Exelon Generation.

4300 Winfield Road
Warrenville, IL 60555

www.exeloncorp.com

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April 30, 2015

U. S. Nuclear Regulatory Commission
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Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Supplement and Response to Request for Additional Information Regarding the License Amendment Request to Install New Low Degraded Voltage Relays and Timers on the 4.16 kV Engineered Safety Features (ESF) Buses

References:

(1) Letter from D. M. Gullott (Exelon Generation Company, LLC) to U. S. NRC, "License Amendment Request to Install New Low Degraded Voltage Relays and Timers on the 4.16 kV Engineered Safety Features (ESF) Buses," dated April 24, 2014

(2) Email from J. S. Wiebe (U. S. NRC) to J. A. Bauer (Exelon Generation Company, LLC), "Preliminary Request for Additional Information Regarding Braidwood and Byron New Low Degraded Voltage Relays and Timers (MF4051, MF4052, MF4053, and MF4054)," dated October 23, 2014

(3) Email from J. S. Wiebe (U. S. NRC) to J. A. Bauer (Exelon Generation Company, LLC), "Preliminary Request (2nd Set) for Additional Information Regarding Braidwood and Byron New Low Degraded Voltage Relays and Timers (MF4051, MF4052, MF4053, and MF4054)," dated November 10, 2014

In Reference 1, Exelon Generation Company, LLC, (EGC) requested an amendment to Facility Operating License Nos. NPF-72 and NPF-77 for Braidwood Station, Units 1 and 2, and Facility Operating License Nos. NPF-37 and NPF-66 for Byron Station, Units 1 and 2. This amendment request proposed to revise Technical Specifications (TS) 3.3.5, "Loss of Power (LOP) Diesel Generator (DG) Start Instrumentation." Specifically, LCO 3.3.5 would be revised to add a new "low degraded voltage" Function. In addition, the associated Surveillance Requirement (SR) 3.3.5.2 would be revised to add a CHANNEL CALIBRATION to verify the specified values for the new low degraded voltage Allowable Value and time delay setting.

In References 2 and 3, the NRC requested that EGC provide additional information to support their review of the subject License Amendment Request (i.e., Reference 1). The response to these requests is provided in Attachment 1. It should be noted that while developing the response to the NRC's request for additional information, EGC identified that some electrical parameters and recently added loads were not properly modeled in the calculations supporting the proposed TS changes presented in Reference 1. Braidwood Station Calculation 19-AN-29, Revision 002B, "Second-Level Undervoltage Relay Setpoint," and Byron Station Calculation 19-AN-28, Revision 001B, "Calc. for Second-Level & Third-Level Undervoltage Relays," which were submitted with Reference 1, have been revised. The revised calculations (i.e., 19-AN-29, Revision 002C and 19-AN-28, Revision 001C), are included as Attachments 4 and 5 to this letter.

These new issues have also prompted the need to revise the TS Allowable Values and associated setpoints for the new degraded voltage function. The revised TS pages for Braidwood Station and Byron Station are provided in Attachments 3A and 3B, respectively.

EGC has reviewed the information supporting the No Significant Hazards Consideration and the Environmental Consideration that was previously provided to the NRC in Reference 1. The additional information provided in this submittal does not affect the conclusion that the proposed license amendment does not involve a significant hazards consideration. This additional information also does not affect the conclusion that neither an environmental impact statement nor an environmental assessment need be prepared in support of the proposed amendment.

In accordance with 10 CFR 50.91, "Notice for public comment; State consultation," paragraph (b), EGC is notifying the State of Illinois of this additional information by transmitting a copy of this letter and its attachment to the designated State Official.

Due to the additional work needed to revise the supporting calculations, it was agreed that EGC would provide the requested information to the NRC in April 2015. It is also noted that, in Reference 1, EGC originally requested that the NRC approve the proposed license amendment by April 24, 2015; however, since Byron Station, Unit 1 will be the first of the Braidwood and Byron units to complete the associated modification and implement the proposed amendment during the Fall 2015 refueling outage, NRC approval by September 1, 2015 will meet EGC's needs. EGC appreciates the NRC's flexibility on the License Amendment Request approval schedule.

This letter contains no new regulatory commitments. If you have any questions concerning this letter, please contact Joseph A. Bauer at (630) 657-2804.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 30th day of April 2015.

Respectfully,

David M. Gullott
Manager – Licensing
Exelon Generation Company, LLC

Attachment 1:	Response to Request for Additional Information
Attachment 2:	Response to Request for Additional Information Westinghouse Electric Corporation A200 Series Contactor Data Sheet and Cutler-Hammer (Eaton) A200 Series Contactor Data Sheet
Attachment 3A:	Markup of Technical Specification Page (Revised) – Braidwood Station
Attachment 3B	Markup of Technical Specification Page (Revised) – Byron Station
Attachment 4	Braidwood Station Calculation 19-AN-29, Revision 002C, "Second-Level Undervoltage Relay Setpoint"
Attachment 5	Byron Station Calculation 19-AN-28, Revision 001C, "Calc. for Second-Level & Third-Level Undervoltage Relays"

cc: NRC Regional Administrator, Region III
NRC Senior Resident Inspector, Braidwood Station
NRC Senior Resident Inspector, Byron Station
Illinois Emergency Management Agency – Division of Nuclear Safety

ATTACHMENT 1
Response to Request for Additional Information

In Reference 1, Exelon Generation Company, LLC, (EGC) requested an amendment to Facility Operating License Nos. NPF-72 and NPF-77 for Braidwood Station, Units 1 and 2, and Facility Operating License Nos. NPF-37 and NPF-66 for Byron Station, Units 1 and 2. This amendment request proposed to revise Technical Specifications (TS) 3.3.5, "Loss of Power (LOP) Diesel Generator (DG) Start Instrumentation." Specifically, LCO 3.3.5 would be revised to add a new "low degraded voltage" Function. In addition, the associated Surveillance Requirement (SR) 3.3.5.2 would be revised to add a CHANNEL CALIBRATION to verify the specified values for the new low degraded voltage Allowable Value and time delay setting.

In References 2 and 3, the NRC requested that EGC provide additional information to support their review of the subject License Amendment Request (i.e., Reference 1). The requested additional information is provided below. It should be noted that while developing the response to the NRC's request for additional information, EGC identified that some electrical parameters and recently added loads were not properly modeled in the calculations supporting the proposed TS changes presented in Reference 1. These issues have prompted the need to revise the TS Allowable Values and associated setpoints for the new degraded voltage function. In summary, the proposed TS Allowable Values have been revised to 3196.4 V and 3113.8 V for Braidwood Station and Byron Station, respectively. These values equate to 76.8% and 74.9% of nominal bus voltage for Braidwood Station and Byron Station, respectively. The responses to the NRC's questions below reflect the revised values. The associated time delays remain unaffected. The revised TS pages for Braidwood Station and Byron Station are provided in Attachments 3A and 3B, respectively. Note that changes to the associated Bases pages will also be made reflecting the revised calculations.

Electrical Engineering Branch (EEB)
Request for Additional Information (Reference 2)

Background

Attachment 1, Section 1.0 of the license amendment request (LAR) states that the addition of the low degraded voltage relays (LDVRs) will continue to allow the existing undervoltage protection circuitry to function as originally designed; i.e., the first-level "loss of voltage relay" protection and the second level "degraded voltage relay" (DVR) protection will remain in place and be unaffected by this change. These new relays and timers will ensure the safety-related loads will not be damaged by appropriately isolating the safety-related loads (at 75% of nominal ESF [Engineered Safety Features] bus voltage) from the normal off-site power source during a sustained degraded bus voltage event under non-accident conditions.

Attachment 1, Section 2.0 of the LAR states that the proposed change would revise this SR to include a new Allowable Value and time delay for the low degraded voltage Function as follows:

SR 3.3.5.2 Perform CHANNEL CALIBRATION with setpoint Allowable Value as follows:

a. Loss of voltage Allowable Value ≥ 2730 V with a time delay of ≤ 1.9 seconds.
b. Degraded voltage Allowable Value ≥ [3930 V - Braidwood; 3793 V - Byron] with a time delay of 310 ± 30 seconds.
c. Low degraded voltage Allowable Value ≥ [3059 V - Braidwood; 3075 V - Byron] with a time delay of ≤ 3.5 seconds.

Attachment 1, Section 3.0 of the LAR states that during a sustained degraded grid voltage condition, the subsequent occurrence of an SI signal (due to a loss of coolant accident (LOCA)) immediately trips the offsite power supply to the 4-kV ESF buses. The above setpoint is based on the maximum positive and negative tolerances of the relay and a minimum voltage of 90% at the terminals of Class 1 E motors.

EEB Question 1

Section 3.1.2 of the LAR states that under LOCA conditions (i.e., SI [Safety Injection] signal is present), the 5-minute time delay is bypassed and, after an initial 10-second time delay, the offsite power feeder breakers would trip and the EDGs [Emergency Diesel Generators] would start and accept the safetyrelated loads according to the prescribed load sequence. Clarify whether there is a separate timer delay for DVR during LOCA condition. If there is a separate DVR time delay provided for the LOCA condition, please provide technical and regulatory bases for not including this time delay in TS SR 3.3.5.2.

Response to EEB Question 1

As noted above, SR 3.3.5.2, Item (b) states:

> "Degraded voltage Allowable Value ≥ [3930 V - Braidwood; 3793 V - Byron] with a time delay of 310 ± 30 seconds."

The stated time delay of 310 seconds is comprised of a 10-second time delay, integral to the degraded voltage relay (DVR) itself, and a separate 5-minute time delay device. The 10-second delay is not part of a separate component apart from the DVR, and cannot be tested or replaced separately. As such, there is no separate 10-second time delay device associated with the 310-second time delay; and the 10-second time delay is not addressed separately in the TS. This 10-second time delay satisfies the requirements of Branch Technical Position (BTP) PSB-1, "Adequacy of Station Electric Distribution System Voltages," Section B.1.b.1 (i.e. the first time delay of the second level of undervoltage protection).

The degraded voltage Allowable Values and associated time delays were approved as part of TS during the initial licensing of Braidwood and Byron Stations. The original Allowable Value was 3728 V for both Braidwood Station and Byron Station; with an associated time delay of 310 ± 30 seconds. During the Improved Technical Specification conversion process to adopt NUREG-1431, "Standard Technical Specifications, Westinghouse Plants," the Allowable Values were revised to the current values and the time delay remained the same. The NRC approved the Improved Technical Specifications for Braidwood and Byron Stations in Amendments 98 and 106, respectively, dated December 22, 1998.

Additional discussion regarding the 10-second time delay, as it relates to a LOCA condition, may be beneficial for clarity. As previously discussed in Reference 1, Attachment 1, Section 3.3, "Proposed Modification and Technical Justification," the purpose of the 10-second time delay, integral to the DVR, is to allow time for bus voltage to recover after normal plant events (e.g., voltage transients due to large motor starts which result in a momentary degraded voltage condition) and avoid unnecessary tripping of the offsite power feeder breakers and start of the EDGs. The 10-second time delay is part of the degraded voltage logic for both degraded voltage conditions without a LOCA (i.e., SI signal) and for degraded voltage conditions with a

LOCA. Therefore, the 10-second time delay is not a separate time delay provided only for the degraded voltage with a LOCA condition.

EEB Question 2

Provide a summary of the analysis including assumptions utilized to show that for sustained degraded voltage conditions (just above 3059 V for Braidwood and 3075 V for Byron) for a time delay period of 340 seconds that safety-related loads will have adequate voltage to start and run without actuating their protective devices and none of the safety-related loads will be damaged.

Response to EEB Question 2

The analysis for low degraded voltage conditions addresses Items (a) through (e) below for all normally running safety-related loads during operation at the low degraded voltage relay (LDVR) minimum allowable voltage for a duration of 340 seconds. A discussion on starting safety-related loads under low degraded voltage conditions is presented in Item (f).

a. Potential Motor Damage

   The safety-related loads will not be damaged.

   Electrical protective devices (e.g., overcurrent relays, Amptectors, Thermal Overload (TOL) relays, and Motor Control Center (MCC) circuit breakers) protect normally running safety-related loads from damage during low degraded voltage conditions. The protective device settings have been selected such that they will protect the loads from damage by tripping the breaker or MCC contactor on an overload or fault condition. The protective device settings are set high enough that the loads will operate and perform their required design functions in the absence of an overload or fault condition. This topic is analyzed in detail in the Engineering Change (EC), Design Considerations Summaries for each of the Byron Station and Braidwood Station units.

b. Potential Motor Stalling

   The safety-related loads (i.e., motors) will not stall due to operation with reduced running torque.

   Braidwood Station Calculation 19-AN-29, Revision 002C, "Second-Level Undervoltage Relay Setpoint," (Attachment 4) and Byron Station Calculation 19-AN-28, Revision 001C, "Calc. for Second-Level & Third-Level Undervoltage Relays," (Attachment 5) verified that the normally running safety-related motors on the 4.16 kV and 480 V ESF buses will not stall due to operation with reduced running torque at the LDVR minimum allowable voltage for 340 seconds. Note that these calculations supersede the previous revisions of these calculations included in the subject License Amendment Request (i.e., Reference 1).

The equation used to calculate the minimum allowed load voltage is as follows (Reference Section 8.1.1.1 of Calculation 19-AN-28 and Section 8.1.1.1 of Calculation 19-AN-29):

$V_{min\ allowed} = V_{rated} \sqrt{((\%T_{BD@Vmin\ allowed})/(\%T_{BD@Vrated}))}$

where: $V_{min\ allowed}$ = the minimum allowed motor terminal voltage

V_{rated} = the rated voltage for the motor

$\%T_{BD@Vmin\ allowed}$ = the minimum required ratio of breakdown torque to full load torque at the minimum allowable voltage for the load

$\%T_{BD@Vrated}$ = the available ratio of breakdown torque to full load torque at rated voltage for the motor

Motor data sheets and National Electrical Manufacturers Association (NEMA) Standard MG 1, "Motors and Generators," were used as design inputs for the available ratios of breakdown torque to full load torque at rated voltage for the motors (reference Sections 4.2.2, 5.1.3, and 5.1.4 of Calculation 19-AN-28 and Sections 2.1.2, 2.1.3, and 3.2.2 of Calculation 19-AN-29).

The break horsepower (BHP) data in the Electrical Load Management System (ELMS) load flow analysis reports were used to determine the minimum required ratio of breakdown torque to full load torque.

Torque is proportional to power ($P_{motor} = T_{motor}\ \omega$)

where: P_{motor} = the motor BHP

T_{motor} = the motor torque

ω = the motor speed

For cases where the motor BHP was less than or equal to the rated BHP, the minimum required ratio of breakdown torque to full load torque was conservatively assumed to equal 100%. However, for cases where the motor BHP was greater than the rated BHP, the minimum required ratio of breakdown torque to full load torque was calculated by taking the ratio of motor BHP to motor rated horsepower (reference Sections 8.1.1.1, 8.1.1.2, and 8.1.1.4 of Calculation 19-AN-28 and Sections 8.1.1.1, 8.1.1.2, and 8.1.1.3 of Calculation 19-AN-29).

To prevent a motor from stalling, the minimum available breakdown torque from the motor has to be equal to the required full load torque for the load. However, at rated voltage, the available breakdown torque will be greater than the required full load torque. As voltage decreases, the available breakdown torque decreases. Therefore, the minimum allowed motor terminal voltage can be calculated for the torque value where the minimum available breakdown torque from the motor equals the required full load torque for the load (reference Sections 8.1.1.1, 8.1.1.4, and 8.1.1.5 of Calculation 19-AN-28 and Sections 8.1.1.1, 8.1.1.3 and 8.1.1.4 of Calculation 19-AN-29).

The ELMS-AC electrical load flow program was used to determine the minimum required 4.16 kV ESF bus voltages that would ensure that each of these motor loads will have the minimum required motor terminal voltage so that the motor loads will not stall. The highest minimum required 4.16 ESF bus voltage (i.e., the analytical limit) is 3088.8 Volts for Byron Station and 3171.4 Volts for Braidwood Station. Therefore, the Minimum Allowable Value (i.e., the TS Allowable Values) for the new LDVRs was selected to be 3113.8 Volts and 3196.4.0 Volts for Byron and Braidwood Stations, respectively (reference Section 8.1.1.5 of Calculation 19-AN-28 and Section 8.1.1.4 of Calculation 19-AN-29).

c. Protective Devices for 4.16 kV Loads Requiring Manual Reset

For 4.16 kV safety-related loads with electrical protective devices that require manual reset (e.g., lockout relays), the analysis verified that the protective devices will not actuate during operation at the LDVR minimum allowable voltage for 340 seconds.

