN), Units 1 and 2; and Facility Operating License Nos. NPF-90 and NPF-96 for the Watts Bar Nuclear Plant (WBN), Units 1 and 2. This license amendment request (LAR) proposed addition of a new level of protection, "Unbalanced Voltage" to the Technical Specifications (TSs) for the loss of power instrumentation. TVA stated that the proposed change provides protection against potentially adverse unbalanced voltage conditions in offsite power sources. In addition, this LAR addresses potential concerns with open phase conditions (OPCs) in U.S. Nuclear Regulatory Commission (NRC) Bulletin 2012-01, "Design Vulnerability in Electric Power System," dated July 27, 2012 (ADAMS Accession No. ML12074A115).

The NRC staff from the Office of Nuclear Reactor Regulation, Division of Engineering, Electrical Engineering Operating Reactor Branch (EEOB) reviewed the information provided by TVA and determined that additional information, as discussed below, is needed to complete its review.

Applicable Regulatory Requirements

NRC Information Notice 2012-03, "Design Vulnerability in Electric Power System," and NRC Bulletin 2012-01, "Design Vulnerability in Electric Power System," described industry operating experience that identified a vulnerability related to General Design Criterion (GDC) 17, "Electric power systems," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the Code of Federal Regulations (10 CFR) Part 50. The identified vulnerability concerned open phase conditions (OPCs) in offsite power sources. GDC 17 states, in part:

> *An onsite electric power system and an offsite electric power system shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for each system (assuming the other system is not functioning) shall be to provide sufficient capacity and capability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents.*

The BFN Units 1, 2, and 3 were not licensed to the 10 CFR Part 50, Appendix A, GDC. The Updated Final Safety Analysis Report (UFSAR), Appendix A, "Conformance to AEC [Atomic Energy Commission] Proposed General Design Criteria," provides an assessment against the draft GDC published in November 1965 (Units 1 and 2) and July 1967 (Unit 3). For BFN, the licensee performed a review of plant-specific requirements and concluded that AEC criterion is sufficiently similar to the Appendix A, GDC 17. UFSAR Section 8.4.6 - "Safety Evaluation" discusses conformance to 10 CFR Part 50, Appendix A, GDC 17, and concludes that the BFN units are in conformance with the requirements of GDC 17.

For the BFN units, AEC Criterion 39, "Emergency Power for Engineered Safety Features," states "Alternate power systems shall be provided and designed with adequate independency, redundancy, capacity, and testability to permit the functioning required of the engineered safety *features. As a minimum, the onsite power system and the offsite power system shall each, independently, provide this capacity assuming a failure of a single active component in each power system." In view of the similarity between AEC Criterion 39 and BFN conformance to GDC 17, the discussion below references GDC 17 only for TVA plants in general.*

Section 50.36 of 10 CFR, "Technical specifications," provides requirements for proposed technical specifications to be included in license applications.

Section 50.36(c)(1)(ii)(A) of 10 CFR states, in part:

> *Limiting safety system settings for nuclear reactors are settings for automatic protective devices related to those variables having significant safety functions. Where a limiting safety system setting is specified for a variable on which a safety limit has been placed, the setting must be so chosen that automatic protective action will correct the abnormal situation before a safety limit is exceeded. If, during operation, it is determined that the automatic safety system does not function as required, the licensee shall take appropriate action, which may include shutting down the reactor.*

10 CFR 50.36(c)(2)(ii) states, in part:

> *A technical specification limiting condition for operation of a nuclear reactor must be established for each item meeting one or more of the following criteria:*
>
> *(C) Criterion 3. A structure, system, or component that is part of the primary success path and which functions or actuates to mitigate a design basis accident or transient that either assumes the failure of or presents a challenge to the integrity of a fission product barrier.*

Section 50.36(c)(3), "Surveillance requirements," of 10 CFR states:

> *Surveillance requirements are requirements relating to test, calibration, or inspection to assure that the necessary quality of systems and components is maintained, that facility operation will be within safety limits, and that the limiting conditions for operation will be met.*

The regulation at 10 CFR 50.55a(h), "Protection and safety systems" requires all portions of the protection and safety systems to be designed in accordance with the Institute of Electrical and Electronic Engineers (IEEE) Standard 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations," or IEEE Standard 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations."

<u>EEOB-Request for Additional Information (RAI)-1</u>

The LAR states, "The main issue with an open phase event degrading an offsite power circuit is that loss of a phase can cause a voltage unbalance in the connected distribution system." For the TVA plants, the licensee has installed Unbalanced Voltage Relays (UVRs) to detect and protect against consequential unbalanced voltages, including those caused by an OPC in the offsite power sources and offsite power circuit. In order for staff to understand the limits at which the UVRs will perform their automatic protective action and how these limits were *developed to correct an abnormal situation, the staff is requesting the following additional information:*

a) A discussion that summarizes the magnitude of the unbalance voltage considered on the associated bus for each UVR setpoint.

b) A discussion of how percentage voltage unbalance is calculated based on negative sequence voltage and whether other sequence components such as zero and positive sequence components were considered in determining the power system unbalance.

c) A discussion explaining the setpoints for the UVR alarm and operator actions taken in accordance with plant procedures.

<u>TVA Response to EEOB-RAI-1</u>

a) The magnitude of unbalanced voltage considered on each bus was from zero to 100 percent (%). Section 3.4 of the LAR contains further information for the analytical limits and UVR nominal setpoints. UVR Setpoints were determined to protect against the loss of safety function for the connected Class 1E loads during a voltage unbalance as discussed below.

- The alarm relay setpoint alerts the main control room (MCR) operators of an abnormal voltage unbalance and can be used to protect against unacceptable loss of life or long-term motor degradation for the connected Class 1E loads. A maximum voltage unbalance of 2.3% was used to prevent an unacceptable reduction of service life from the additional heating caused by the voltage unbalance. This setpoint was determined by ensuring the additional heating does not outpace that accounted for in traditional overload protection settings, which only consider balanced conditions. [see the EEOB-RAI-1 b) response for the calculational basis of this value]
- The low trip relay setpoint protects the point at which the required safety loads must perform their safety function during a voltage unbalance for all anticipated transients, operational occurrences, and design basis events. The industry standard, National Electrical Manufacturers Association (NEMA) MG-1, “Motors and Generators,” recommends not exceeding 5% voltage unbalance for motor operation. Therefore, a maximum voltage unbalance of 5% was used to determine the time delay that is no greater than the safety analysis time allowed for the emergency diesel generators (EDGs) to come up to rated speed and voltage and be ready to accept load.
- The high trip relay setpoint provides faster tripping time for high-level voltage unbalances, where catastrophic load failure may occur within a few seconds. Using a bounding analytical method, a maximum voltage unbalance of 100% was used to determine the time delay prior to catastrophic failure.

b) Voltage unbalance is regarded as any difference in the three phase voltage magnitudes and/or shift in the phase separation of the phases from 120 degrees. Voltage unbalance is expressed as the negative phase sequence divided by the positive phase sequence, as a percentage, measured using line to line voltages. The following is an example of how percent voltage unbalance and negative and positive sequence voltages are utilized for analytical limit determination of the alarm relay. Zero sequence is not required in this analysis and was not used.

The equation for calculating an equivalent current for an unbalanced system is:

$$I_{eq} = \sqrt{I_1^2 + 175\left(\frac{I_2}{LR}\right)^2}$$

Where: I_{eq} = Equivalent Current; I_1 = Positive Sequence Current; I_2 = Negative Sequence Current; LR = Per Unit Locked Rotor Current

The worst case phase current (i.e., the hardest to detect with phase overcurrent relays) occurs when the positive sequence and negative sequence values are 60 degrees out of phase. The equation for worst case phase current I_{wc} is:

$$I_{WC} = |I_1 + I_2\angle 60°|$$

The boundary where the heating from I_{eq} increases past the current measurable by phase overcurrent relays I_{wc}, is the condition of interest for alarming.

Setting the I_{eq} and I_{wc} equations equal to each other, and substituting voltage for current where:

$$I_1 = \frac{1}{V_1} = 1$$

$$I_2 = V_2 * LR$$

Yields:

$$V_2 = \frac{LR}{175 - LR^2}$$

Note: In unbalanced voltage conditions, the positive sequence voltage V_1 decreases proportionally to the unbalance. In the application of finding a V_2 limit where $I_{wc} \geq I_{eq}$, lowering V_1 produces a less conservative limit. Therefore, maintaining V_1 equal to one per unit is conservative.

From TVA Design Guide DG-E2.4.6 “Equipment Typical Data,” motors have a locked rotor current that typically ranges from five to seven times full load current. TVA conservatively chose a motor with locked rotor current equal to 3.75 times the nominal full load current that provides margin from the equipment typical data. From the above equation, a maximum V_2 of 2.3% for the alarm setpoint was calculated. Multiplying this percentage by the nominal bus voltage, reflecting it across the potential transformers, and converting the line to neutral values gives the upper voltage analytical limit of the alarm relay.

c) The discussion explaining the basis for and calculation of UVR alarm setpoints is included in the above EEOB-RAI-1 a) and b) responses.

The operator actions that will be taken in response to a UVR alarm will be included in plant procedures after the NRC approval of the LAR and the relays become active.

Based on similar operator actions contained in site procedures for grid and plant issues, when the UVR alarm relay actuates with no emergency bus transfer, the anticipated station specific operator actions will include:

BFN

1. Check to determine if the alarm is valid at the associated shutdown board
2. If alarm is found to be valid:
    a. Contact duty engineer for support
    b. Contact transmission operations to determine system abnormalities
    c. Monitor temperatures for equipment powered from associated shutdown board.
3. If offsite power is lost, enter 0-AOI-57-1A, “Loss of Offsite Power (161 and 500 KV)/Station Blackout”
4. Check grid frequency or voltage, if abnormal enter 0-AOI-57-1E, “Grid Instability”

SQN

1. Check to determine if the alarm is valid at the associated shutdown board
2. If the alarm is valid, then enter AOP-P.07, “Degraded Grid or Abnormal Voltage Conditions”
3. Monitor to determine whether shutdown boards should be placed on diesel generators
4. Monitor for inoperable offsite power source(s)
5. Monitor for reactor coolant pump (RCP) trip and reactor trip criteria
6. Attempt to restore voltage or enter AOP-P.01, “Loss of Offsite Power”

WBN

1. Check to determine if the alarm is valid at the associated shutdown board
2. If alarm is valid, then enter 0-PI-OPS-1-500KV, “Main Control Room Voltage Monitoring”
3. Monitor to determine whether shutdown boards should be placed on diesel generators
4. Monitor for inoperable offsite power source(s)
5. Monitor for RCP trip and reactor trip criteria
6. Attempt to restore voltage or enter 0-AOI-35, “Loss of Offsite Power”

<u>*EEOB-RAI-2*</u>

The NRC staff notes the discussion in the LAR related to offsite power operability as determined by several factors including but not limited to: breaker alignment, communication from transmission system operator, voltage indications in the nuclear power station, voltage correcting device availability/operation, and transformer cooling fans operational. The LAR further states that "Any additional actions to provide reasonable assurance of offsite power capacity and capability (i.e., operability due to an open phase) will be consistent with existing practices of providing reasonable assurance of offsite power capacity and capability (i.e., operability due to degraded voltage) and are not part of this LAR." The LAR further states "Non-automatic methods of detection are not included in this LAR. The operators' determination of offsite power source operability would satisfy the required non-automatic detection criteria for an open phase on a standby source within a reasonable time as stated in the Voluntary Industry Initiative."