Based on a review of the electrical schematic drawings for the normally running 4.16 kV ESF bus loads, the only loads that would require a manual reset following a trip on overcurrent are the Main Control Room (MCR) chiller compressors. The Byron Station and Braidwood Station analyses evaluated the existing overcurrent relay settings for the MCR chiller compressors and determined that the settings needed to be revised to ensure that the MCR chiller compressors would continue to operate under low degraded voltage conditions. As a result of this calculation revision, the time-overcurrent primary pickup setting will be increased from 50 amps to 60 amps. The time dial setting remained at 0.75. Therefore, the time-overcurrent response characteristic for the overcurrent relays was not changed. The calculation verified that the revised settings will adequately protect the MCR chiller compressors from overloads while also allowing them to continue operating under low degraded voltage conditions.

d. Protective Devices for 4.16 kV Loads with Automatic Reset

For 4.16 kV safety-related loads with protective devices that will automatically reset following clearance of the overcurrent condition, the analysis assumed that the protective devices may trip during operation at the LDVR minimum allowable voltage during the 340-second time delay. Tripping of protective devices with an automatic reset is considered to be acceptable by EGC since, once bus voltage has been restored to normal (e.g., from the EDG), the affected safety-related loads would be capable of restarting and performing their required design functions.

With the exception of the MCR chiller compressors, discussed previously in Item (c) above, the remaining normally running 4.16 kV ESF bus loads are protected by protective devices that will automatically reset following an overcurrent trip. For these loads, the analysis did not specifically verify that the overcurrent relay protection will not trip during low degraded voltage conditions; therefore, it is possible that these loads may trip on overcurrent during low degraded voltage conditions. Once the EDGs restore normal bus voltage, either with or without a SI signal, these 4.16 kV loads would be available for an automatic restart. This analysis is considered to be acceptable since BTP PSB-1, "Adequacy of Station Electric Distribution System Voltages," Section B.1.b.2 states in part, "The second time delay should be of a limited duration such that the permanently connected Class 1E loads will not be damaged," and does not specify that normally running safety-related loads need to continue running during low degraded voltage conditions.

e. Protective Devices for 480 V Loads

For all 480 V safety-related loads, the analysis verified that the protective devices will not actuate during operation at the LDVR minimum allowable voltage for 340 seconds.

Normally running 480 V safety-related loads are powered by either 480 V ESF MCCs or 480 V switchgear. The normally running motors powered by 480 V ESF MCCs are protected by thermal overload (TOL) relays that require manual reset following a trip on overload. The normally running motors powered by 480 V ESF switchgear have Amptectors that will automatically reset following a trip on overload. EGC evaluated the performance of the 480 V loads under low degraded voltage conditions. As a result of these evaluations, the TOL heaters for some loads at Byron Station and Braidwood Station will be replaced with larger sized TOL heaters. The evaluations verified that the revised TOL heater sizes will adequately protect the loads from overloads while also allowing the loads to continue operating under low degraded voltage conditions. The evaluations also verified that the overload protection for the remaining normally running 480 V loads is adequately sized for low degraded voltage conditions.

f. Starting Loads Under Low Degraded Voltage Conditions

BTP PSB-1, "Adequacy of Station Electric Distribution System Voltages," Section B.1.b.2 states in part, "The second time delay should be of a limited duration such that the permanently connected Class 1E loads will not be damaged." The BTP does not specifically require that loads be capable of starting under low degraded voltage conditions; therefore, the Byron Station and Braidwood Station low degraded voltage evaluations did not specifically analyze the potential starting of loads under low degraded voltage conditions. If an SI signal were to occur during a low degraded voltage condition, the SI signal would bypass the degraded voltage 5-minute time delay and immediately start the EDGs (i.e., after the initial 10-second time delay expires). Once the EDGs reenergize the ESF buses and restore normal bus voltage, the SI sequencer would automatically start the required safety-related loads.

It should be noted that there are some loads that could receive auto-start signals due to conditions other than an SI signal. For example, the Standby Component Cooling Water (CC) Pump could also receive an automatic start signal on CC Pump low discharge pressure; and the Motor Driven Auxiliary Feedwater (AF) Pump could receive an automatic start signal on Reactor Coolant Pump (RCP) bus undervoltage, Lo-Lo steam generator level, or an Anticipated Transient Without Scram (ATWS) signal. If either the CC Pump or the AF Pump were to attempt to start under low degraded voltage conditions, the load may trip; however, once the EDGs reenergize the ESF buses and restore normal bus voltage, the safe shutdown sequencers would automatically start the CC Pump, the AF Pump, and the other required safe shutdown loads on each train.

EEB Question 3

Section 3.3 of the LAR states that the new relays and timers will ensure the safetyrelated loads will not be damaged by appropriately isolating the safety-related loads (at 75% of nominal ESF bus voltage) from the normal off-site power source during a sustained degraded bus voltage event under non-accident conditions. The 75% voltage on the 4.16kV buses includes relay setpoint margins.

a. *Explain the technical bases for the above statement.*
b. *Confirm that the equipment fed from all safety buses will continue to operate satisfactorily at the analytical limits of the proposed LDVR setpoint.*
c. *Confirm that a momentary voltage dip lasting approximately 3 seconds to a value marginally above the loss of voltage relay setpoint, with a recovery to the reset point of the LDVR will not adversely impact any important to safety equipment which may be required to operate for more than 5 minutes. Elaborate if equipment such as valves and contactors were evaluated for this scenario.*
d. *Provide appropriate supporting documentation including a summary of typical procurement document that includes data for motor control center contactor drop out values*

Response to EEB Question 3

NOTE: The setpoint of 75% of nominal ESF bus voltage referred to in this question has been revised to 76.8% for Braidwood Station and 74.9% for Byron Station (see Table 2-1 below in response to EEB Question 4).

a. *Explain the technical bases for the above statement.*

Calculation 19-AN-28 Rev. 001C (Attachment 5 - Byron Station) and 19-AN-29 Rev. 002C (Attachment 4 - Braidwood Station) explain the technical basis for the statement in Section 3.3 of the LAR, noted above. Calculation 19-AN-29, Section 6.0, "Method of Analysis," and Calculation 19-AN-28, Section 2.0, "Methodology," describe the calculation methodology used to determine the LDVR Minimum Allowable Value, Maximum Allowable Value, and Time Delay Setting. The Minimum Allowable Value for the new LDVRs must be high enough to prevent the stalling, damaging, and tripping of loads due to actuation of overcurrent protection devices that require manual reset.

The Acceptance Criteria in Calculation 19-AN-29, Section 7.0 (Calculation 19-AN-28, Section 3.0) specifies that the setpoint should be high enough to prevent the stalling, damaging, and tripping (due to overcurrent protection devices) of Class 1E motors due to low voltage. Also, the setpoint should be low enough to prevent spurious actuation during transients such as those experienced during the block starting of ESF motors following a SI initiation.

Calculation 19-AN-29, Section 8.0, "Calculations and Results," and Calculation 19-AN-28, Section 8.0, "Calculations," document the calculations noted in the "methodology" section of each calculation. These sections address the selection of the limiting breakdown torque and the utilization of the ELMS AC electrical software program to determine the analytical limits, allowable values and associated setpoints for Braidwood Station and for Byron Station.

As discussed in detail in the response to EEB Question 2 above, the protective device settings have been selected such that they will protect the loads from damage by tripping the breaker or MCC contactor on an overload or fault condition. The protective device settings are set high enough such that the loads will operate and perform their required design functions in the absence of an overload or fault condition.

b. *Confirm that the equipment fed from all safety buses will continue to operate satisfactorily at the analytical limits of the proposed LDVR setpoint.*

See responses for Question 2 and 3.a above which confirm that, at the LDVR setpoints and the associated analytical limits, the equipment fed from all safety buses will not be damaged and will continue to operate satisfactorily.

c. *Confirm that a momentary voltage dip lasting approximately 3 seconds to a value marginally above the loss of voltage relay setpoint, with a recovery to the reset point of the LDVR will not adversely impact any important to safety equipment which may be required to operate for more than 5 minutes.*

The LDVR settings and associated time delays have been chosen to adequately protect the equipment important to safety. The acceptance criteria, defined in Braidwood Calculation 19-AN-29, Revision 002C, Section 7.0, have been satisfied as summarized in Calculation 19-AN-29, Revision 002C Section 8.3. The equipment will also be adequately protected, given the above scenario, as overcurrent protection devices (e.g., overcurrent relays, Amptectors, TOL relays, and MCC circuit breakers) will actuate to protect equipment from damage irrespective of the relay time delays (i.e., the 3.0 second time delay for the LDVR, or the 5 minute time delay for the degraded voltage relay).

Note that Byron Station Calculation 19-AN-28, Revision 001C, Section 3.0 and 8.2 contain the same information

Based on the above discussion, a momentary voltage dip lasting approximately 3 seconds to a value marginally above the loss of voltage relay setpoint, with a recovery to the reset point of the LDVR, will not adversely impact any important to safety equipment which may be required to operate for more than 5 minutes.

Elaborate if equipment such as valves and contactors were evaluated for this scenario.

<u>Valves</u>

Valves were not evaluated because they are not continuous loads and are not expected to operate during a degraded voltage condition. Therefore, valves were considered outside the scope of the BTP PSB-1 requirements.

<u>Contactors</u>

The following information is discussed in the Braidwood Station, Unit 2 EC 392216, Revision 005, Design Considerations Summary, Section 4.1.35, "Identify Electrical Requirements," and addresses this issue.

Specifically, motor control for loads powered from the MCCs is provided from control power transformers off the MCCs. Therefore, the degraded voltage condition at the MCC will result in a corresponding reduction in control power voltage. For the A200 series starters (Sizes 00 to 4) used in the MCCs, the pick-up voltage is 85% and drop out is 40-60% of coil rated voltage. For continuously energized motors, the starter is provided with seal-in circuit internal to the MCC. Therefore, there is minimal circuit length and the starter coil will see approximately the same % voltage as the MCC. As seen from the ELMS-AC analysis in 19-AN-29 Rev. 002C, the lowest MCC voltage remains above 60% of rated voltage. Note that due to the methodology of the calculation, this voltage is lower than what would be seen at the 78% trip rating at ESF Buses. Therefore, adequate holding voltage is maintained at the starter to prevent drop out of the coil and loss of the associated load.

For control panels fed from the MCC 120V distribution, operating voltage to relays may drop below manufacturer ratings. The most common control relays are the Westinghouse AR control relays and Agastat E7000 time delay relays. The AR relays have an 85% pickup voltage and 60% drop out voltage. The Agastat time delay relays have an 85% pickup voltage and 50% drop out voltage. As identified above, the minimum MCC voltage remains above 60% of rated voltage. ELMS-AC does not model the 120V distribution, but voltage at the 120V distribution is expected to be only slightly lower than the 480V voltages as a result of transformer losses. Therefore, given the 60% or 50% drop out voltages, adequate voltage exists to prevent drop out of any relays.

MCC control power circuits will have adequate hold in voltage to the starter coil. Therefore, the starters for operating MCCs loads will remain energized and the loads continue running. The MCC voltages are below the pick-up voltage for the starter coils, which may prevent a motor from starting, but the starter coil would not be damaged. Since the starter will not pick-up, the associated load will not energize and will not see a starting transient. Operating voltages for control panels fed from 120V MCC distribution panels are above the dropout voltages for the control relays, but below the pick-up voltages. Since the energized relays will not dropout, no transients are expected. If a relay was energized during the degraded condition, the relay may not actuate, but the relay would not be damaged by the lower voltage condition.

This discussion is also applicable to Braidwood Station, Unit 1 and Byron Station, Units 1 and 2.

Based on the above information, contactors were appropriately evaluated considering the subject low degraded voltage conditions.

d. *Provide appropriate supporting documentation including a summary of typical procurement document that includes data for motor control center contactor drop out values.*

Byron Station and Braidwood Station use Westinghouse / Cutler-Hammer (Eaton) A200 series contactors. (Note that the A200 series contactors were originally manufactured by Westinghouse and are now manufactured by Cutler-Hammer (Eaton).) As noted in both the original Westinghouse and the newer Cutler-Hammer (Eaton) data sheets (provided in Attachment 2), the rated coil drop-out voltage for sizes 00 to 4 is 40-60% of rated voltage. Byron Station and Braidwood Station did not take exception to the published data and did not specify a lower drop-out voltage as was sometimes done in control circuit voltage drop analyses. Byron Station and Braidwood Station used the published values for coil drop-out

voltage. The published data from the vendor bounds the Byron Station and Braidwood Station applications.

EEB Question 4

Section 2.0 of the LAR states that the associated setpoints for the proposed TS Allowable Values for the new low degraded voltage Function will be specified in the Technical Requirement Manual (TRM), Table T2.0.b-1, "Engineered Safety Feature Actuation System Instrumentation Trip Setpoints." Attachments 2A and 2B provide proposed marked up sections of the TS for Byron and Braidwood Units. Clarify that the proposed setpoints for the loss of voltage, degraded voltage and low degraded voltage relays will be maintained in the TS and the TRM Table 2-1 is intended to differentiate between TS Allowable Values (AV) and TRM Setpoints (SP).

Response to EEB Question 4

The intended location of the Allowable Values (AVs) and setpoints associated with the loss of voltage, degraded voltage, and low degraded voltage relays, is correct as stated in Question 4. Currently, the AVs associated with the existing loss of voltage and degraded voltage relays are located in TS SR 3.3.5.2. The new low degraded voltage relay AV will be added to TS SR 3.3.5.2 as shown in the proposed License Amendment Request (i.e., Reference 1, Attachments 2A and 2B) for Braidwood Station and Byron Station respectively. The current setpoints associated with the existing loss of voltage and degraded voltage relays are located in TRM Table T2.0.b-1. The new low degraded voltage relay setpoint will also be added to TRM Table T2.0.b-1. Note that the proposed TS Allowable Values for the new low degraded voltage relays have been revised from the values noted in Reference 1 due to the subject calculation revisions. The revised TS Allowable Values are presented in Attachments 3A and 3B (i.e., markup of the affected TS pages) of this letter. For clarity, Table 2-1, "TS Allowable Values (AV) and TRM Setpoints (SP)," from Reference 1 is reproduced below with revised TS Allowable Values and associated setpoints that are maintained in the TRM.

Table 2-1
TS Allowable Values (AV) and TRM Setpoints (SP)

	Braidwood	Byron
TS AV – Loss of Voltage	≥2730V (65.6%) w/ ≤1.9 sec time delay	≥2730V (65.6%) w/ ≤1.9 sec time delay
TRM SP – Loss of Voltage	≥2870V (69.0%) w/ ≤1.8 sec time delay	≥2870V (69.0%) w/ ≤1.8 sec time delay
TS AV – Degraded Voltage	≥3930V (94.5%) w/ 310±30 sec time delay	≥3793V (91.2%) w/ 310±30 sec time delay
TRM SP – Degraded Voltage	≥3987V (95.8%) w/ 310 sec time delay	≥3847V (92.5%) w/ 310 sec time delay
TS AV – Low Degraded Voltage (proposed)	≥3196.4V (76.8%) w/ ≤3.5 sec time delay	≥3113.8V (74.9%) w/ ≤3.5 sec time delay
TRM SP – Low Degraded Voltage (proposed)	≥3244.2V (78.0%) w/ 3.0 sec time delay	≥3160.2V (76.0%) w/ 3.0 sec time delay

NOTE: Percentages are given as percent of the nominal bus voltage of 4160 volts

It should be noted that both the AVs and setpoints for the loss of voltage and degraded voltage relays were originally located in the TS for Braidwood Station and Byron Station. As part of the Improved Technical Specifications conversion process to adopt NUREG-1431, these setpoints were relocated to the TRM. Relocation of these setpoints was consistent with the criteria stated in the Final Commission Policy Statement on Technical Specifications Improvements for Nuclear Power Reactors, dated July 22, 1993 (58 FR 39132) which was subsequently codified by changes to 10 CFR 50.36, "Technical specifications," dated July 19, 1995 (60 FR 36953). The NRC approved these setpoint relocations to the TRM as part of the Improved Technical Specifications for Braidwood and Byron Stations in Amendments 98 and 106, respectively, dated December 22, 1998.