Operating experience discussed in Attachment 1.4 of the LAR Enclosure 1 provides examples of plant events where degraded power sources could not be detected for extended durations and continued to supply plant safety-related loads. In some cases where a single pole of breaker or disconnect switch did not fully close or conductor strands in overhead transmission lines have broken, resulting in a high impedance connection and reducing conductor capacity, the OPC cannot be detected by visual methods.

At the TVA plants, for offsite power sources that are lightly loaded, the magnetization effects in transformer windings may mask an unbalanced voltage caused by an open phase that is not visually observable.

Please provide a discussion of how the UVR relays would detect (and protect safety-related equipment) for this condition. Please include in your discussion how the unbalanced voltage protection circuitry ensures that the offsite power system is capable of performing its design function during any period that this condition is not detected at TVA Plant(s). Additionally, considering the UVR is on the medium voltage shutdown board, include a discussion for light to no-load on the safety bus.

<u>**TVA Response to EEOB-RAI-2**</u>

The following information describes how the UVR relays would detect and protect safety-related equipment for the condition described in the RAI.

As stated in GDC 17, the offsite power system's design function is to provide power to permit functioning of structures, systems, and components important to safety. LAR Section 3.3 states for trip functions, "…analyses confirm the time delays, with and without an accident signal, which would ensure all Class 1E loads required for postulated design basis accidents auto-transfer to the onsite power supply if the UVR-monitored bus experiences unbalanced voltage conditions that affect the function of the connected equipment." The trip setpoints were selected to ensure that if the offsite power system is incapable of performing its design function with respect to unbalanced voltage, the relays actuate to transfer from the offsite power system to the onsite power system.

LAR Section 3.4 defines the alarm setpoint as that which “protects against unacceptable ‘loss of life’ or long-term motor degradation for the connected Class 1E loads.” The UVR alarm relay setpoints do not protect against a loss of safety function (e.g., offsite power system capability) referred to in GDC 17. For steady state conditions, low level unbalanced voltages (i.e., under setpoint voltage/time delay) are natural occurrences that are expected in power systems. Detection of unbalanced voltages by the UVRs is determined by relay setpoints. Any open phase that is not visually observable and does not produce measurable effects that establish the existence of a degraded condition (i.e., relay actuation), by definition of relay setpoint requirements listed in EEOB-RAI-1, is an acceptable configuration that will not adversely affect the function of any of the connected Class 1E equipment. This is true for any loading or configuration for the shutdown board.

In summary, if the unbalanced voltage condition does not reach the trip setpoints, there is no effect on equipment function and no protection is needed.

For changing or transient conditions, refer to the response to EEOB-RAI-3 for the specific sequence of events.

<u>*EEOB-RAI-3*</u>

Section 4.0, "Regulatory Evaluation" in Enclosure 1 of the LAR discusses applicable regulatory requirements/criteria and provides the justification for including UVR setpoints in TS according to 10 CFR 50.36 Criteria. Section 4 states:

> *The need to include the proposed negative sequence voltage protection function operability and surveillance requirements into the BFN, SQN, and WBN TS was evaluated against the 10 CFR 50.36(c) criteria, and it was determined to meet Criterion 3 of 10 CFR 50.36(c)(2)(ii) as discussed below.*
>
> *Criterion 3 states:*
>
> *"A structure, system, or component that is part of the primary success path and which functions or actuates to mitigate a design basis accident or transient that either assumes the failure of or presents a challenge to the integrity of a fission product barrier."*
>
> *The operability of the station electric power sources is part of the primary success path for mitigating an accident assuming a loss of all onsite AC power sources (e.g., loss of all EDGs [Emergency Diesel Generators]). An operable offsite power circuit must be capable of maintaining rated voltage while connected to the Class 1E buses and accepting required loads during an accident. Similar to the loss of voltage and degraded voltage protective circuitry, <u>**the unbalanced voltage protection circuitry is integral to ensuring that the offsite power system is capable of performing its design function**</u> [emphasis added] of powering the medium voltage Class 1E buses. Therefore, the BFN, SQN, and WBN unbalanced voltage scheme satisfies Criterion 3 for inclusion in the TS.*

*The LAR states, "The Class 1 E UVR protection scheme exceeds the requirements of both the VII and BTP 8-9 by including <u>**all events in any location**</u> [emphasis added] outside the Class 1E* *boundary that can negatively affect voltage balance to Class 1E equipment." The LAR also states, "The main issue with an open phase event degrading an offsite power circuit is that loss of a phase can cause a voltage unbalance in the connected distribution system."*

GDC 17 states that at least one of the offsite power circuits, with adequate capacity and capability, shall be designed to be available within a few seconds following a loss-of-coolant accident to assure that core cooling, containment integrity, and other vital safety functions are maintained.

Please provide a discussion of the sequence of events for BFN, SQN, and WBN, including associated equipment response times when emergency loads need to start (e.g., postulated accident conditions, anticipated operational occurrences, etc.) during the period of operation when an unbalanced voltage may not be detected for an extended duration.