Instrumentation and Controls Branch (ICB)
Request for Additional Information (Reference 3)

To complete its review of the LAR, the U.S. Nuclear Regulatory Commission (NRC) staff requires additional information to make a determination that the proposed changes comply with Title 10 of the Code of Federal Regulations (10 CFR) Section 50.36, "Technical Specifications" and Section 50.34(b)(2), "Final Safety Analysis Report."

ICB Question 1

The Calculations provided in Attachments 4, and 5 (ADAMS Accession Nos. ML14120A040 and ML14120A041, respectively) of the LAR do not include instrument uncertainty factors other than the base instrument accuracy and no method is provided for the determination of other instrument uncertainty values. Sections 8.1.1.4, and 8.1.1.5 of Attachment 4 for Braidwood, and Sections 8.1.1.6, and 8.1.1.7 of Attachment 5 for Byron provide instrument uncertainty information which appears to be based on basic instrument accuracy only. The calculations do not include factors such as Measuring and Test Equipment uncertainty, or instrument drift. It is also unclear what uncertainty factors are included in the "Total Negative Error" term used in the calculations. There is no explanation or basis for this uncertainty factor.

Provide information of how uncertainty factors are being derived and accounted for in the determination of acceptable tolerances for the surveillance test procedures.

<u>Response to ICB Question 1</u>

The same type of relays, ABB / ITE 27N relays, are used for both the Degraded Voltage Relays (DVRs) and the Low Degraded Voltage Relays (LDVRs). As discussed in Byron Station Calculation 19-AN-28, Revision 001C, Section 8.1.1.6 (Attachment 5) and Braidwood Calculation 19-AN-29, Revision 002C, Section 8.1.1.5 (Attachment 4), the Total Positive Error (TPE) is 0.94%; and the Total Negative Error (TNE) is 1.46%. The error terms were originally calculated in earlier revisions of the subject calculations; i.e., Calculation 19-AN-28, Revision 001 and Calculation 19-AN-29, Revision 002 for Byron Station and Braidwood Station, respectively.

As documented in Calculation 19-AN-28, Revision 001, Section IX.C and Calculation 19-AN-29, Revision 002, Section IX.C, the TPE and TNE included non-random errors from:

- the potential transformers (PTs)
- relay temperature effect
- relay control voltage effect

The TPE and TNE also included random errors from:

- relay reference accuracy
- calibration instrument error (i.e., measurement and test equipment)
- relay setting tolerance

As discussed in the revised calculations, new calibration instrument error and relay setting tolerance values were calculated and used to determine the TNE and TPE for the LDVRs. The remaining error terms, which were originally calculated for the degraded voltage relays, remain applicable to the LDVRs.

ICB Question 2

Neither the LAR nor the calculations provided in Attachments 4, and 5 provide any information on As-Found or As-Left tolerances to be used for surveillance testing of the low degraded voltage relay.

Provide information that demonstrates how Exelon will address surveillance test results exceeding As-Found and As-Left acceptance criteria for the new low degraded voltage safety function, specifically:

> *Explain what actions will be taken and what evaluations will be performed if the As-Found channel setpoint exceeds its predefined As-Found or allowable value acceptance criteria band during surveillance testing to verify that the instrument is functioning as required before returning the channel to service. Include a discussion of plant requirements for returning an instrument channel setpoint to a value that is within the as-left tolerance of the Limiting Trip Setpoint prior to returning an instrument to an operable status.*

<u>Response to ICB Question 2</u>

As stated in Calculation 19-AN-28, Revision 001C, Section 8.1.1.6 and Calculation 19-AN-29, Revision 002C, Section 8.1.1.5, the setpoints for the LDVRs are 90.29 V and 92.69 V, for Byron Station and Braidwood Station, respectively. If the as-found relay setting is outside the tolerance band of 90.29 V +/- 0.2 V [92.69 V +/- 0.2 V], an Issue Report (IR) would be written as part of the Corrective Action Program (CAP) and the Operations Shift Manager would evaluate the relay for operability. In addition, Maintenance personnel would take actions to recalibrate the relays to a value within the setpoint tolerance band prior to returning the channel to service, as directed by site-specific Maintenance Procedures.

ICB Question 3

Provide information to demonstrate that an acceptable setpoint methodology has been used to determine the setpoints associated with the low degraded voltage safety functions. Include a discussion of the calculated total loop uncertainty or otherwise demonstrate the acceptability of the setpoint methodology.

Response to ICB Question 3

As noted in Reference 1, Attachment 1, Section 3.3, "Proposed Modification and Technical Justification," the new low degraded voltage relay setpoint and time delay values "were developed in accordance with the EGC setpoint methodology."

The methodology used to develop the LDVR setpoints in Calculations 19-AN-28, Revision 001C and Calculation 19-AN-29, Revision 002C, is the same methodology that was used to develop the DVR setpoints as discussed in Calculations 19-AN-28, Revision 001 and Calculation 19-AN-29, Revision 002. This methodology is based on Exelon (formerly CECo) Standards TID-E/I&C-10, Revision 0, "Procedure for Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy," and TID-E/I&C-20, Revision 0, "Basis for Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy." This methodology is similar to the methodology described in the Exelon Nuclear Engineering Standard NES-EIC-20.04, Revision 6, "Analysis of Instrument Channel Setpoint Error and Instrument Loop Accuracy," which is the current Exelon standard for instrument loop error analysis. NES-EIC-20.04 has superseded TID-E/I&C-10 and TID-E/I&C-20.

The EGC setpoint methodology (i.e., NES-EIC-20.04, Revision 3) was approved by the NRC in Reference 4. In the Reference 4 Safety Evaluation, the NRC specifically stated: "The staff also finds that the instrument setpoint methodology used by the licensee to determine the allowable values is acceptable." Note that since the initial NRC approval of NES-EIC-20.04, Revision 3, this procedure has been revised in accordance with the 10 CFR 50.59 process.

As discussed in the response to ICB Question 1, the TPE (i.e., total loop uncertainty) is 0.94%; and the TNE (i.e., total loop uncertainty) is 1.46%. The Total Positive / Negative Error included non-random errors from:

- the potential transformers (PTs)
- relay temperature effect
- relay control voltage effect

The Total Positive / Negative Error also included random errors from:

- relay reference accuracy
- calibration instrument error
- relay setting tolerance

Based on the above information, an acceptable setpoint methodology was used to develop the setpoints for the new LDVRs.

REFERENCES

1. Letter from D. M. Gullott (Exelon Generation Company, LLC) to U. S. NRC, "License Amendment Request to Install New Low Degraded Voltage Relays and Timers on the 4.16 kV Engineered Safety Features (ESF) Buses," dated April 24, 2014

2. Email from J. S. Wiebe (U. S. NRC) to J. A. Bauer (Exelon Generation Company, LLC), "Preliminary Request for Additional Information Regarding Braidwood and Byron New Low Degraded Voltage Relays and Timers (MF4051, MF4052, MF4053, and MF4054)," dated October 23, 2014

3. Email from J. S. Wiebe (U. S. NRC) to J. A. Bauer (Exelon Generation Company, LLC), "Preliminary Request (2nd Set) for Additional Information Regarding Braidwood and Byron New Low Degraded Voltage Relays and Timers (MF4051, MF4052, MF4053, and MF4054)," dated November 10, 2014

4. Letter from S. N. Bailey (U. S. NRC) to O. D. Kingsley (EGC), "Issuance of Amendments (TAC Nos. MA8388 and MA8390)," dated March 30, 2001.

ATTACHMENT 2
Response to Request for Additional Information

Westinghouse Electric Corporation
A200 Series Contactor Data Sheet

and

Cutler-Hammer (Eaton)
A200 Series Contactor Data Sheet

STARTERS AND CONTACTORS
Full Voltage Ac, NEMA Sizes 00-9
Technical Data

TECHNICAL DATA, *Continued*

Operating Coil Characteristics at Rated Coil Volts, Sizes 00-9
The following represent typical production test values and should not be interpreted as a guarantee of actual performance.

	Size 00,0,1	Size 2	Size 3	Size 4⑦	Size 5	Size 6	Size 7	Size 8	Size 9
AC Coil									
Burden (Open VA)	160 VA	160 VA	625 VA	625 VA	1700 VA	2900 VA	(DC Operated	(DC Operated	(DC Operated
(Closed VA)	25 VA	25 VA	50 VA	50 VA	180 VA	220 VA	Only)	Only)	Only)
(Closed Watts)	7.8 W	7.8 W	18 W	18 W	32 W	42 W	......	......	......
Pick-up Volts①	85%	85%	85%	85%	78%	70%	......	......	......
Drop-out Volts①②	40 – 60%	40 – 60%	40 – 60%	40 – 60%	70%	65%	......	......	......
Pick-up Time Hz④	1 – 1½	1½ – 2	2 – 2½	2 – 2½	1.5	4.0	......	......	......
Drop-out Time Hz③	¾ – 1	¾ – 1	¾ – 1	¾ – 1	0.75	0.75	......	......	......
DC Coil									
Burden (Open VA)	......	......	......	......	600 VA	2120 VA	400 VA	400 VA	2100 VA
(Closed VA)	......	......	......	......	22 VA	21 VA	400 VA	400 VA	350 VA
(Closed Watts)	18 W	18 W	35 W	35 W	20 W	20 W	400 W	400 W	350 W
Pick-up Volts①	80%	80%	80%	80%	64%	73%	45% – 65%②	45% – 65%②	50% – 65%②
Drop-out Volts①	5 – 10%	5 – 10%	5 – 10%	5 – 10%	18%	13%	30% – 45%②	30% – 46%②	40% – 50%②
Pick-up Time Cycles④	......	25 – 75 MS	25 – 75 MS	25 – 75 MS	2.7 Cycles	3 Cycles	21 – 41 Cycles②	17 – 29 Cycles②	16 – 18 Cycles②
Drop-out Time Cycles④	......	16 – 25 MS	16 – 25 MS	16 – 25 MS	9.3 Cycles	17.5 Cycles	7 – 12 Cycles③	7 – 12 Cycles③	18 – 20 Cycles③

NEMA Std. ICS 2-110
Direct-current operated contactors shall withstand 110 percent of their rated voltage continuously without injury to the operating coils and shall close successfully at 80 percent of their rated voltage.

Alternating-current operated contactors shall withstand 110 percent of their rated voltage continuously without injury to the operating coils and shall close successfully at 85 percent of their rated voltage.

Mechanical Characteristics, Sizes 00-9

	Type A								
	Size 00,0,1	Size 2	Size 3	Size 4	Size 5	Size 6	Size 7	Size 8	Size 9
Dimensions – Inches									
Height	6.45 In.	7.16 In.	9.93 In.	9.93 In.	12.00 In.⑥	13.50 In.⑥	18.62 In.⑥	19.25 In.⑥	25.00 In.⑥
Width	3.31	3.31	4.62	4.62	7.00⑥	7.00⑥	23.50⑥	23.50⑥	32.00⑥
Depth	4.61	4.96	6.75	6.75	7.75⑥	8.75⑥	11.00⑥	11.00⑥	13.00⑥
Panel Area – Square Inches	21.35	23.7	46.0	46.0	84.0	94.5	437.5	452.4	800
Weight – Pounds	3.5 Lbs.	3.5 Lbs.	11.5 Lbs.	11.5 Lbs.	25 Lbs.	42 Lbs.	215 Lbs.	265 Lbs.	315 Lbs.
Cable Connection	4.8	4.8	......	......	Front	Front	Front/Rear	Front/Rear	Front/Rear
Maximum Cable Size/Phase Copper (AWG/MCM)	#6	#3	1/0	4/0	1-500 MCM	2-500 MCM	3-500 MCM	4-500 MCM	8-500 MCM
Auxiliary Electrical Circuits Available	8	6	6	6	4	4	3	3	4
Mechanical Latch Available	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Mechanical Interlock Combinations Available									
Sizes 00, 0, 1, 2	Vert., Horiz.	Vert., Horiz.	Vert., Horiz.	Vert., Horiz.	Vert., Horiz.	......	......	......	......
3, 4	Vert., Horiz.	Vert., Horiz.	Vert., Horiz.	Vert., Horiz.	Vert., Horiz.	......	......	......	......
5	......	......	......	......	Vert., Horiz.	Vert., Horiz.	......	......	......
6	......	......	......	......	Vert., Horiz.	Vert., Horiz.	Vertical	Vertical	......
7	......	......	......	......	......	Vertical	Vertical	Vertical	Vertical
8	......	......	......	......	......	Vertical	Vertical	Vertical	Vertical
9	......	......	......	......	......	......	Vertical	Vertical	Vertical

① Percent of rated coil voltage.
② Lower figure when coil is cold. Higher figure when coil is hot.
③ Drop-out time to clear arc. Time varies with type of load and contact wear.
④ At 60 hertz base.
⑤ To contact touch.
⑥ For sizes 5-9 contactors only; for starter sizes 5-9, refer to Westinghouse.
⑦ Data pertains to Model J; for Model K, refer to Westinghouse.

DC Power Pole Ratings

The following represent typical production test values and should not be interpreted as a guarantee of actual performance.

Table 33-234. DC Operated 120 and 240V Coils

Contactor Size	DC Contact Amp Rating 2 Poles in Series ①	
	120V	240V
0	—	—
1	20	10
2	45	30
3	75	40
4	90	70

① Non-inductive load.

380V, 50 Hz Starter Maximum Horsepower Ratings

Table 33-235. 380V, 50 Hz Starters — Maximum Horsepower Ratings

NEMA Size	00	0	1	2	3	4	5	6	7	8
Maximum Horsepower	1-1/2	5	10	25	50	75	150	300	450	700

Operating Coil Characteristics at Rated Coil Volts, Sizes 00 – 9

The following represent typical production test values and should not be interpreted as a guarantee of actual performance.

Table 33-236. Operating Coil Characteristics

	Sizes 00, 0, 1	Size 2	Size 3	Size 4 ②	Size 5	Size 6	Size 7	Size 8	Size 9
AC Coil									
Burden (Open VA)	160 VA	160 VA	625 VA	700 VA	1700 VA	2900 VA	③	③	③
(Closed VA)	25 VA	25 VA	50 VA	64 VA	180 VA	220 VA	③	③	③
(Closed Watts)	7.8 W	7.8 W	18 W	21 W	32 W	42 W	—	—	—
Pick-Up Volts ④	85%	85%	85%	85%	78%	70%	—	—	—
Drop-Out Volts ④	40 – 60%	40 – 60%	40 – 60%	40 – 60%	65 to 75%	60 to 70%	—	—	—
Pick-Up Time Hz ⑤⑥	1 – 1-1/2	1-1/2 – 2	2 – 2-1/2	1 – 1-1/2	1.5	4.0	—	—	—
Drop-Out Time Hz ⑤	3/4 – 1	3/4 – 1	3/4 – 1	3/4 – 1	.75	.75	—	—	—
DC Coil									
Burden (Open VA)	17 VA	17 VA	35 VA	35 VA	600 VA	2120 VA	400 VA	400 VA	2100 VA
(Closed VA)	17 VA	17 VA	35 VA	35 VA	22 VA	21 VA	400 VA	400 VA	350 VA
(Closed Watts)	18 W	18 W	35 W	35 W	20 W	20 W	400 W	400 W	350 W
Pick-Up Volts ④	80%	80%	80%	80%	64%	73%	45% – 65% ⑦	45% – 65% ⑦	50% – 65% ⑦
Drop-Out Volts ④	5 – 10%	5 – 10%	5 – 10%	5 – 10%	18%	13%	30% – 45% ⑦	30% – 45% ⑦	40% – 50% ⑦
Pick-Up Time Hz ⑥	—	25 – 75 mS	25 – 75 mS	25 – 75 mS	2.7 Hz ⑤	3 Hz ⑥	21 – 41 Hz ⑦⑤	17 – 29 Hz ⑦⑤	16 – 18 ⑦⑥
Drop-Out Time Hz ⑤	—	16 – 25 mS	16 – 25 mS	16 – 25 mS	9.3 Hz ⑥	17.5 Hz ⑤	7 – 12 Hz ⑧⑤	7 – 12 Hz ⑧⑤	18 – 20 Hz ⑦⑤

② AC coil data pertains to Model K, DC coil data pertains to Model J.
③ DC Operated only.
④ Percent of rated coil voltage.
⑤ At 60 Hz base.
⑥ To contact touch.
⑦ Lower figure when coil is cold. Higher figure when coil is hot.
⑧ Drop-out time to clear arc. Time varies with type of load and contact wear.