TVA Response to EEOB-RAI-3

The sequence of events for the TVA fleet does not change from current design and licensing basis during the period of operation when an unbalanced voltage is not detected coincident with a subsequent event. Additionally, the response times for emergency loads in both accident and non accident conditions for the GDC 17 offsite power circuit that is designed to be available within a few seconds following a loss-of-coolant accident remains unchanged.

Using loading values from the offsite power calculations for each plant and the delta between the highest and lowest postulated loading, the change in unbalanced voltage as seen at the medium voltage shutdown boards can be calculated. In the cases studied by TVA, which are represented below, where an unbalance exists below the setpoint for the alarm relay, the loading or configuration change does not actuate a trip relay. Therefore, there is no effect of adding the UVRs during the period of operation when an unbalanced voltage may not be detected for an extended duration, because the plants would respond in the same way as they would have before the UVRs were installed.

The below scenarios are presented as follows:

By plant (e.g., BFN, SQN, WBN)

- **By offsite power connection (e.g., Grid through Main Transformers with unit online, Grid through Main Transformers with unit offline, Grid through Common Station Service Transformer (CSST))**
  - *By cause of the unbalance (e.g., Maximum grid unbalance, Open phase)*
    - By anticipated operational occurrence, as applicable [e.g., unit trip, loss of coolant accident (LOCA), or LOCA with subsequent unit trip]

BFN

As shown in the BFN electrical distribution system diagram included in the LAR as Attachment 2.1, BFN Units 1, 2, and 3 are always connected to the one GDC 17 offsite power circuit to assure that core cooling, containment integrity, and other vital safety functions are maintained. The maximum sustained voltage unbalance that could occur without detection is less than 2.3%, which is below the NEMA MG-1 recommendation of 5%.

1. Unit 1, 2, or 3 Connected to Grid through Main Transformers with Unit Online

a. *Maximum grid unbalance that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board under normal operation.*

- A unit trip can result in an automatic unbalanced voltage alarm with no automatic protective action (i.e., shutdown board transfer) required, because the unbalanced voltage level would be below the UVR trip setpoints. Equipment functionality and life expectancy are not challenged. When the automatic alarm setpoint is met, the MCR alarm will occur in approximately three seconds after the unit trip.
- With the initiation of an accident signal, a loading change from "normal" to "design basis accident" loading would result in no automatic alarm or trip associated with the UVRs, because the unbalanced voltage level would be below the UVR trip setpoints. Equipment functionality and life expectancy are not challenged.
- Initiation of an accident signal and a subsequent unit trip can produce an unbalanced voltage alarm, but would not produce automatic protective actions, because the unbalanced voltage level would be below the UVR trip setpoints. Equipment functionality and life expectancy are not challenged. When the automatic alarm setpoint is met, the MCR alarm will occur in approximately three seconds after the unit trip.

b. *Open phase that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board under normal operation.*

- Any open phase that can not be seen by the connected negative sequence relays with the generator running will result in the generator or main transformer protection actuation and therefore cannot remain undetected for an extended duration.

2. Unit 1, 2, or 3 Connected to Grid through Main Transformers with Unit Offline

a. *Maximum grid unbalance that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board with refuel conditions.*

- An accident signal changes the loading from "refuel" to "design basis accident" loading and results in no automatic alarm or trip associated with the UVRs. No detection is required because the unbalanced voltage level is below all setpoints. Equipment functionality and life expectancy are not challenged.

b. *Open phase that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board under refuel conditions.*

- An accident signal changes the loading from "refuel" to "design basis accident" loading and results in no automatic alarm or trip associated with the UVRs. No detection is required because the unbalanced voltage level is below all setpoints. Equipment functionality and life expectancy are not challenged.

3. **Shutdown Boards A & B, C & D, or 3EA & 3EB Connected to Grid through CSST A or Shutdown Boards 3EC & 3ED Connected to Grid through CSST B**
   Note: For the following cases, starting from refuel conditions bounds starting from normal operation.

   a. *Maximum grid unbalance that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board with refuel conditions.*

      - An accident signal changes the loading from “refuel” to “design basis accident” loading and results in no automatic alarm or trip associated with the UVRs. No detection is required because the unbalanced voltage level is below all setpoints. Equipment functionality and life expectancy are not challenged.

   b. *Open phase that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board under refuel conditions.*

      - An accident signal changes the loading from “refuel” to “design basis accident” loading and results in an automatic unbalance voltage alarm with no automatic protective action (i.e., shutdown board transfer) because unbalanced voltage level is below the trip setpoints. Equipment functionality and life expectancy are not challenged. When the automatic alarm setpoint is met, the MCR alarm will occur in approximately three seconds.

In summary, no instance at BFN was identified where an existing unbalanced voltage condition that could not be detected for an extended duration would result in an automatic transfer to the onsite power source for any anticipated operational occurrence.

<u>SQN</u>

As shown in the SQN electrical distribution system diagram included in the LAR as Attachment 3.1, SQN Units 1 and 2 are always connected to the one GDC 17 offsite power circuit to assure that core cooling, containment integrity, and other vital safety functions are maintained. The maximum sustained voltage unbalance that could occur without detection is less than 2.3%, which is below the NEMA MG-1 recommendation of 5%.

1. **Unit 1 or 2 Connected to Grid through Main Transformers with Unit Online**

   a. *Maximum grid unbalance that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board with normal operation.*

      - A unit trip can result in an automatic unbalance voltage alarm with no automatic protective action (i.e., shutdown board transfer) required, because the unbalanced voltage level is below the UVR trip setpoints. Equipment functionality and life expectancy are not challenged. When the automatic alarm setpoint is met, the MCR alarm will occur in approximately three seconds after unit trip.

- With the initiation of an accident signal, a loading change from “normal” to “design basis accident” loading would result in no automatic alarm or trip associated with the UVRs, because the unbalanced voltage level would be below the UVR trip setpoints. Equipment functionality and life expectancy are not challenged.
- Initiation of an accident signal and a subsequent unit trip can produce an unbalanced voltage alarm, but would not produce automatic protective actions, because the unbalanced voltage level would be below the UVR trip setpoints. Equipment functionality and life expectancy are not challenged. When the automatic alarm setpoint is met, the MCR alarm will occur in approximately three seconds after the unit trip.

b. *Open phase that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board under normal operation.*

- Any open phase that can not be seen by the connected negative sequence relays with the generator running will result in the generator or main transformer protection actuation and therefore cannot remain undetected for an extended duration.

2. Unit 1 or 2 Connected to Grid through Main Transformers with Generator Offline

a. *Maximum grid unbalance that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board with refuel conditions.*

- An accident signal changes the loading from “refuel” to “design basis accident” loading and results in no automatic alarm or trip associated with the UVRs. No detection is required, because the unbalanced voltage level is below all setpoints. Equipment functionality and life expectancy are not challenged.

b. *Open phase that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board under refuel conditions.*

- An accident signal changes the loading from “refuel” to “design basis accident” loading and results in no automatic alarm or trip associated with the UVRs. No detection is required, because the unbalanced voltage level is below all setpoints. Equipment functionality and life expectancy are not challenged.

3. Unit 1 or 2 Connected to Grid through CSSTs

Note: For the following cases, starting from refuel conditions bounds starting from normal operation.

a. *Maximum grid unbalance that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board with refuel conditions.*

- An accident signal changes the loading from “refuel” to “design basis accident” loading and results in no automatic alarm or trip associated with the

UVRs. No detection is required, because the unbalanced voltage level is below all setpoints. Equipment functionality and life expectancy are not challenged.

b. *Open phase that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board under refuel conditions.*

- There is no identified loading for open phase events that can not be initially seen by the connected negative sequence alarm relay. Transformers with refuel loading or greater are visible to the UVRs and therefore cannot remain undetected for an extended duration.

In summary, no instance at SQN was identified where an existing unbalanced voltage condition that could not be detected for an extended duration would result in an automatic transfer to the onsite power source for any anticipated operational occurrence.

<u>WBN</u>

As shown in the WBN electrical distribution system diagram included in the LAR as Attachment 4.1, WBN Units 1 and 2 are always connected to the one GDC 17 offsite power circuit to assure that core cooling, containment integrity, and other vital safety functions are maintained. The maximum sustained voltage unbalance that could occur without detection is less than 2.3%, which is below the MG-1 recommendation of 5%.

Unlike BFN and SQN, WBN does not have generator circuit breakers. Per the WBN design and licensing basis, Class 1E loads may not be powered through the Unit Station Service Transformers; therefore, consideration of unit generation is not required. The below WBN scenarios bound actual plant responses by calculating the unbalance by using the lightest loading (refueling) and heaviest loading (accident) for any anticipated operational event.

1. Connected to Grid through CSSTs C/D or CSSTs A/B

Note: For the following cases, starting from refuel conditions bounds starting from normal operation.

a. *Maximum grid unbalance that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board with refuel conditions.*

- An accident signal changes the loading from “refuel” to “design basis accident” loading and results in an automatic unbalance voltage alarm with no automatic protective action (i.e., shutdown board transfer), because the unbalanced voltage level is below the trip setpoints. Equipment functionality and life expectancy are not challenged. When the automatic alarm setpoint is met, the MCR alarm will occur in approximately three seconds.

b. *Open phase that can not be seen by the connected unbalanced alarm relay on the medium voltage shutdown board under refuel conditions.*

- An accident signal changes the loading from “refuel” to “design basis accident” loading and results in an automatic unbalance voltage alarm with no automatic protective action (i.e., shutdown board transfer), because the unbalanced voltage level is below the trip setpoints. Equipment functionality and life expectancy are not challenged. When the automatic alarm setpoint is met, the MCR alarm will occur in approximately three seconds.

In summary, no instance at WBN was identified where an existing unbalanced voltage condition that could not be detected for an extended duration would result in an automatic transfer to the onsite power source for any anticipated operational occurrence.

EEOB-RAI-4

This RAI is related to the highest magnitude of consequential unbalanced voltage conditions resulting from an OPC in the offsite power source.

In Section 3.4 of Enclosure 1, "Analytical Limits and UVR Nominal Setpoints," the LAR states that the analytical limits for the unbalanced voltage relays were established based on a "bottom-up" manner that considers load requirements, and are independent of characteristics of the incoming power source. The NRC staff notes that there is a 3.5-second time delay proposed for high unbalanced voltage conditions. The magnitude of unbalanced voltage conditions experienced at the point of detection will vary according to configuration of electrical systems. In order for staff to understand the basis and adequacy of the proposed UVR setpoints to protect safety-related equipment for postulated events and accidents:

a) *Please provide a summary of the limiting case analyses, key assumptions used, and the results obtained for all the loading conditions and operating configurations including plant trip(s) followed by bus transfers (if required) for the unbalanced voltages considered at the three plants.*

b) *Please include a discussion on the maximum unbalanced voltage condition that can occur at the safety busses in the three plants.*

TVA Response to EEOB-RAI-4

a) For the limiting case analysis, which is the highest magnitude of consequential unbalanced voltage condition, a bounding analysis was performed using the most consequential percent unbalanced voltage that could result in catastrophic load failure (see the response to EEOB-RAI-1 a) high trip relay setpoint). This analytical technique utilizes the assumption of a 100% unbalanced voltage condition, which bounds all resulting unbalanced voltage values that could occur from an OPC in the offsite power source. The results show that for the highest magnitude of consequential unbalanced voltage condition resulting from any event, the shutdown board would be disconnected from offsite power after the high trip relay time delay and subsequently loaded to the EDG. This is consistent for all three sites.