ATTACHMENT 3A

Markup of Technical Specifications Page

BRAIDWOOD STATION
UNITS 1 AND 2

Docket Nos. 50-456 and 50-457

Facility Operating License Nos. NPF-72 and NPF-77

<u>REVISED TS PAGE</u>

3.3.5-2

ACTIONS (continued)

CONDITION	REQUIRED ACTION		COMPLETION TIME
C. Required Action and associated Completion Time not met.	C.1	Enter applicable Condition(s) and Required Action(s) for the associated DG made inoperable by LOP DG start instrumentation.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.3.5.1	-------------------NOTE-------------------- Verification of relay setpoints not required. -- Perform TADOT.	In accordance with the Surveillance Frequency Control Program
SR 3.3.5.2	Perform CHANNEL CALIBRATION with setpoint Allowable Value as follows: a. Loss of voltage Allowable Value ≥ 2730 V with a time delay of ≤ 1.9 seconds. b. Degraded voltage Allowable Value ≥ 3930 V with a time delay of 310 ± 30 seconds. ~~c. Low degraded voltage Allowable Value ≥ 3196.4 V with a time delay of ≤ 3.5 seconds.~~	In accordance with the Surveillance Frequency Control Program

ATTACHMENT 3B

Markup of Technical Specifications Page

BYRON STATION
UNITS 1 AND 2

Docket Nos. 50-454 and 50-455

Facility Operating License Nos. NPF-37 and NPF-66

<u>REVISED TS PAGE</u>

3.3.5-2

ACTIONS (continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
C. Required Action and associated Completion Time not met.	C.1 Enter applicable Condition(s) and Required Action(s) for the associated DG made inoperable by LOP DG start instrumentation.	Immediately

SURVEILLANCE REQUIREMENTS

	SURVEILLANCE	FREQUENCY
SR 3.3.5.1	-------------------NOTE------------------- Verification of relay setpoints not required. -- Perform TADOT.	In accordance with the Surveillance Frequency Control Program
SR 3.3.5.2	Perform CHANNEL CALIBRATION with setpoint Allowable Value as follows: a. Loss of voltage Allowable Value ≥ 2730 V with a time delay of ≤ 1.9 seconds. b. Degraded voltage Allowable Value ≥ 3793 V with a time delay of 310 ± 30 seconds. c. Low degraded voltage Allowable Value ≥ 3113.8 V with a time delay of ≤ 3.5 seconds.	In accordance with the Surveillance Frequency Control Program

ATTACHMENT 4

BRAIDWOOD STATION
UNITS 1 AND 2
Docket Nos. 50-456 and 50-457
Facility Operating License Nos. NPF-72 and NPF-77

Calculation 19-AN-29, Revision 002C
"Second-Level Undervoltage Relay Setpoint"

ATTACHMENT 1
Design Analysis Cover Sheet
Page 1 of 1

Design Analysis		**Last Page No.:** [6] **Appendix F, Page CF5**	
Analysis No.: [1] 19-AN-29		**Revision:** [2] 002C Major ☐	Minor ☒
Title: [3] Second-Level Undervoltage Relay Setpoint			
EC/ECR No.: [4] 392851 & 392216		**Revision:** [5] 003 & 005	

		Component(s): [14]	
Station(s): [7]	Braidwood		
Unit No.: [8]	1 & 2		
Discipline: [9]	ELDC		
Descrip. Code/Keyword: [10]	E07 & E15		
Safety/QA Class: [11]	SR		
System Code: [12]	AP		
Structure: [13]			

CONTROLLED DOCUMENT REFERENCES [15]

Document No.:	From/To	Document No.:	From/To
See Section 4.0 of this Calculation			

Is this Design Analysis Safeguards Information? [16] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] Yes ☐ No ☒ If yes, ATI/AR#:

This Design Analysis SUPERCEDES: [18] **Calculation 19-AN-29, Rev. 002B** **in its entirety.**

Description of Revision (list changed pages when all pages of original analysis were not changed): [19]
This revision adds a third level of protection to the degraded voltage protection scheme via a new Low Degraded Voltage Relay (DVR) with a lower setpoint than the existing DVR (second-level). The existing analysis from Revision 002 is not affected; the new low degraded voltage relay is added to the analysis. The original body of the calculation is unchanged. As such, only Attachment C and the associated appendices are included as part of this minor revision, which are to be added to base calculation. This calculation supersedes Calculation 19-AN-29, Rev. 002B in its entirety. Approval from Darrel Riedinger (SMDE) for a minor revision to 19-AN-29 was given on 03/30/2015.

	Print Name	Sign Name	Date
Preparer: [20]	J. Kolodziej	James Kolodziej	4/24/15

Method of Review: [21] Detailed Review ☒ Alternate Calculations (attached) ☐ Testing ☐

	Print Name	Sign Name	Date
Reviewer: [22]	G. Hinshaw	Greg Hinshaw	4-24-15

Review Notes: [23] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [24]	J. MATTHEWS	[signature]	4/24/2015
Exelon Reviewer: [25]	WAHHAJ IRFAN	[signature]	04/27/15

Independent 3[rd] Party Review Reqd? [26] Yes ☐ No ☒

	Print Name	Sign Name	Date
Exelon Approver: [27]	F.P. PIRIANO	[signature]	04/29/2015

ATTACHMENT 2
Owner's Acceptance Review Checklist for External Design Analyses
Page 1 of 3

Design Analysis No.: 19-AN-29 Rev: 002C

No	Question	Instructions and Guidance	Yes / No / N/A
1	Do assumptions have sufficient documented rationale?	All Assumptions should be stated in clear terms with enough justification to confirm that the assumption is conservative. For example, 1) the exact value of a particular parameter may not be known or that parameter may be known to vary over the range of conditions covered by the Calculation. It is appropriate to represent or bound the parameter with an assumed value. 2) The predicted performance of a specific piece of equipment in lieu of actual test data. It is appropriate to use the documented opinion/position of a recognized expert on that equipment to represent predicted equipment performance. Consideration should also be given as to any qualification testing that may be needed to validate the Assumptions. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☑ ☐ ☐
2	Are assumptions compatible with the way the plant is operated and with the licensing basis?	Ensure the documentation for source and rationale for the assumption supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters. If the Analysis purpose is to establish a new licensing basis, this question can be answered yes, if the assumption supports that new basis.	☑ ☐ ☐
3	Do all unverified assumptions have a tracking and closure mechanism in place?	If there are unverified assumptions without a tracking mechanism indicated, then create the tracking item either through an ATI or a work order attached to the implementing WO. Due dates for these actions need to support verification prior to the analysis becoming operational or the resultant plant change being op authorized.	☐ ☐ ☑
4	Do the design inputs have sufficient rationale?	The origin of the input, or the source should be identified and be readily retrievable within Exelon's documentation system. If not, then the source should be attached to the analysis. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☑ ☐ ☐
5	Are design inputs correct and reasonable with critical parameters identified, if appropriate?	The expectation is that an Exelon Engineer should be able to clearly understand which input parameters are critical to the outcome of the analysis. That is, what is the impact of a change in the parameter to the results of the analysis? If the impact is large, then that parameter is critical.	☑ ☐ ☐
6	Are design inputs compatible with the way the plant is operated and with the licensing basis?	Ensure the documentation for source and rationale for the inputs supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters.	☑ ☐ ☐

ATTACHMENT 2
Owner's Acceptance Review Checklist for External Design Analyses
Page 2 of 3

Design Analysis No.: 19-AN-29 Rev: 002C

No	Question	Instructions and Guidance	Yes / No / N/A
7	Are Engineering Judgments clearly documented and justified?	See Section 2.13 in CC-AA-309 for the attributes that are sufficient to justify Engineering Judgment. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☐ ☐ ☑
8	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	Ensure the justification for the engineering judgment supports the way the plant is currently or will be operated post change and is not in conflict with any design parameters. If the Analysis purpose is to establish a new licensing basis, then this question can be answered yes, if the judgment supports that new basis.	☐ ☐ ☑
9	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	Why was the analysis being performed? Does the stated purpose match the expectation from Exelon on the proposed application of the results? If yes, then the analysis meets the needs of the contract.	☑ ☐ ☐
10	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	Make sure that the results support the UFSAR defined system design and operating conditions, or they support a proposed change to those conditions. If the analysis supports a change, are all of the other changing documents included on the cover sheet as impacted documents?	☑ ☐ ☐
11	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	Does the analysis support a temporary condition or procedure change? Make sure that any other documents needing to be updated are included and clearly delineated in the design analysis. Make sure that the cover sheet includes the other documents where the results of this analysis provide the input.	☑ ☐ ☐
12	Have margin impacts been identified and documented appropriately for any negative impacts (Reference ER-AA-2007)?	Make sure that the impacts to margin are clearly shown within the body of the analysis. If the analysis results in reduced margins ensure that this has been appropriately dispositioned in the EC being used to issue the analysis.	☐ ☐ ☑
13	Does the Design Analysis include the applicable design basis documentation?	Are there sufficient documents included to support the sources of input, and other reference material that is not readily retrievable in Exelon controlled Documents?	☑ ☐ ☐
14	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	Determine if sufficient searches have been performed to identify any related analyses that need to be revised along with the base analysis. It may be necessary to perform some basic searches to validate this.	☑ ☐ ☐
15	Do the sources of inputs and analysis methodology used meet committed technical and regulatory requirements?	Compare any referenced codes and standards to the current design basis and ensure that any differences are reconciled. If the input sources or analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code	☑ ☐ ☐

ATTACHMENT 2
Owner's Acceptance Review Checklist for External Design Analyses
Page 3 of 3

Design Analysis No.: 19-AN-29 Rev:002C

No	Question	Instructions and Guidance	Yes / No / N/A
16	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	Based on the risk assessment performed during the pre-job brief for the analysis (per HU-AA-1212), ensure that sufficient reviews of any supporting documents not provided with the final analysis are performed.	☑ Yes ☐ No ☐ N/A
17	Do operational limits support assumptions and inputs?	Ensure the Tech Specs, Operating Procedures, etc. contain operational limits that support the analysis assumptions and inputs.	☑ Yes ☐ No ☐ N/A

Create an SFMS entry as required by CC-AA-4008. SFMS Number: 49726

DESIGN ANALYSIS TABLE OF CONTENTS

1.0 PURPOSE

The normal (non-accident) time delay associated with the degraded grid voltage relays (DVR) could allow the voltage at the 4.16kV level to remain at extremely low levels for an extended period as long as 5 minutes and 40 seconds (Section 3.3.5.2 of Ref. 4.16). To ensure that the safety-related motors will be available and undamaged, new low degraded voltage, definite time relays are installed. This revision establishes a setpoint for the new low degraded voltage relays below the existing second-level DVRs and above the first-level loss of voltage relays on 4.16kV ESF Buses 141, 142, 241, and 242.

The accuracy of the relay, the relay setting tolerance, and the accuracy of any associated components are considered when establishing the setpoint for the newly installed relay.

Analytical limits are developed in this calculation for the voltage and time delay settings.

This calculation supersedes Calculation 19-AN-29, Rev. 002B in its entirety.

2.0 INPUTS

2.1 Monitoring Circuit Elements

2.1.1 Potential Transformers (Ref. 4.3)

Type	Westinghouse Model 9146D46G02
Voltage Ratio	4200 – 120V
Accuracy Class	0.3W, X, Y and 1.2 Z

The PT error and PT ratio used in the calculations in Section 8 are derived from the input data as follows:

$$PT\_error = 1 - \frac{Accuracy\_Class}{100} = 1 - \frac{0.3}{100} = 0.997$$

$$PT\_ratio = \frac{4200}{120} = 35$$

2.1.2 4.16kV ESF Motor Breakdown Torques

Motor	**Rated Voltage (V)**	**BHP (HP)**	**Rated HP (HP)**	**Running Load % (Worst Case)**	**Rated Full Load Torque (FLT) LB-ft**	**Breakdown Torque (BDT) LB-ft**	**BDT/ FLT**	**Reference #**
Aux. Bldg. Vent Sys. Exh Fans	4000	444	500	88.8%	2209	5478	248%	4.4, 4.8, & 4.9
Component Cooling Pumps	4000	400	450	88.9%	-	-	238%	4.4, 4.8, & 4.9
Centrifugal Charging Pumps	4000	560	600	93.4%	-	-	270%	4.4, 4.8, & 4.9

Motor	Rated Voltage (V)	BHP (HP)	Rated HP (HP)	Running Load % (Worst Case)	Rated Full Load Torque (FLT) LB-ft	Breakdown Torque (BDT) LB-ft	BDT/ FLT	Reference #
Aux. Bldg. Vent Sys. Sup. Fans	4000	298	350	85.2%	1030	2750	267%	4.4, 4.8, & 4.9
Containment Spray Pumps	4000	0	600	0%	1760	4360	248%	4.14, 4.8, & 4.9
Aux. FW Pumps	4000	0	1250	0%	1840	4960	270%	4.13, 4.8, & 4.9
RHR Pumps	4000	0	400	0%	-	-	266%	4.4, 4.8, & 4.9
SI Pumps	4000	0	400	0%	-	-	262%	4.4, 4.8, & 4.9
ESW Pumps	4000	1265	1250	101.2%	7407	-	250%	4.15, 4.8, & 4.9
Control Room Chillers	4000	340	461	73.8%	473	1155	244%	4.4, 4.8, & 4.9

(Note, BHP and Rated HP values taken from ELMS, see Appendix C, pages CC7-CC8, CC38-CC39, CC69-CC70, and CC97-CC98)

2.1.3 460V ESF Motor Breakdown Torques

2.1.3.1 The 460V ESF motors' breakdown torque to rated torque ratio is 200% and is addressed in Assumption 3.2.2.

2.1.3.2 The 460V Control Room HVAC Return Fans (0VC02CA & 0VC02CB) have a breakdown torque of 225% of motor rated torque. (Ref. 4.35)

2.1.4 ABB ITE-27N Undervoltage Relay

From the base calculation (Ref. 4.21), the 27N relay (catalog number 411T4375-L-HF-DP) has the following characteristics: the pickup/dropout ratio is 0.5%, and the relay is equipped with a harmonic filter (Reference 4.21. Pages 5 and 16). The 27N relays added per EC's 392851 and 392216 (Refs. 4.11-4.12) are catalog number 411T6375-L-HF-DP and have an adjustable time delay dropout from 0.1-1 seconds (Ref. 4.6. Page 4). The time delay error is equal to the greater of ± 10% or ± 20 milliseconds. (Ref. 4.6, Page 5)

2.1.5 NTS Series 812 Timing Relay

The relays are accurate to 2% of the setpoint over the entire operating range. The Series 812 relays, added per EC's 392851 and 392216 (Refs. 4.11-4.12), are Model 812-1-6-02-O and have an operating range of 0.5 – 5 seconds (Ref. 4.22).

2.1.6 ELMS-AC Plus Files for Braidwood Units 1 and 2 (Refs. 4.7-4.9).

2.1.7 EC 389241 Rev. 009, "Degraded Voltage 5 Minute Timer Resolution – Unit 1" (Ref. 4.5).

2.1.8 The brake horsepower values were revised for twenty ventilation fans that are modeled as normally running loads. The brake horsepower values were revised due to the installation of HELB dampers in the ventilation fan flow paths. The fans and their associated brake horsepower values are shown in the following table (Ref. 4.36). The ELMS files (Refs. 4.8 and 4.9) are modified to reflect these values.