   The high trip setpoint is established to ensure all Class 1E loads required for postulated design basis accidents would successfully auto-transfer to the onsite power supply if the UVR monitored bus experiences high magnitude unbalanced voltage conditions. For the analysis to determine the allowable time to transfer to the EDG without equipment locking out and becoming unavailable, it is not necessary to demonstrate adequate terminal voltage for Class 1E equipment exposed to the highest magnitude consequential unbalanced voltage. Instead, this protective device analysis shows the coordination between the lower unbalanced voltage trip and any protective devices that are capable of preventing transfer to the onsite supply (e.g., overcurrent devices that could trip and require manual reset).

b) As described in Section 3.1 of the LAR, "because it would take an almost unlimited number of simulations to produce accurate results for every eventuality (e.g., various transformer loading, temperature variations, impedance tolerances, grid voltage variation, grid voltage balance), [the vulnerability] study used bounding techniques to account for the competing conservatisms needed to address these variations and tolerances." The highest calculated unbalanced voltages in the vulnerability studies were < 40% for single OPCs and ≤ 95% for double OPCs. A bounding analytical technique was used to establish the analytical limit setpoint. The highest magnitude of unbalanced voltage considered for setpoint determination on each shutdown board was 100% as detailed in the response to EEOB-RAI-4 a) and in EEOB-RAI-1.

EEOB-RAI-5

Section 3.4 of Enclosure 1, "Analytical Limits and UVR Nominal Setpoints," provides an overview of the criteria used for establishing the lower and upper analytical limits related to alarm, low trip and high trip setpoints for the UVRs. The LAR states, "The main issue with an open phase event degrading an offsite power circuit is that loss of a phase can cause a voltage unbalance in the connected distribution system." The LAR does not provide plant-specific parameters that were established to protect safety-related equipment from unbalanced voltage conditions. In order to understand the margin between allowable range(s) of unbalance conditions that can exist and the limiting values established for protection of equipment please provide:

a) A discussion on the magnitude of unbalance observed during the monitoring phase of the unbalanced voltage relays at each of the safety buses for the three plants where the UVR relays are installed.

b) A discussion on the applicable plant-specific industry standards used for establishing these analytical limits.

TVA Response to EEOB-RAI-5

a) Class 1E ABB 60Q relays were installed at each TVA nuclear site on the medium voltage shutdown boards for data acquisition during an established monitoring period. These relays were set to very low levels when compared to final setpoints; the purpose was to capture data associated with normal transient events and voltage unbalances in both the plant and transmission system.

BFN UVR installation began in February 2016 and was completed in March 2018 with installations occurring simultaneously with unit refuel outages. SQN UVR installation began in April 2016 and was completed in June 2016 with installations occurring independent of unit refuel outages. WBN UVR installation began in May 2016 and was completed in March 2018 with installations occurring independent of unit refuel outages.

There have been 176 data points captured as of April 15, 2018, that document transitory and anticipated operational occurrences that produce unbalanced voltages at the Class 1E boundary. Significant margin (typically > 1000%) to the final low and high trip setpoints was experienced for transient events in the fleet during the monitoring phase. Any instance that would have resulted in an alarm in the MCR was documented as an event where there was a loss of voltage on the shutdown board; an MCR alarm is the appropriate response to this event. As documented in the monitoring phase, there have been no instances where the UVR protection scheme would have initiated the transfer of the safety system from offsite power to the onsite EDG.

In addition to the insight provided by data point triggers, the lack of data points for events such as lightning strikes, board transfers, main generator power level changes, outage activities, transfer from 161kV to 500kV switchyards, hot functional testing, loss of phase not directly connected to safety bus, and spurious SI signal, validates that there are no negative unbalanced voltage effects for these types of events.

b) As presented in the response to EEOB-RAI-1, NEMA MG-1 was the industry standard used for establishing the analytical limits. Specifically, NEMA MG-1 was used in calculating the analytical limit for the upper pickup voltage for the low trip relay and the high trip relay for all plants.

TVA invokes the requirements of the NEMA MG-1 standard at TVA's nuclear plants using General Engineering Specification SS E9.2.01, "Alternating-Current Induction Motors (Squirrel-Cage Type)," when purchasing AC induction motors.

EEOB-RAI-6

In Section 3.5 of Enclosure 1, "Failure Modes and Effects Considerations," the LAR states, "If one of the Class 1E PTs [potential transformers] fail, all levels of undervoltage protection would be actuated and begin timing. Due to the longer time delay of the UVR with respect to the Loss of Voltage (LOV) protection scheme, the LOV scheme would actuate the transfer due to the substantially low voltage measurements." This design feature has the potential for a single spurious failure in the sensing element to disable both offsite and onsite power systems if the UVR and LOV outputs are factored in the logic associated with the breakers for onsite power systems.

Section 7 of the UFSAR for WBN discusses instrumentation and controls and states, in part, "The information provided in this chapter emphasizes those instruments and associated equipment which constitute the protection system as defined in IEEE Std. 279-1971 'IEEE Standard: Criteria for Protection Systems for Nuclear Power Generating Stations.'" Similarly, IEEE 279-1971 requirements are stated for conformance in Section 7.1.2.1.2, "Engineered Safety Features Actuation System (ESFAS)." UFSAR Section 7.1.2.1.4 identifies standby power as part of protection systems. UFSAR Section 7.1.2.2.2, "Specific Systems," states that "Channel independence is carried throughout the system, extending from the sensor through to the devices actuating the protective function." The regulation at 10 CFR 50.55a(h), "Protection and Safety Systems," requires that all portions of the protection and safety systems should to designed in accordance with IEEE Standard 279-1971 or IEEE Standard 603-1991.

a) Please provide a discussion on how the UVR design is in conformance with the licensing basis of the TVA plants.

b) The LAR states that the UVR logic scheme is set up in a permissive 1-out-of-2 logic to ensure reliability and security. Please provide a discussion on how the 1-out-of-2 logic is satisfied if there is a common sensing point for multiple channels.

<u>TVA Response to EEOB-RAI-6</u>

The RAI states that "this design feature has the potential for a single spurious failure in the sensing element to disable both offsite and onsite power systems if the UVR and LOV outputs are factored in the logic associated with the breakers for onsite power systems." The UVR design feature does not have the potential for a single spurious failure in the sensing element to disable both offsite and onsite power systems if the UVR and LOV outputs are factored in the logic associated with the breakers for onsite power systems. The UVR logic initiates a transfer from the offsite power system to the onsite power system and does not provide trip logic when connected to the EDGs.

The response to items a) and b) of the RAI is provided below.

a) TVA's licensing basis for the standby power <u>system</u> at each plant includes:
   - Class 1E diesel generators
   - Medium voltage (6.9kV or 4.16kV) shutdown boards and medium voltage logic panels
   - Medium to low voltage transformers and 480V shutdown boards
   - Motor control centers supplied by shutdown boards

   The standby power system serving each unit is divided into two redundant load groups power trains. SQN, WBN, and BFN Units 1 and 2, include two onsite EDGs per unit; BFN Unit 3 includes four onsite EDGs. The licensing basis for the TVA standby power source (EDG) at each site with respect to voltage protection is as follows.

   - Each EDG is connected to a separate medium voltage shutdown board inside the boundary of the Class 1E system to provide power to the connected loads.
   - Existing undervoltage protection schemes (e.g., loss of voltage and degraded voltage) and logic are part of each station's existing licensing basis.
   - Existing undervoltage protection schemes independently measure from existing sensors to device actuating protective function (e.g., breaker) for each shutdown board/EDG.
   - Separation and independence for each standby power source and associated undervoltage protection scheme required to remove the inadequate voltage level(s) measured in the offsite power source and transfer to the onsite power source, is in conformance with the licensing basis of each TVA plant.

   Channel independence requirements (i.e., between the two separate onsite power sources) is carried throughout the standby power system in accordance with the TVA licensing basis. Independence and separation, from sensor through the devices actuation the protective function are in conformance with the licensing basis of the TVA plants for the standby power system.

   The UVR design is in conformance with the licensing basis of the TVA plants as follows:

   - A separate UVR protection scheme is installed for each shutdown board/EDG.
   - Each new UVR scheme utilizes the existing sensor as input to the UVRs and the existing logic and actuating device for the action, as the undervoltage protection schemes (e.g., loss of voltage and degraded voltage), without modification.

- There is no connection/communication between separate UVR installations associated with separate shutdown boards, consistent with the existing undervoltage protection schemes.

b) There is no common sensing point for multiple channels for the standby power system as stated in the response to EEOB-RAI-6 a). The permissive 1-out-of-2 logic refers to the protection scheme associated with only one standby power source (i.e., one channel of the standby power system). If there is a failure of a Class 1E potential transformer, the undervoltage protection (e.g., loss of voltage, degraded voltage, and unbalanced voltage) for that board is affected with no effect on the other shutdown boards in the standby power system. Therefore, there is no commonality between the two channels of the standby power system as defined in IEEE Std. 279-1971 and in TVA's design and licensing basis for each of its plants.

EEOB-RAI-7

The LAR states, "The need to include the proposed negative sequence voltage protection function operability and surveillance requirements into the BFN, SQN, and WBN TS was evaluated against the 10 CFR 50.36(c) criteria, and it was determined to meet Criterion 3 of 10 CFR 50.36(c)(2)(ii) as discussed below."

The LAR also states Surveillance of the UVRs is required as defined in 10 CFR 50.36(c)(3) to "assure that the necessary quality of systems and components is maintained, that facility operation will be within safety limits, and that the limiting conditions for operation will be met."

The UVR Setpoints are proposed for inclusion in Section 3.3, "Instrumentation," of the TSs, specifically in the "Loss of Power (LOP) Diesel Generator (DG) Start Instrumentation." The requirements for LOP DG start instrumentation are delineated in 10 CFR 50.36(c)(1)(ii)(A), which states, "Limiting safety system settings for nuclear reactors are settings for automatic protective devices related to those variables having significant safety functions. Where a limiting safety system setting is specified for a variable on which a safety limit has been placed, the setting must be so chosen that automatic protective action will correct the abnormal situation before a safety limit is exceeded." Please provide a detailed discussion on how the proposed TS amendment is in conformance with 10 CFR 50.36(c)(1)(ii)(A).