Elec Equipment	Equipment ID	Rated HP	BHP	Ref.	ELMS Load No.	Div.	MCC
Elec Equipment Rm Vent Fan	1VE01C	50	45.3	4.36.2	895	12	132X4
Elec Equipment Rm Vent Fan	2VE01C	50	45.1	4.36.4	710	22	232X4
Battery Rm Exhaust Fan	1VE02C	3	2.3	4.36.2	888	12	132X4
Battery Rm Exhaust Fan	2VE02C	3	2.4	4.36.4	703	22	232X4
Battery Rm Exhaust Fan	1VE03C	3	2.4	4.36.1	355	11	131X5
Battery Rm Exhaust Fan	2VE03C	3	2.6	4.36.3	303	21	231X5
Misc Elec Equipment Rm Vent Fan	1VE04C	5	3.3	4.36.1	346	11	131X4
Misc Elec Equipment Rm Vent Fan	2VE04C	5	3.7	4.36.3	296	21	231X4
Misc Elec Equipment Rm Vent Fan	1VE05C	7.5	7.1	4.36.2	927	12	132X5
Misc Elec Equipment Rm Vent Fan	2VE05C	7.5	7.2	4.36.4	737	22	232X5
ESF Swgr Rm Cable Tunnel Vent Fan	1VX01C	50	49.4	4.36.2	839	12	132X2
ESF Swgr Rm Cable Tunnel Vent Fan	2VX01C	50	42.0	4.36.4	659	22	232X2
Cable Spreading Rm Vent Fan	1VX03C	40	41.2	4.36.2	894	12	132X4
Cable Spreading Rm Vent Fan	2VX03C	40	35.9	4.36.4	709	22	232X4
ESF Swgr Rm Vent Fan	1VX04C	50	51.9	4.36.1	356	11	131X5
ESF Swgr Rm Vent Fan	2VX04C	50	50.7	4.36.3	304	21	231X5
EDG Rm Exhaust Fan	1VD03CA	3	2.8	4.36.5	329	11	131X3
EDG Rm Exhaust Fan	1VD03CB	3	2.4	4.36.6	868	12	132X3
EDG Rm Exhaust Fan	2VD03CA	3	2.9	4.36.7	281	21	231X3
EDG Rm Exhaust Fan	2VD03CB	3	2.8	4.36.8	686	22	232X3

2.1.9 A summary table of the load changes to the input ELMS-AC files (Refs. 4.8 and 4.9) for Conditions 2 and 3 are listed in Appendix E. These changes are shown on the marked-up ELMS-AC reports (Refs. 4.8 and 4.9) in Appendix C.

3.0 ASSUMPTIONS

3.1 Assumptions Requiring Verification

None.

3.2 Assumptions NOT Requiring Verification

3.2.1 It is assumed that onsite events, such as large motor starts, will cause larger transients in onsite system voltages than events elsewhere in the offsite electrical system. The strength and stability of the offsite electrical system is routinely evaluated considering various transients to ensure its adequacy to support the onsite distribution system.

3.2.2 At the 480V level, the breakdown torque of each of the Class 1E motors, with the exception of the Control Room HVAC Return Fans (See Section 2.1.3.2), is assumed to be 200% of the rated running torque. This is the

minimum required by NEMA Standard MG 1-1978 (Ref. 4.2) for Design A and B motors ≤ 200HP. This is acceptable for Braidwood Station since the safety-related motors at the 480V level are less than 200HP.

3.2.3 It is assumed that the brake horsepower of the Control Room HVAC Return Fans (0VC02CA and 0VC02CB) is 49HP. The existing ELMS-AC files model a brake horsepower of 33HP for the Control Room HVAC Return Fans. Calculation VC-208 shows that the system is capable of operating at 49 HP; therefore, a bounding brake horsepower of 49HP is used.

4.0 REFERENCES

4.1 NUREG-0800, Standard Review Plan, Chapter 8, Branch Technical Position PSB-1, Rev. 0, July 1981.

4.2 NEMA MG 1-1978, Part 12 (Appendix B, Page CB2).

4.3 S&L DIT No. BB-EPED-0178-01, dated 6-5-1992, ITE-27N Undervoltage Relay and Potential Transformer Data (Appendix B, Page CB3.0-CB3.2).

4.4 Calculation 19-AN-3, Rev. 16, "Protective Relay Settings for 4.16kV ESF Switchgear."

4.5 EC 389241 Rev. 009, "Degraded Voltage 5 Minute Timer Resolution – Unit 1"

4.6 ABB IB 7.4.1.7-7 Issue E, Instructions Single Phase Voltage Relays.

4.7 Exelon TODI DIT-BRW-2013-0017, Rev. 01, ELMS File Revision Information (Appendix B, Page CB10).

4.8 ELMS-AC PLUS modification files for Braidwood – Unit 1; A1A4141.MA2 and A1A4142.MA2.

4.9 ELMS-AC PLUS modification files for Braidwood – Unit 2; A2A4241.M77 and A2A4242.M77.

4.10 Station Drawing 20E-1-4001A, Rev Q, "Station One Line Diagram."

4.11 EC 392851 Rev. 003, "Degraded Voltage 5 Minute Timer Resolution – Unit 1."

4.12 EC 392216 Rev. 005, "Degraded Voltage 5 Minute Timer Resolution – Unit 2."

4.13 Vendor Drawing 664834, Westinghouse Speed vs. Torque, Load Torque vs. Speed, Speed vs. Current Curves (Appendix B, Page CB4).

4.14 Vendor Drawing 664832, Westinghouse Speed vs. Torque, Load Torque vs. Speed, Speed vs. Current Curves (Appendix B, Page CB5).

4.15 Vendor Drawing DHC770322-1, ESW Pump Motors (Appendix B, Page CB6).

4.16 Technical Specification 3.3.5, Amendment 165, Loss of Power (LOP) Diesel

Generator (DG) Start Instrumentation.

4.17 Station Drawing 20E-1-4030AP30, Rev. T, Schematic Diagram 4160V ESF Switchgear Bus 141 Undervoltage Relays – PR9A-427-B141 & PR9C-427-B141, PR29A-427-ST11 & PR29C-427-ST11.

4.18 Station Drawing 20E-1-4030AP39, Rev. S, Schematic Diagram 4160V ESF Switchgear Bus 142 Undervoltage Relays – PR10A-427-B142 & PR10C-427-B142, PR32A-427-ST12 & PR32C-427-ST12.

4.19 Station Drawing 20E-2-4030AP30, Rev. R, Schematic Diagram 4160V ESF Switchgear Bus 241 Undervoltage Relays – PR31A-427-B241 & PR31C-427-B241, PR11A-427-ST21 & PR11C-427-ST21.

4.20 Station Drawing 20E-2-4030AP39, Rev. R, Schematic Diagram 4160 ESF Switchgear Bus 242 Undervoltage Relays – PR29A-427-B242 & PR29C-427-B242, PR5A-427-ST22 & PR5C-427-ST22.

4.21 Calculation 19-AN-29, Rev. 002, Calc. for Second-Level Undervoltage Relay Setpoint.

4.22 NTS Manual No. 812-01, NTS Series 812 Timing Relay, March 1999 (Appendix B, Pages CB7-CB-8).

4.23 IEEE Std. 141-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (Appendix B, Page CB9).

4.24 Procedure MA-MW-772-799, Rev. 004, "Acceptance Criteria for Protective Relays."

4.25 Station Drawing 20E-1-4002C, Rev. S, Single Line Diagram 4.16kV Switchgear Bus 141 & 143 Diesel Generator 1A & 480V Switchgear.

4.26 Calculation 19-AN-7, Rev. 11, Protective Relay Settings for 4.16kV ESF Switchgear.

4.27 Calculation 19-AQ-63, Rev. 007, "Division Specific Degraded Voltage Analysis".

4.28 EC 393032 Rev. 002, "Affected Relay Setting Orders (RSO) and Thermal Overloads (TOL) for DVR Project – U1 & U2".

4.29 Calculation 19-AU-4, Rev. 18, "480V Unit Substation Breaker and Relay Settings".

4.30 Calculation 19-AU-5, Rev. 13, "480V Unit Substation Breaker and Relay Settings".

4.31 EC 357385 Rev. 000, "Evaluation of AP System Block Start Capability" (Braidwood).

4.32 EC 365038 Rev. 000, "Evaluation of AP System Block Start Capability" (Byron).

4.33 Calculation 19-AK-4, Rev. 002, "ELMS-AC Plus Project Specific Implementation".

4.34 Calculation 19-AN-3, Rev. 16H, "Protective Relay Settings for 4.16kV ESF Switchgear."

4.35 Reliance A-C Motor Performance Data No. E0111A-B-007, Dated 06/10/77 (Appendix B, Page CB13)

4.36 Technical Evaluations

4.36.1 EC 394912 Rev. 0, "Evaluation of Integrated Testing of VD, VE, and VX Systems for EC's 388398, 388397, and 388742. 1VD01CA, 1VE03C, 1VE04C, 1VX04C, and 1VX02C Fans"

4.36.2 EC 394915 Rev. 0, "Evaluation of Integrated Testing of VD, VE, and VX Systems for EC's 388398, 388397, and 388742. 1VD01CB, 1VE02C, 1VE01C, 1VX03C, 1VX01C, AND 1VE05C Fans"

4.36.3 EC 394921 Rev. 0, "Evaluation of Integrated Testing of VD, VE, and VX Systems for EC's 388948, 388947, and 389635. 2VD01CA, 2VE03C, 2VE04C, 2VX04C, and 2VX02C Fans"

4.36.4 EC 394923 Rev. 0, "Evaluation of Integrated Testing of VD, VE, and VX Systems for EC's 388948, 388947, and 389635. 2VE01C, 2VE02C, 2VE05C, 2VX01C, 2VX03C, and 2VD01CB"

4.36.5 EC 394964 Rev. 0, "Evaluation of 1VD03CA and Division 11 Diesel Generator Ventilation System Integrated Testing for EC 392191 and EC 388398"

4.36.6 EC 394742 Rev. 0, "Evaluation of 1VD03CB and Division 12 Diesel Generator Ventilation System Integrated Testing for EC 392191 HELB Project"

4.36.7 EC 394633 Rev. 0, "Evaluation of 2VD03CA and Division 21 Diesel Generator Ventilation System Integrated Testing for EC 392192"

4.36.8 EC 394749 Rev. 0, "Evaluation of 2VD03CB and Division 22 Diesel Generator Ventilation System Integrated Testing for EC 392192 HELB Project"

4.37 Calculation VC-208, Rev. 000, "System Pressure Drop Change Due to Relocation of Makeup Air Intakes"

5.0 IDENTIFICATION OF COMPUTER PROGRAMS

5.1 Microsoft Word 2003 (Text only), S&L Computer No. ZD6585, Program No. 03.2.286-1.0.

5.2 Advanced AC Electrical Load Monitoring System (ELMS-AC PLUS) Ver. 1.2, S&L Computer No. 8809, Program No. 03.7.379-1.2. (See Appendix F for ELMS Audit Trail Information)

5.3 Mathcad Version 14.35, S&L Computer No. ZD6585, Program No. 03.7.548-1435. (See Appendix F for Mathcad Audit Trail Information)

5.4 ETAP PowerStation Version 7.0.0N S&L Computer No. ZD6585, Program No. 03.7.696-7.00. (See Appendix F for ETAP Audit Trail Information)

6.0 METHOD OF ANALYSIS

The new relays (low degraded voltage) are harmonically filtered ABB 27N undervoltage relays, which are the same as the existing DVRs (2nd level) and mounted in the same location (Aux. PT & Relay Compartment of the associated switchgear), and therefore use the same methodology used in the base revision of this calculation to calculate the tolerances used to determine the relay setpoint.

The overcurrent protection on the 4.16kV and 480V system motors is set to trip the breakers and thermal overload heaters to protect the Class 1E motors from being damaged. The motor trip setting coordination is addressed in separate analyses as described in the remainder of this paragraph. The protective relay settings for the 4.16kV ESF Switchgear loads are analyzed in Calculations 19-AN-3 & 19-AN-7 (Units 1 & 2, respectively, Refs. 4.4 and 4.26), and the 480V Switchgear loads are analyzed in Calculations 19-AU-4 & 19-AU-5 (Units 1 & 2, respectively, Refs. 4.29 and 4.30). The thermal overload settings for the low voltage motors, under normal operating conditions at a reduced bus voltage, are addressed in EC 393032 (Ref. 4.28).

6.1 <u>Minimum Allowable Value</u>

The setpoint for the new low degraded voltage relays must be high enough to prevent the stalling, damaging, and tripping of loads (due to actuation of overcurrent protection devices).

6.1.1 The most limiting ESF motor ratio of breakdown torque to running torque will be determined.

6.1.2 Using Equation 6.1.2, the breakdown torque will be determined for lowered system voltages.

$$\%T_{BD @ V_{reduced}} = \left(\frac{V_{reduced}}{V_{rated}}\right)^2 \times \%T_{BD @ V_{rated}} \quad \text{Equation 6.1.2}$$

6.1.3 The lowest voltage at each 4.16kV ESF bus that supports an acceptable breakdown torque will be determined by iteration using ELMS-AC PLUS.

6.1.4 In order to preclude ESF motor stalling, the worst case (highest) of the voltages determined using the methodology from Section 6.1.3 is used as the analytical limit when determining the new low degraded voltage relay setpoint. The ELMS-AC model will be revised to model the applicable ESF Loads that are normally running, as identified in EC 393032 (Ref. 4.28). In addition, the ELMS-AC model will be revised to model the ventilation fan loads as identified in Input 2.1.8. A summary of all changes is shown in Appendix E. Conditions 2 and 3 in the station ELMS-AC load-flow models (Refs. 4.8, 4.9, and 4.33) represent maximum summer and

winter loading under normal operating conditions, respectively. Both Conditions 2 and 3 with Source 2 (SAT supply) will be analyzed to determine the minimum allowable setpoint value.

6.2 Maximum Allowable Value

The function of the low degraded voltage relay is to ensure that equipment is not damaged by prolonged exposure to extremely low voltages. The maximum allowable voltage is such that the DVRs do not operate if the ESF motors block start following an SI signal. The chosen setpoint is analyzed to ensure that the relay will not spuriously actuate during a block start.

The setpoint will be chosen based on the value determined using the methodology of Section VIII of the base calculation.

6.3 Time Delay Setting

Section 8.3 of the Braidwood UFSAR states that the 4.16kV ESF buses are protected from faults via relays (Westinghouse CO series overcurrent relays, Table 8.3-6) to disconnect faults with minimum system disturbance. Thus, the initial time delay associated with the low degraded voltage relays should allow the overcurrent relays to clear faults prior to tripping the bus. The low degraded voltage time delay setpoint is based on the following consideration. The time needed for a 4.16kV circuit breaker to clear a high impedance fault on a 480V bus will be longer than the time needed to clear a faulted 4.16kV bus. Therefore, Appendix D of this calculation determines the maximum fault clearing time for a 4.16kV circuit breaker based on a high impedance fault on a 480V bus fed from a protected 4.16kV ESF bus. This is used as a starting point to determine the initial setpoint, which ultimately must be long enough to prevent spurious trips from system transients and short enough to prevent equipment damage. Additional time delay is added for margin. The methodology used in Appendix D is as follows:

6.3.1 Using the ELMS-AC models, the division (11, 12, 21, or 22) with the highest impedance is selected to determine the longest fault clearing time.

6.3.2 The phase-to-phase fault current is calculated using a simplified ETAP model (created from the ELMS AC files) and reduced to account for an arcing fault via Ref. 4.23.

6.3.3 The phase-to-phase fault current on the 4.16kV bus is compared to the trip curve for the CO-9 overcurrent relay to determine the fault clearing time (Page H12 of Ref. 4.4).

7.0 ACCEPTANCE CRITERIA

7.1 Low Degraded Voltage Relay

Consistent with industry practice, the ultimate tripping point of the low degraded voltage relay setpoint should meet the following requirements:

7.1.1 The setpoint should be high enough to prevent the stalling of normally running Class 1E motors due to low voltage.

7.1.2 The setpoint should be high enough to prevent damage and to prevent tripping due to actuation of overcurrent devices for normally running Class 1E loads with overcurrent devices that require manual reset. This acceptance criterion is addressed in Calculation 19-AN-3 (Ref. 4.34) and in EC 393032 (Ref. 4.28).

7.1.3 The setpoint should be low enough to prevent spurious actuation during transients such as those experienced during the starting of a large plant motor or during the block starting of ESF motors following an SI initiation.

7.1.4 The time delay setpoint should be long enough to prevent spurious tripping during faults and to allow the overcurrent protective devices to clear faults prior to tripping the bus on low degraded voltage.

7.1.5 The time delay setpoint should be short enough to protect the motors with protective devices requiring manual reset from tripping on overload due to prolonged exposure to low bus voltage.

8.0 CALCULATIONS AND RESULTS

8.1 The minimum allowable voltage for the new low degraded voltage relay actuation has been selected as follows:

8.1.1 Selection of Limiting Breakdown Torque

8.1.1.1 Motors running at reduced voltages have reduced torque output proportional to the square of the voltage ratio. Therefore, Equation 6.1.2 is used to determine the breakdown torque at reduced voltage.

$$\%T_{BD@Vreduced} = \left(\frac{V_{reduced}}{V_{rated}}\right)^2 \times \%T_{BD@Vrated}$$

The minimum allowable voltage to preclude motor stall at the 4.16kV level has been determined as follows:

$$V_{min\_allowed} = 4000\sqrt{\frac{\%T_{BD@Vreduced}}{\%T_{BD@Vrated}}}$$

(See Section 2.1.2 for Table Input)

Motor	BHP (HP)	Rated HP (HP)	$T_{BD@Vrated}$ (%)	$T_{BD@Vreduced}$* (%)	$V_{min\_allowed}$ (V)
Aux. Bldg. Vent Sys. Exh. Fans	444	500	248%	100%	2540.0
Component Cooling Pumps	400	450	238%	100%	2592.8
Centrifugal Charging Pumps	560	600	270%	100%	2434.3
Aux. Bldg. Vent Sys. Sup. Fans	298	350	267%	100%	2448.0
Containment Spray Pumps	0	600	248%	100%	2540.0
Aux. FW Pumps	0	1250	270%	100%	2434.3
RHR Pumps	0	400	266%	100%	2452.6
SI Pumps	0	400	262%	100%	2471.2
ESW Pumps	1265	1250	250%	101.2%	2545.0
Control Room Chillers	340	461	244%	100%	2560.7

*$T_{BD@reduced}$ is proportional to the motor BHP from References 4.8 & 4.9. For motors below rated HP, 100% torque is used for conservatism.

At a reduced voltage of 2592.8V (64.8% of 4000V), the breakdown torque will equal the running torque for the Component Cooling Pumps. This bounds the 4.16kV system motors.

8.1.1.2 Per Assumption 3.2.2, the minimum breakdown torque for the Class 1E motors at the 480V level is 200%.

8.1.1.3 Motors running at reduced voltages have reduced torque output proportional to the square of the voltage ratio.

$$\%T_{BD\ @\ Vreduced} = \left(\frac{V_{reduced}}{V_{rated}}\right)^2 \times \%T_{BD\ @\ Vrated}$$

The minimum allowable voltage to preclude motor stall at the 480V level, for motors running at or below full load, has been determined as follows:

$$\%T_{BD\ @\ Vreduced} = 100 = \left(\frac{\text{VMinAllow460V}}{460\text{V}}\right)^2 \times 200$$

$$\Rightarrow V_{MinAllow460V} = 325.3\text{V}$$

Based on a review of the ELMS files, five low voltage motors are running above rated horsepower. The minimum voltages to preclude stalling for motors that are running above rated motor horsepower are calculated in the following table. The breakdown torques of the motors are taken from Input 2.1.3.

Equipment ID	Rated HP	BHP	$T_{BD@Vrated}$ (%)	$T_{BD@Vreduced}$* (%)	$V_{min\_allowed}$ (V)	Div.	Limiting Component
1VX03C	40	41.2	200	103	330.1	12	
1VX04C	50	51.9	200	103.8	331.4	11	
2VX04C	50	50.7	200	101.4	327.5	21	
0VC02CA	40	49	225	122.5	339.4	11	Div. 11
0VC02CB	40	49	225	122.5	339.4	12	Div. 12

*$T_{BD@Vreduced}$ is proportional to the motor BHP

Other limiting cases are listed below:

Equipment ID	$V_{min\_allowed}$ (V)	Div.	Limiting Component
2DG01KA-A	325.3	21	Div. 21
2VE05C	325.3	22	Div. 22

8.1.1.4 The station ELMS model has been analyzed to determine the 4.16kV ESF bus voltage required to ensure that the terminal voltages at all motors are above the minimum allowable values determined in Sections 8.1.1.1 and 8.1.1.3. The voltage was iterated down, for each division, until the terminal voltage at any one of the motors on that division reached its minimum allowable value. From Appendix A page CA1, the minimum required voltage on each of the four buses, 141, 142, 241, & 242, are 3136.9V, 3171.4V, 2987.7V, and 3030.7V, respectively; therefore, the highest minimum voltage required on all four buses (141, 142, 241, & 242) is determined to be 3171.4V, which is the analytical limit. An additional 25V of margin is added for conservatism and therefore 3196.4V (3196.4V/35 = 91.33V, PT secondary voltage) is determined to be the Minimum Allowable Value.

8.1.1.5 Voltage Setpoint

4.16kV Buses 141 (Div. 11), 142 (Div. 12), 241 (Div. 21), and 242 (Div. 22).

The Total Negative Error and Total Positive Error in the base calculation is based on a nominal relay setpoint near 110V. The low degraded voltage relay will be set near 90V and therefore these errors are recalculated.

The calibration error is recalculated for a nominal relay setpoint near 90V in accordance with Section IX.B.2 of the base calculation:

2*σ reference accuracy = ±0.2% of reading + 10 least significant digits, where each digit corresponds to 0.01V

(10*0.01V) / 90V = 0.111%

The 2*σ reference accuracy is 0.2% + 0.111% = 0.311%

Thus, σ for calibration error is 0.156%

The relay setting tolerance is recalculated for a nominal relay setpoint near 90V in accordance with Sections VI.A.1 and IX.B.5 of the base calculation:

For a ±0.2V setting tolerance, the random error is 0.2V/90V = 0.222%

Thus, σ for the setting tolerance is 0.111%

The Total Error is recalculated in accordance with Section IX.C of the base calculation using the new calibration instrument error and relay setting tolerance values calculated above:

$$\text{Random Error} = \sqrt{(0.05\%)^2 + (0.156\%)^2 + (0.111\%)^2}$$
$$= 0.198\%$$

The base calculation determined the negative and positive non-random error to be 1.055% and 0.544%, respectively.

The Total Error is calculated using the following equation:

Total = Non-Random +2*Random

Total Negative Error (TNE) = 1.06% +2*0.198% = 1.46%
Total Positive Error (TPE) = 0.54% +2*0.198% = 0.94%

Nominal Relay Dropout Setpoint = Minimum Relay Dropout (MRD) + Total Negative Error (in percent of nominal relay dropout setpoint, from Section IX.D of the base calculation). The minimum allowable value as determined in Section 8.1.1.5 is 3196.4V. Therefore, the MRD = 3196.4V/35 = 91.33V

Nominal Relay Dropout = MRD / (1-TNE)
= 91.33 / (1-0.0146)
= 92.69V

Therefore, the new LDVR setpoint is 92.69V. This equates to 92.69V*35 (PT Ratio) = 3244.15V.

8.1.1.6 Time Delay Setting

The LDVR time delay setting needs to be long enough to prevent spurious tripping, and short enough to protect the motors from overload tripping and lockout due to prolonged exposure to low bus voltage (low degraded voltage). The LDVR should trip before overload relays for a sustained low bus voltage condition

Minimum Setting Criteria

Section 8.3 of the Braidwood UFSAR states that the 4.16kV ESF buses are protected from faults via relays (Westinghouse CO series overcurrent relays, Table 8.3-6) to disconnect faults with minimum system disturbance. Thus, the initial time delay associated with the low degraded voltage relays should allow the overcurrent relays to clear faults prior to tripping the bus. Appendix D of this calculation determines the maximum fault clearing time for a 4.16kV circuit breaker based on a high impedance fault on a 480V bus fed from a protected 4.16kV ESF bus. The longest fault clearing time has been determined to be approximately 1 second, with additional margin of 2 seconds to establish the nominal setpoint (3 seconds) and allow time for the bus voltage to recover. The contacts of the new low degraded voltage relays that are part of the trip circuit are connected in series with a new NTS time delay relay connected to prevent spurious 4.16kV bus trips when repowering a dead bus (Refs. 4.11 and 4.12).

The total time delay setpoint for the LDVR and NTS time delay relay is 3 seconds. The LDVRs will have a time delay of 0.5 second and the NTS time delay relays will have a time delay of 2.5 seconds.

The time delay tolerance is taken from Sections 2.1.4 and 2.1.5 and the total time delay error is calculated below:

TPE = TNE = (LDVR time delay * tol.) + (NTS time delay * tol.)

= 0.5s * 10% + 2.5s * 2% = 0.1s

Maximum Setting Criteria

The 4kV and 480V ESF motors are protected from damage, due to overcurrent, by thermal overload (TOL) relays and phase overcurrent relays. The maximum LDVR time delay is evaluated below to ensure coordination with the motor overcurrent protection.

The WO MCR chillers are the only normally running 4.16kV loads running on Buses 141, 142, 241, and 242 that lockout following a trip. The 480V MCC motor loads have thermal overload relays that lockout following a trip. The remaining 4.16kV loads and 480V switchgear loads will restart if tripped on overcurrent prior to the LDVRs disconnecting the associated bus (Ref. 4.28).

Calculation 19-AN-3, Rev. 16H (Ref. 4.34) establishes that the WO MCR Chiller motor overcurrent relay, with a pickup of 146% of full load current, does not trip at the LDVR analytical limit. For a sustained undervoltage at the Loss of Voltage

Relay allowable value of 65.6% (Section 3.3.5.2 of Ref. 4.16), full load current for the motors would be 1/(65.6%) = 152.4%. Even at a full load current of 250%, the WO MCR chiller motor CO-5 relay would trip in approximately 5 seconds. The TOL trip curves for the 480V MCC loads show a cold start minimum trip time of approximately 25 seconds for 250% of the trip rating. Therefore, the LDVR setting should not be any higher than 5 seconds.

LDVR Time Delay Setting

In order to have margin between the maximum allowable value and the setpoint for the time delay, the maximum allowable value is set at 3.5 seconds. The maximum allowable value of 3.5 seconds is greater than the nominal setpoint (3 seconds) plus the total positive error (0.1 seconds). The LDVR setting of 3.5 seconds is acceptable because it is above the minimum setting and below the maximum setting, with margin for timing tolerances.

8.1.1.7 Maximum Relay Reset

The maximum reset voltage is calculated from the maximum dropout voltage and PU/DO ratio as shown in Section 2.1.4:

Max. Relay Dropout = Nominal Relay Dropout (DO) + TPE (in % of DO)

= 92.69 * (1.0 + 0.0094)

= 93.57V

Max. Relay Pickup = Max. Relay Dropout / PU/DO ratio

= 93.57V / 0.995 = 94.04V

Max. Reset Bus Voltage = 94.04V * 35 = 3291.4V

8.2 Maximum Allowable Setpoint Value

The low degraded voltage relay setpoint chosen in Section 8.1 is analyzed to ensure that the relay will not spuriously actuate during a block motor start. A block start analysis has been performed in EC 389241 (Input 2.1.7) for Byron Divisions 11 & 12 based on the loads listed in Table 8.3-5 of the UFSAR as continuously energized during the initial period. Previous block start analyses in EC Eval 357385 for Braidwood (Ref. 4.31) and EC Eval 365038 for Byron (Ref. 4.32) have shown that Unit 1 is the bounding case for both plants. Furthermore, the results of these EC Evaluations show that the voltages at ESF Buses 141 and 142 are higher at Braidwood than at Byron. This is mainly due to the fact that the Braidwood DVR setpoint (95.8%) is higher than the Byron DVR setpoint (92.5%), which affects the analytical limit for the block start evaluation, as described below. Additionally, comparison of the loads listed in Table 8.3-5 of the UFSAR for Byron and Braidwood shows that the ESF Switchgear load for Byron is higher than for Braidwood. Therefore, the block start analysis performed under EC 389241 (Input 2.1.7) is bounding and can be considered as adequate justification that the new low DVRs will not spuriously actuate during a block start.

In EC 389241 (Input 2.1.7), the block start was run using ELMS Load Condition 4 (LOCA) at the DVR minimum pickup voltage, 0.5% above the analytical limit of bus voltage on the 4.16kV bus (141 and 142) to simulate the lowest possible bus voltage the 4.16 kV bus can recover to post motor start without the DVR transferring the bus to the EDG. The analytical limit voltage at Buses 141 & 142 and the pick up to dropout ratio for the DVR were obtained from the Byron Degraded Voltage Calculation 19-AQ-63 Rev. 7 (Ref. 4.27). This is based on the Byron DVR setpoint, which is lower than the Braidwood DVR setpoint (92.5% compared to 95.8%).

Block starting of loads places a large voltage transient on the AP system from the large starting currents drawn by the various motors. If the voltage drops below the top of the relay tolerance band the new low DVRs could dropout and trip the 4.16kV ESF bus (141 or 142) spuriously. The new low DVR's maximum relay reset voltage, as calculated in Section 8.1 of this calculation, is 94.04V x 35 (PT Ratio) = 3291.4V. The results of the analysis in EC 389241 show that the minimum block start voltage at the 4.16kV buses for Byron Unit 1 is 3425.9V (Input 2.1.7). This is higher than the maximum reset voltage of 3291.4V for the new low DVRs at Braidwood. Since the conditions for Byron Unit 1 are bounding of Braidwood (both units), this is true for Braidwood as well. This is the largest design transient created as a result of plant operations; the voltage dip from a block start will not spuriously cause the new DVRs to actuate.

8.3 Results

With the new LDVR set at 92.69V and 3 seconds, this calculation determined that the LDVRs will actuate prior to any normally running safety-related motors stalling. This satisfies the first acceptance criterion.

Motor protection is analyzed with the LDVRs set at 92.69V and 3 seconds in EC 393032 (Ref. 4.28) and in Calculation 19-AN-3 Rev. 16H (Ref. 4.34). The analyses determined that the motor protection, for loads that will lockout following a trip, will not trip on the normally running, safety-related motors during a degraded voltage condition and that normally running safety-related motors will not be damaged prior to the DVR 5-minute timer transferring the safety-related loads to the emergency diesel generator. This satisfies the second acceptance criterion.

Block starting of the ESF motors following an SI initiation is analyzed with the LDVRs set at 92.69V and 3 seconds. This calculation determined that the LDVRs will not trip due to the voltage transient caused by the block start of ESF motors. This satisfies the third acceptance criterion.

This calculation determined that the LDVR time delay setpoint of 3 seconds is long enough to prevent spurious tripping during faults and to allow the overcurrent protective devices to clear faults prior to tripping the bus on low degraded voltage. This satisfies the fourth acceptance criterion.

This calculation determined that the LDVR time delay setpoint of 3 seconds is short enough to protect the motors with protective devices requiring manual reset from tripping on overload due to prolonged exposure to low bus voltage. This satisfies the fifth acceptance criterion.

9.0 CONCLUSIONS

9.1 Low Degraded Voltage Relay Settings

Based on the acceptance criteria of Section 7.0 and the calculations of Section 8.0, the following relay settings are recommended:

Nom. Relay Dropout Setpoint	= 92.69 V
Nom. Relay Pickup (Reset) Setpoint	= 92.69 V/ 0.995 = 93.16 V
Time Delay Setpoint	= 0.5 second

9.2 Time Delay Relay Setting

Based on the acceptance criteria of Section 7.0 and the calculations of Section 8.0, the following relay setting is recommended:

Time Delay Setpoint	= 2.5 seconds

10.0 APPENDICES

A) ELMS-AC Plus Load Flow Reports

B) Calculation Input

C) ELMS-AC Station File Changes

D) High Impedance Fault Clearing Time

E) Input Changes Listing

F) Audit Trail: ELMS-AC Plus, ETAP, Mathcad

ATTACHMENT 5

BYRON STATION
UNITS 1 AND 2
Docket Nos. 50-454 and 50-455
Facility Operating License Nos. NPF-37 and NPF-66

Calculation 19-AN-28, Revision 001C
"Calc. for Second-Level & Third-Level Undervoltage Relays"

ATTACHMENT 1
Design Analysis Cover Sheet

Design Analysis		**Last Page No.:** [6] Attachment A, Appendix E Page AE3	
Analysis No.: [1] 19-AN-28		**Revision:** [2] 001C Major ☐	Minor ☒
Title: [3] Calc. for Second-Level & Third-Level Undervoltage Relays			
EC/ECR No.: [4] EC 389241 & EC 389242		**Revision:** [5] 009 & 004	
Station(s): [7]	BYR	**Component(s):** [14]	
Unit No.: [8]	1 & 2	1AP05E-462-B141X	
Discipline: [9]	ELDC	1AP06E-462-B142X	
Descrip. Code/Keyword: [10]	E15	2AP05E-T-462-B241X	
Safety/QA Class: [11]	SR	2AP06E-S-462-B242X	
System Code: [12]	AP		
Structure: [13]	N/A		

CONTROLLED DOCUMENT REFERENCES [15]

Document No.:	From/To	Document No.:	From/To
See Section 5 of this calculation			

Is this Design Analysis Safeguards Information? [16] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [17] Yes ☐ No ☒ If yes, ATI/AR#:

This Design Analysis SUPERCEDES: [18] **Calculation 19-AN-28, Rev. 001B** **in its entirety.**

Description of Revision (list changed pages when all pages of original analysis were not changed): [19]

This revision adds a third level of protection to the undervoltage protection scheme via new Low Degraded Voltage Relays (LDVRs), with a lower setpoint than the existing DVRs (Second-Level Undervoltage Protection).