TVA Response to EEOB-RAI-7

The UVRs protect the specified safety limit in conformance to 10 CFR 50.36(c)(1)(ii)(A) in the same manner as the degraded voltage relays (DVRs). In the case of the UVRs, when the unbalanced voltage condition exceeds both the alarm setpoint and either the low or high unbalanced voltage setpoint, the relays initiate the logic to disconnect the shutdown board from the offsite power source and connect to the onsite power source. The abnormal condition in this case is that the offsite power source is not providing acceptable power from an unbalanced voltage consideration. The UVR settings are chosen such that the abnormal condition is corrected before any safety limit is exceeded by initiating a transfer to the EDG associated with the affected shutdown board and part of the onsite standby power system.

The setpoint methodology employed considers uncertainty allowances and setpoint discrepancies to ensure that the equipment operates to protect the safety function, as discussed in Regulatory Guide 1.105, "Setpoints for Safety-Related Instrumentation." Analytical limits (ALs) were determined for each setpoint at each plant to protect equipment function from an unacceptable unbalanced voltage condition. Suitable margin was then determined to calculate individual allowable values (AVs), which are contained in the TS, to ensure that the health and safety of the public is maintained.

Therefore, the proposed LAR is in conformance with 10 CFR 50.36(c)(1)(ii)(A) for limiting safety system settings.

EEOB-RAI-8

Excerpts from UFSAR sections for BFN, SQN, and WBN pertinent to the electrical system design and operation are provided in Attachments to Enclosure 1 of the LAR. These excerpts include information about current design of offsite power systems and degraded voltage protection that is referenced as part of the unbalanced voltage protection scheme. The staff did not notice any changes to the UFSAR sections with regard to proposed installation of UVRs. In order for NRC staff to develop an understanding of the changes to the UFSAR, please provide a mark-up of the proposed UFSAR section(s).

TVA Response to EEOB-RAI-8

UFSAR change request packages are completed as part of the design modification package process and controlled under NPG-SPP-03.15, “FSAR Management.” Following NRC approval of this LAR, the implementation process will include modifying the UFSAR; this process has not been completed. Enclosure 3 contains an example of the level of detail of the anticipated UFSAR mark-ups for information only.

Enclosure 3
Proposed Level of Detail for UFSAR Markups
(for information only)

System Operation

Each 6.9kV shutdown board can be powered through any one of four shutdown board supply breakers. For normal operation, power is supplied from the common station service transformers C and D through the 6.9kV common switchgear C and D circuits. The normal supply breakers are shown normally closed on Figure 8.1-2a. Shown normally open are the breakers that connect the alternate offsite power circuits to the shutdown boards (via CSSTs C or D), the emergency supply breakers that connect each shutdown board to a separate standby diesel generator, and the maintenance supply breakers that can provide power to the shutdown boards via the unit boards.

loss of voltage, degraded voltage, and unbalanced voltage

Automatic fast-bus transfers from the normal to the alternate source are initiated by CSST protection devices. Return to the normal supply is manual only. Manual transfers are fast transfers completed in approximately six cycles. Manual transfer may be effected between any incoming feeder breakers.

Each 6.9kV shutdown board is equipped with ~~loss-of-voltage and degraded-voltage~~ relaying. When a shutdown board is connected to either its normal or alternate power source, loss-of-voltage ~~or degraded-voltage~~ initiates bus transfers to the standby diesel generator supply.

degraded voltage, or unbalanced voltage

The degraded-voltage relays (27 DAT, DBT, DCT) have a voltage setpoint of 96% of 6.9kV (nominal, decreasing). These relays are arranged in a two-out-of-three coincidence logic (Figure 8.3-5A) to initiate a 10-second (nominal) time delay. If the voltage is still low at the end of 10 seconds, an alarm will be annunciated in the Control Room, a trip of the 6.9kV shutdown-board supply breaker will occur, load shedding from the 6.9kV and 480V shutdown boards and diesel generator start will be initiated, and the 480V shutdown-board current-limiting reactor-bypass breaker will close.

The undervoltage protection consists of three sets of relays. The first set of these relays (27LVA, LVB, LVC) has a voltage setpoint of 87% of 6.9kV (nominal, decreasing). These relays are arranged in a two-out-of-three coincidence logic (Figure 8.3-5A) to initiate a time delay that is set at 0.75 seconds. At the end of this time delay, if the voltage is still low, a trip of the 6.9kV shutdown-board supply breaker will occur. Once the supply breakers have been opened, a second set of induction disk-type undervoltage relays, 27D, which has a voltage setpoint of 70% of 6.9kV (nominal, decreasing) and an internal time delay of 0.5 seconds (nominal) at zero volts, will start the diesel generator. A third set of induction disk-type undervoltage relays, 27S, which has a voltage setpoint of 70% of 6.9kV (nominal, decreasing) and an internal time delay of 3 seconds (nominal) at zero volts, will initiate load shedding of the loads on the 6.9kV shutdown board, selected loads on the 480V shutdown board, and closure of the 480V shutdown-board current-limiting reactor bypass breaker.

There are three unbalanced voltage relays (60Q) for each of the 6.9kV shutdown-boards: 60Q Alarm, 60Q Low, and 60Q High. These relays are arranged in a permissive one-out-of-two logic which annunciates in the main control room. Relays 60Q Alarm, Low, and High operate on an unbalanced voltage detection signal dependent on the length of time the signal is detected. If the one-out-of-two logic is met (Alarm relay permissive and either the High or Low relay), the 6.9kV board will trip.