The existing analysis from Revision 001 is not affected; the new third-level undervoltage relays (LDVRs) are added to the analysis. The original body of the calculation is unchanged. As such, only Attachment A and the associated appendices are included as part of this minor revision. This calculation supersedes Calculation 19-AN-28, Rev. 001B in its entirety. Approval from Kevin Passmore (SMDE) for a minor revision to 19-AN-28 was given on 02/03/2015.

	Print Name	Sign Name	Date
Preparer: [20]	J. Kolodziej	James Kolodziej	4/24/15

Method of Review: [21] Detailed Review ☒ Alternate Calculations (attached) ☐ Testing ☐

	Print Name	Sign Name	Date
Reviewer: [22]	G. Hinshaw	Greg A Hinshaw	4-24-15

Review Notes: [23] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [24]	J. MATTHEWS	[signature]	4/24/2015
Exelon Reviewer: [25]	Fred Beutler	Fred Beutler	4/27/2015

Independent 3rd Party Review Reqd? [26] Yes ☐ No ☒

	Print Name	Sign Name	Date
Exelon Approver: [27]	EAKACZMARSKI	EAKaczmarski	04/28/15

ATTACHMENT 2
Owner's Acceptance Review Checklist for External Design Analyses

Design Analysis No.: 19-AN-28 **Rev:** 001C

No	Question	Instructions and Guidance	Yes / No / N/A
1	Do assumptions have sufficient documented rationale?	All Assumptions should be stated in clear terms with enough justification to confirm that the assumption is conservative. For example, 1) the exact value of a particular parameter may not be known or that parameter may be known to vary over the range of conditions covered by the Calculation. It is appropriate to represent or bound the parameter with an assumed value. 2) The predicted performance of a specific piece of equipment in lieu of actual test data. It is appropriate to use the documented opinion/position of a recognized expert on that equipment to represent predicted equipment performance. Consideration should also be given as to any qualification testing that may be needed to validate the Assumptions. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☒ Yes ☐ No ☐ N/A
2	Are assumptions compatible with the way the plant is operated and with the licensing basis?	Ensure the documentation for source and rationale for the assumption supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters. If the Analysis purpose is to establish a new licensing basis, this question can be answered yes, if the assumption supports that new basis.	☒ Yes ☐ No ☐ N/A
3	Do all unverified assumptions have a tracking and closure mechanism in place?	If there are unverified assumptions without a tracking mechanism indicated, then create the tracking item either through an ATI or a work order attached to the implementing WO. Due dates for these actions need to support verification prior to the analysis becoming operational or the resultant plant change being op authorized.	☐ Yes ☐ No ☒ N/A
4	Do the design inputs have sufficient rationale?	The origin of the input, or the source should be identified and be readily retrievable within Exelon's documentation system. If not, then the source should be attached to the analysis. Ask yourself, would you provide more justification if you were performing this analysis? If yes, the rationale is likely incomplete.	☒ Yes ☐ No ☐ N/A
5	Are design inputs correct and reasonable with critical parameters identified, if appropriate?	The expectation is that an Exelon Engineer should be able to clearly understand which input parameters are critical to the outcome of the analysis. That is, what is the impact of a change in the parameter to the results of the analysis? If the impact is large, then that parameter is critical.	☒ Yes ☐ No ☐ N/A
6	Are design inputs compatible with the way the plant is operated and with the licensing basis?	Ensure the documentation for source and rationale for the inputs supports the way the plant is currently or will be operated post change and they are not in conflict with any design parameters.	☒ Yes ☐ No ☐ N/A

ATTACHMENT 2
Owner's Acceptance Review Checklist for External Design Analyses
Page 2 of 3

Design Analysis No.: 19-AN-28 **Rev:**001C

No	Question	Instructions and Guidance	Yes / No / N/A
7	Are Engineering Judgments clearly documented and justified?	See Section 2.13 in CC-AA-309 for the attributes that are sufficient to justify Engineering Judgment. Ask yourself, would you provide more justification if you were performing this analysis? **If** yes, the rationale is likely incomplete.	☐ ☐ ☒
8	Are Engineering Judgments compatible with the way the plant is operated and with the licensing basis?	Ensure the justification for the engineering judgment supports the way the plant is currently or will be operated post change and is not in conflict with any design parameters. **If** the Analysis purpose is to establish a new licensing basis, **then** this question can be answered yes, if the judgment supports that new basis.	☐ ☐ ☒
9	Do the results and conclusions satisfy the purpose and objective of the Design Analysis?	Why was the analysis being performed? Does the stated purpose match the expectation from Exelon on the proposed application of the results? **If** yes, **then** the analysis meets the needs of the contract.	☒ ☐ ☐
10	Are the results and conclusions compatible with the way the plant is operated and with the licensing basis?	Make sure that the results support the UFSAR defined system design and operating conditions, or they support a proposed change to those conditions. If the analysis supports a change, are all of the other changing documents included on the cover sheet as impacted documents?	☒ ☐ ☐
11	Have any limitations on the use of the results been identified and transmitted to the appropriate organizations?	Does the analysis support a temporary condition or procedure change? Make sure that any other documents needing to be updated are included and clearly delineated in the design analysis. Make sure that the cover sheet includes the other documents where the results of this analysis provide the input.	☐ ☐ ☒
12	Have margin impacts been identified and documented appropriately for any negative impacts (Reference ER-AA-2007)?	Make sure that the impacts to margin are clearly shown within the body of the analysis. If the analysis results in reduced margins ensure that this has been appropriately dispositioned in the EC being used to issue the analysis.	☒ ☐ ☐
13	Does the Design Analysis include the applicable design basis documentation?	Are there sufficient documents included to support the sources of input, and other reference material that is not readily retrievable in Exelon controlled Documents?	☒ ☐ ☐
14	Have all affected design analyses been documented on the Affected Documents List (ADL) for the associated Configuration Change?	Determine if sufficient searches have been performed to identify any related analyses that need to be revised along with the base analysis. It may be necessary to perform some basic searches to validate this.	☒ ☐ ☐
15	Do the sources of inputs and analysis methodology used meet committed technical and regulatory requirements?	Compare any referenced codes and standards to the current design basis and ensure that any differences are reconciled. If the input sources or analysis methodology are based on an out-of-date methodology or code, additional reconciliation may be required if the site has since committed to a more recent code	☒ ☐ ☐

ATTACHMENT 2
Owner's Acceptance Review Checklist for External Design Analyses

Design Analysis No.: 19-AN-28 Rev: 001C

No	Question	Instructions and Guidance	Yes / No / N/A
16	Have vendor supporting technical documents and references (including GE DRFs) been reviewed when necessary?	Based on the risk assessment performed during the pre-job brief for the analysis (per HU-AA-1212), ensure that sufficient reviews of any supporting documents not provided with the final analysis are performed.	☒ Yes ☐ No ☐ N/A
17	Do operational limits support assumptions and inputs?	Ensure the Tech Specs, Operating Procedures, etc. contain operational limits that support the analysis assumptions and inputs.	☒ Yes ☐ No ☐ N/A

Create an SFMS entry as required by CC-AA-4008. SFMS Number: 49735

CALCULATION TABLE OF CONTENTS

1.0 PURPOSE

The normal (non-accident) time delay associated with the 4.16 kV ESF bus degraded voltage relays (DVRs) could allow the voltage at the 4.16 kV level to remain at extremely low levels for an extended period as long as 5 minutes and 40 seconds (Section 3.3.5.2 of Ref. 6.16). To ensure that the safety-related motors will be available and undamaged during a degraded grid voltage condition, new definite-time third-level undervoltage relays (i.e., low degraded voltage relays (LDVRs)) are being installed. This revision establishes a voltage setpoint for the new LDVRs that is below the existing second-level undervoltage relays (i.e., DVRs) and above the first-level undervoltage relays (i.e., loss of voltage relays (LVRs)) on the 4.16 kV ESF Buses 141, 142, 241, and 242.

The accuracy of the relay, the relay setting tolerance and the accuracy of any associated components are considered when establishing the setpoint for the newly installed relay.

Analytical limits are developed in this calculation for the voltage and time delay settings.

2.0 METHODOLOGY

The new LDVRs (3rd level) are harmonically filtered ABB 27N undervoltage relays, which are the same as the existing DVRs (2nd level) and are mounted in the same location (Aux. PT & Relay Compartment of the associated switchgear), and therefore use the same methodology used in the base revision of this calculation to calculate the tolerances used to determine the relay setpoint.

The 4.16 kV Switchgear loads are analyzed in Calculations 19-AN-3 & 19-AN-7 (Units 1 & 2 respectively), and the 480V Switchgear loads are analyzed in Calculations 19-AU-4 & 19-AU-5 (Units 1 & 2 respectively). An individual analysis of the overcurrent protection for each low voltage safety-related load, under normal operating conditions at a reduced bus voltage is included in References 6.11 & 6.12.

2.1 Minimum Allowable Value

The setpoint for the new LDVRs must be high enough to prevent the stalling of loads. The setpoint for the new LDVRs must also be high enough to prevent tripping of loads due to actuation of overcurrent devices for loads with overcurrent devices that require manual reset.

2.1.1 The most limiting ESF motor ratio of breakdown torque to running torque will be determined.

2.1.2 Using Equation 2.1.2, the breakdown torque will be determined for lowered system voltages.

$$\%T_{BD\ @\ V_{reduced}} = \left(\frac{V_{reduced}}{V_{rated}}\right)^2 \times \%T_{BD\ @\ V_{rated}} \qquad \text{Equation 2.1.2}$$

2.1.3 The lowest voltage at the ESF 4.16 kV Switchgear buses that supports an acceptable breakdown torque will be determined by iteration using ELMS-AC PLUS.

2.1.4 In order to preclude ESF motor stalling, the worst case (highest) of the voltages determined using the methodology from Section 2.1.3 is used as the analytical limit when

determining the new LDVR setpoint. The ELMS-AC model will be revised to model the applicable ESF loads that are normally running, as identified in Reference 6.10 (shown in Appendix C). In addition, the ELMS-AC model will be revised to model the ventilation fan loads as identified in Input 5.1.7. Conditions 2 and 3 in the station ELMS-AC load-flow models (References 6.8 & 6.9) represent maximum summer and winter loading under normal operating conditions, respectively. This calculation will use Condition 3 for the analysis since the 4.16 kV ESF bus loading is higher for Condition 3.

2.2 Maximum Allowable Value

The function of the LDVR is to ensure that equipment is not damaged by prolonged exposure to extremely low voltages. The maximum allowable voltage is such that the LDVRs do not operate if the ESF motors block start following an SI signal; this scenario is evaluated in References 6.11 & 6.12. The setpoint will be chosen based on the value determined using the methodology of Section VIII of the base calculation.

2.3 Time Delay Setting

Section 8.3 of the Byron UFSAR states that the 4160 V ESF Switchgear are protected from faults via relays (Westinghouse CO series overcurrent relays, Table 8.3-6) to disconnect faults with minimum system disturbance. Thus, the initial time delay associated with the LDVRs should allow the overcurrent relays to clear faults prior to tripping the bus. Appendix D of this calculation determines the maximum fault clearing time for a 4.16 kV circuit breaker based on a high impedance fault on a 480 V bus fed from a protected 4.16 kV ESF bus. Appendix D is used as a starting point to determine the initial setpoint which ultimately must be long enough to prevent spurious trips from system transients and short enough to prevent equipment damage. The LDVR time delay setpoint is based on engineering judgment. The methodology used in Appendix D is as follows:

2.3.1 Using the ELMS-AC models, the division with the highest impedance was selected to determine the longest fault clearing time.

2.3.2 The three phase, bolted fault current is calculated from the system impedance, converted to a phase-to-phase fault, and reduced to account for an arcing fault via References 6.26 & 6.27.

2.3.3 The phase-to-phase fault current on the 4.16 kV bus is compared to the trip curve for the CO-9 overcurrent relay to determine the fault clearing time (Reference 6.4).

3.0 ACCEPTANCE CRITERIA

3.1 Low Degraded Voltage Relay

Consistent with industry practice, the ultimate tripping point of the LDVR setpoint should meet the following requirements:

3.1.1 The setpoint should be high enough to prevent the stalling of normally running Class 1E motors due to low voltage.

3.1.2 The setpoint should be high enough to prevent damage and to prevent tripping due to actuation of overcurrent devices for normally running Class 1E loads with overcurrent devices that require manual reset. This acceptance criteria is addressed in Calculation 19-AN-3, Rev. 16G and in ECs 389241 and 389242.

3.1.3 The setpoint should be low enough to prevent spurious actuation during transients such as those experienced during the starting of a large plant motor or during the block starting of ESF motors following an SI initiation. This acceptance criteria is addressed in ECs 389241 and 389242.

3.1.4 The time delay setpoint should be long enough to prevent spurious tripping during faults and to allow the overcurrent protective devices to clear faults prior to tripping the bus on low degraded voltage.

3.1.5 The time delay setpoint should be short enough to protect the motors with protective devices requiring manual reset from tripping on overload due to prolonged exposure to low bus voltage.

4.0 ASSUMPTIONS AND LIMITATIONS

4.1 **Assumptions Requiring Verification**

None.

4.2 **Assumptions NOT Requiring Verification**

4.2.1 It is assumed that onsite events, such as large motor starts, will cause larger transients in onsite system voltages than events elsewhere in the offsite electrical system. The strength and stability of the offsite electrical system is routinely evaluated considering various transients to ensure its adequacy to support the onsite distribution system.

4.2.2 At the 480 V level the breakdown torque of each of the Class 1E motors, with the exception of the Control Room HVAC Return Fans (See Section 5.1.4.2) and the ESF Switchgear Room Cable Tunnel Fan 1VX01C (See Section 4.2.3 and 5.1.4.3), is assumed to be 200% of the rated running torque. This is the minimum required by NEMA Standard MG 1-1978 (Reference 6.2) for Design A and B motors ≤200hp. This is acceptable for Byron Station since the safety-related motors at the 480 V level are less than 200hp.

4.2.3 It is assumed that the breakdown torque of the ESF Switchgear Room Cable Tunnel Fan 1VX01C is 230% of the rated running torque. The motor performance data sheet for 1VX01C (P/N 500826-2213) shows a breakdown torque of 238% of full load torque (Ref. 6.32); however, per work order WO 01526179 (Ref. 33), this motor was refurbished. Therefore it is assumed that the refurbished motor has performance characteristics similar to the original motor. A breakdown torque of 230% of the rated running torque, instead of 238%, is used for 1VX01C to provide additional margin.

5.0 DESIGN INPUT

5.1 Monitoring Circuit Elements

5.1.1 Loss of Voltage Relays (Reference 6.22)

Type	Westinghouse Model CV-7
Voltage Tap Settings (Vac)	55, 64, 70, 82, 93, 105, 120, 140
Time Lever Settings	½, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

The LVRs are currently set to time lever setting 2 which corresponds to 1.8 seconds with a 10% setting tolerance (References 6.5 & 6.22).

5.1.2 Potential Transformers (Reference 6.3)

Type	Westinghouse Model 9146D46G02
Voltage Ratio	4200 – 120V
Accuracy Class	0.3W, X, Y and 1.2 Z

The PT error and PT ratio used in the calculations in Section 8 are derived from the input data as follows:

$$PT\_error = 1 - \frac{Accuracy\_Class}{100} = 1 - \frac{0.3}{100} = 0.997$$

$$PT\_ratio = \frac{4200}{120} = 35$$

5.1.3 4 kV ESF Motor Breakdown Torques

Motor	Rated Voltage (V)	Running Load % (Worst Case)	Rated Full Load Torque (FLT) LB-ft	Breakdown Torque (BDT) LB-ft	BDT/ FLT	Reference #
Aux. Bldg. Vent Sys. Exh Fans	4000	98.8%	2209	5478	248%	6.4, 6.8, & 6.9
Component Cooling Pumps	4000	88.9%	-	-	238%	6.4, 6.8, & 6.9
Centrifugal Charging Pumps	4000	93.3%	-	-	270%	6.4, 6.8, & 6.9
Aux. Bldg. Vent Sys. Sup. Fans	4000	108.3%	1030	2750	267%	6.4, 6.8, & 6.9
Containment Spray Pumps	4000	0%	1760	4360	248%	6.14, 6.8, & 6.9
Aux. FW Pumps	4000	0%	1840	4960	270%	6.13, 6.8, & 6.9
RHR Pumps	4000	0%	-	-	266%	6.4, 6.8, & 6.9
SI Pumps	4000	0%	-	-	262%	6.4, 6.8, & 6.9
ESW Pumps	4000	109.6%	7407	-	250%	6.15, 6.8, & 6.9
Control Room Chillers	4000	73.8%	473	1155	244%	6.4, 6.8, & 6.9

5.1.4 460 V ESF Motor Breakdown Torques

5.1.4.1 The 460 V ESF motors breakdown torque to rated torque ratio is 200% and is addressed in Assumption 4.2.2.

5.1.4.2 The 460 V Control Room HVAC Return Fans (0VC02CA & 0VC02CB) run at 49HP and are rated 40HP (Reference 6.8). The fans have a breakdown torque of 225% of motor rated torque (Reference 6.23).

5.1.4.3 The 460 V ESF Switchgear Room Cable Tunnel Fan (1VX01C) has a breakdown torque of 230% of motor rated torque (Assumption 4.2.3).

5.1.5 ABB ITE-27N Undervoltage Relay

The pickup/dropout ratio is 0.5%, and the relay is equipped with a harmonic filter, 411T6375-L-HF-DP (Reference 6.21 Pages 5 & 16). The relay has an adjustable time delay from 0.1-1 seconds (Reference 6.6 Page 4). The time delay error is equal to the greater of ± 10% or ± 20 milliseconds. (Reference 6.6 Page 5)

5.1.6 NTS Series 812 Timing Relays

The relays are accurate to 2% of the setpoint over the entire operating range. The 812-1-6-02-O relay has an operating range of 0.5 – 5 seconds (Reference 6.25).

5.1.7 Ventilation Fan BHP

TODI BYR-15-021 (Ref. 6.34) contains the brake horsepower values for twenty ventilation fans that are modeled as normally running loads. The fans and their associated brake horsepower values from Ref. 6.34 are shown in the following table. The ELMS files (Refs. 6.8 and 6.9) are modified to reflect these values.

Ventilation Fan Motor	Equipment ID	Rated HP	BHP	ELMS Load No.	Div.	MCC
Elec Equipment Rm Vent Fan	1VE01C	50	45.7	856	12	132X4
Elec Equipment Rm Vent Fan	2VE01C	50	45.5	756	22	232X4
Battery Rm Exhaust Fan	1VE02C	3	2.7	850	12	132X4
Battery Rm Exhaust Fan	2VE02C	3	2.7	749	22	232X4
Battery Rm Exhaust Fan	1VE03C	3	2.6	227	11	131X5
Battery Rm Exhaust Fan	2VE03C	3	2.99	299	21	231X5
Misc Elec Equipment Rm Vent Fan	1VE04C	5	3.9	214	11	131X4
Misc Elec Equipment Rm Vent Fan	2VE04C	5	3.8	292	21	231X4
Misc Elec Equipment Rm Vent Fan	1VE05C	7.5	7.5	888	12	132X5
Misc Elec Equipment Rm Vent Fan	2VE05C	7.5	7.7	782	22	232X5
ESF Swgr Rm Cable Tunnel Vent Fan	1VX01C	50	58.4	799	12	132X2
ESF Swgr Rm Cable Tunnel Vent Fan	2VX01C	50	51.7	703	22	232X2
Cable Spreading Rm Vent Fan	1VX03C	40	43.7	855	12	132X4
Cable Spreading Rm Vent Fan	2VX03C	40	41.9	755	22	232X4
ESF Swgr Rm Vent Fan	1VX04C	50	53.2	228	11	131X5
ESF Swgr Rm Vent Fan	2VX04C	50	44.6	300	21	231X5
EDG Rm Exhaust Fan	1VD03CA	3	3.1	196	11	131X3
EDG Rm Exhaust Fan	1VD03CB	3	3.1	830	12	132X3
EDG Rm Exhaust Fan	2VD03CA	3	3.2	275	21	231X3
EDG Rm Exhaust Fan	2VD03CB	3	2.9	732	22	232X3

5.1.8 The brake horsepower for 1(2)SX01PA-M BHP during normal operating conditions is 1265 HP. (References 6.35 and 6.36)

5.1.9 One of the refueling water purification pumps is normally running. However, for conservatism, both pumps (0FC03PA and 0FC03PB) will be modeled as running at rated motor horsepower (Ref. 6.34).

5.1.10 A summary of the load changes to the input ELMS-AC files (References 6.8 and 6.9) for Conditions 2 and 3 are listed in Appendix E. These changes are shown on the marked-up ELMS-AC reports (References 6.8 and 6.9) in Appendix C.

6.0 REFERENCES

6.1 NUREG-0800, Standard Review Plan, Chapter 8, Branch Technical Position PSB-1, Rev. 0, July 1981.

6.2 NEMA MG 1-1978, Part 12 (Appendix B Page AB2).

6.3 S&L DIT No. BB-EPED-0178-01, dated 6-5-1992, ITE-27N Undervoltage Relay and Potential Transformer Data (Appendix B Page AB3).

6.4 Calculation 19-AN-3, Rev. 16, Protective Relay Settings for 4.16kV ESF Switchgear (Appendix B Pages AB4 – AB10).

6.5 Work Order 00492205, 03/31/04 Bus 242 Tech Spec Undervoltage Relays (Appendix B Page AB11).

6.6 ABB IB 7.4.1.7-7 Issue E, Instructions Single Phase Voltage Relays.

6.7 Exelon TODI BYR-15-005, Rev. 0, Transmittal of U1 & U2 ELMS Files.

6.8 ELMS-AC PLUS modification files for Byron – Unit 1; B1A4141.MB4 and B1A4142.MB4 (Selected Pages, Appendix B Pages AB12 & AB13).

6.9 ELMS-AC PLUS modification files for Byron – Unit 2; B2A4241.M89 and B2A4242.M89.

6.10 EC 377631 Rev. 000, Evaluation And Technical Basis For The AP System Second Level Undervoltage (Degraded Voltage) Time Delay Setting, Approved Feb. 3, 2010 (Appendix B Page AB14).

6.11 EC 389241 Rev. 009, Degraded Voltage 5 Minute Timer Resolution - Unit 1.

6.12 EC 389242 Rev. 004, Degraded Voltage 5 Minute Timer Resolution - Unit 2.

6.13 Vendor Drawing 664834, Westinghouse Thermal Limit and Acceleration Time vs. Current Curve (Appendix B Page AB17).

6.14 Vendor Drawing 664832, Westinghouse Thermal Limit and Acceleration Time vs. Current Curve (Appendix B Page AB18).

6.15 Vendor Drawing DHC770322-1, ESW Pump Motors (Appendix B Page AB19).

6.16 Technical Specification 3.3.5, Loss of Power (LOP) Diesel Generator (DG) Start Instrumentation.

6.17 Station Drawing 6E-1-4030AP30, Rev. U, Schematic Diagram 4160V ESF SWGR Bus 141

Undervoltage Relays: PR9A-427-B141, PR9C-427-B141, PR29A-427-ST11, & PR29C-427-ST11.

6.18 Station Drawing 6E-1-4030AP39, Rev. U, Schematic Diagram 4160V ESF SWGR Bus 141 Undervoltage Relays: PR10A-427-B142, PR10C-427-B142, PR32A-427-ST12, & PR32C-427-ST12

6.19 Station Drawing 6E-2-4030AP30, Rev. T, Schematic Diagram 4160V ESF SWGR Bus 241 Undervoltage Relays: PR31A-427-B241, PR31C-427-B241, PR29A-427-ST21, & PR29C-427-ST21.

6.20 Station Drawing 6E-2-4030AP39, Rev. Q, Schematic Diagram 4160V ESF SWGR Bus 242 Undervoltage Relays PR29A- 427-B242, PR29C-427-B242, PR5A- 427-ST22, & PR5C-427-ST22.

6.21 Calculation 19-AN-28, Rev. 001, Calc. For Second-level Undervoltage Relay Setpoint (Selected Pages, Appendix B Pages AB20 & AB21).

6.22 Westinghouse I.L. 41-201Q, Type CV Voltage Relay, December 1988(Appendix B Page AB22).

6.23 Reliance A-C Motor Performance Data No. E0111A-B-007, June 1977 (Appendix B Page AB23).

6.24 Exelon Procedure MA-MW-772-702 Rev. 0, Calibration of Voltage Protective Relays (Appendix B Page AB24).

6.25 NTS Manual No. 812-01, NTS Series 812 Timing Relay, March 1999 (Appendix B Pages AB25 – AB26).

6.26 IEEE Std 141-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (Appendix B Page AB27).

6.27 IEEE Std 242-2001, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Appendix B Page AB28).

6.28 IEEE Std C37.91-2008, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Appendix B Page AB29).

6.29 Calculation 19-AN-7, Rev. 11, Protective Relay Settings for 4.16kV ESF Switchgear (Appendix B Page AB30).

6.30 Fitzgerald, A. E., Kingsley Jr., Charles, and Umans, Stephen D. *Electric Machinery*. Sixth Edition. New York: McGraw-Hill, 2003 (Appendix B Page AB31 – AB33).

6.31 Calculation 19-AN-3, Rev. 16G, Protective Relay Settings for 4.16kV ESF Switchgear

6.32 Reliance A-C Motor Performance Data No. E5607A-A-006, Issued 10/28/77 (Appendix B Page AB16)

6.33 WO 01526179, Motor Refurbishment – 1VX01C

6.34 TODI BYR-15-021 Rev. 0, "Electrical Loading Changes for the LDVR Analysis" (Appendix B, Pages AB34-AB37)

6.35 EC 381775 Rev 001, "Calculate BHP Values for the 1A SX Pump Based on Field Test Data"

6.36 EC 379433 Rev 000, "Calculate BHP Values for the 2A SX Pump Based on Field Test Data Gathered During B2R15"

7.0 IDENTIFICATION OF COMPUTER PROGRAMS

7.1 Microsoft Word 2003 (Text only), S&L Computer No. ZD6585, Program No. 03.1.286-1.0.

7.2 Advanced AC Electrical Load Monitoring System (ELMS-AC PLUS) Ver 1.2, S&L Computer No. 8809, Program No. 03.7.379-1.2. (See Appendix A Pages AA137-AA138 for ELMS Audit Trail Information)

7.3 Mathcad Version 14.35, S&L Computer No. ZL8156, Program No. 03.7.548-1435. (See Appendix D, Page D4 for Mathcad Audit Trail Information)

8.0 CALCULATIONS

8.1 The minimum allowable voltage for the new LDVR actuation has been selected as follows:

8.1.1 Selection of Limiting Breakdown Torque

8.1.1.1 Motors running at reduced voltages have reduced torque output proportional to the square of the voltage ratio. Therefore, Equation 2.1.2 is used to determine the breakdown torque at reduced voltage.

$$\%T_{BD\,@\,Vreduced} = \left(\frac{V_{reduced}}{V_{rated}}\right)^2 \times \%T_{BD\,@\,Vrated}$$

The minimum allowable voltage to preclude motor stall at the 4.16kV level has been determined as follows:

$$V_{min\_allowed} = 4000\sqrt{\frac{\%T_{BD\,@\,Vreduced}}{\%T_{BD\,@\,Vrated}}}\text{, where } V_{min\_allowed} = V_{reduced}$$

(See Section 5.1.3)

Induction motors are typically utilized in constant-speed applications, and because $P_{motor} = T_{motor}\,\omega$, the motor BHP is proportional to the motor torque (Ref. 6.30). Therefore, for motors running above rated power, the BHP (from References 6.8 and 6.9) as a percent of motor rated power is used for $T_{BD@Vreduced}$.

Motor	$T_{BD@V_{rated}}$ (%)	$T_{BD@V_{reduced}}$ * (%)	$V_{min\_allowed}$ (V)
Aux. Bldg. Vent Sys. Exh Fans	248	100	2540.0
Component Cooling Pumps	238	100	2592.8
Centrifugal Charging Pumps	270	100	2434.3
Aux. Bldg. Vent Sys. Sup. Fans	267	108.3	2547.5
Containment Spray Pumps	248	100	2540.0
Aux. FW Pumps	270	100	2434.3
RHR Pumps	266	100	2452.6
SI Pumps	262	100	2471.2
ESW Pumps	250	109.6	2648.5
Control Room Chillers	244	100	2560.7

*$T_{BD@Vreduced}$ is proportional to the motor BHP from References 6.8 & 6.9. For motors running below rated HP, 100% torque is used for conservatism.

At a reduced voltage of 2648.5V (66.2% of 4000V), the breakdown torque will equal the running torque for the Essential Service Water Pump. This bounds the 4 kV motors.

8.1.1.2 Per Assumption 4.2.2, the minimum breakdown torque for the Class 1E motors at the 480 V level is 200%.

8.1.1.3 The 480 V level motors running above rated load are listed in the following table. (References 6.8-6.9 and Input 5.1.7)

Equipment ID	Rated HP	BHP
2VE05C	7.5	7.7
1VX01C	50	58.4
2VX01C	50	51.7
1VX03C	40	43.7
2VX03C	40	41.9
1VX04C	50	53.2
1VD03CA	3	3.1
1VD03CB	3	3.1
2VD03CA	3	3.2
0VC02CA	40	49
0VC02CB	40	49

8.1.1.4 Motors running at reduced voltages have reduced torque output proportional to the square of the voltage ratio. Therefore, Equation 2.1.2 is used to determine the breakdown torque at reduced voltage of low voltage motors. The minimum allowable voltage to preclude stalling for low voltage motors running at or

below full load is calculated as follows:

$$\%T_{BD\,@\,Vreduced} = \left(\frac{V_{reduced}}{V_{rated}}\right)^2 \times \%T_{BD\,@\,Vrated}$$

$$\%T_{BD\,@\,Vreduced} = 100 = \left(\frac{VMinAllow460V}{460V}\right)^2 \times 200$$

$$\Rightarrow V_{MinAllow460V} = 325.3V$$

The minimum voltages to preclude stalling for loads that are running above rated motor horsepower (Section 8.1.1.3) are calculated using Equation 2.1.2. The breakdown torques of the motors are taken from Input 5.1.4.

Equipment ID	Rated HP	BHP	$T_{BD@Vrated}$ (%)	$T_{BD@Vreduced}$* (%)	$V_{min\_allowed}$ (V)	Div.	Limiting Component
2VE05C	7.5	7.7	200	102.67	329.6	22	Div. 22
1VX01C	50	58.4	230	116.8	327.8	12	
2VX01C	50	51.7	200	103.4	330.8	22	
1VX03C	40	43.7	200	109.25	340.0	12	
2VX03C	40	41.9	200	104.75	332.9	22	
1VX04C	50	53.2	200	106.4	335.5	11	
1VD03CA	3	3.1	200	103.33	330.7	11	
1VD03CB	3	3.1	200	103.33	330.7	12	
2VD03CA	3	3.2	200	106.67	336.0	21	Div. 21
0VC02CA	40	49	225	122.5	339.4	11	Div. 11
0VC02CB	40	49	225	122.5	339.4	12	Div 12

*$T_{BD@Vreduced}$ is proportional to the motor BHP from Reference 6.34.

Example Calculation: 2VE05C

$$\%T_{BD@Vreduced} = 100\% \times \frac{7.7}{7.5} = 102.67\%$$

$$\%T_{BD\,@\,Vreduced} = \left(\frac{V_{reduced}}{V_{rated}}\right)^2 \times \%T_{BD\,@\,Vrated}$$

$$V_{reduced} = \sqrt{\frac{T_{BD@Vreduced}}{T_{BD@Vrated}}} \times V_{rated}$$

$$V_{reduced} = \sqrt{\frac{102.67\%}{200\%}} \times 460V = 329.6V$$

8.1.1.5 The station ELMS model has been analyzed to determine the 4.16kV ESF bus voltage required to ensure that the terminal voltages at all motors are above the minimum allowable values determined in Sections 8.1.1.1 and 8.1.1.4. The voltage was iterated down, for each division, until the terminal voltage at the any one of the motors on that division reached its minimum allowable value. From Appendix A page AA1 the minimum required voltage on each of the four

buses, 141, 142, 241 & 242, are 3064.3V, 3088.8V, 2953.1V and 3004.0V respectively; therefore highest minimum voltage required on all four buses (141, 142, 241 & 242) is determined to be 3088.8V, which is the analytical limit. An additional 25V of margin is added for conservatism and therefore 3113.8V (3113.8/35 = 88.97, PT secondary voltage) is determined to be the Minimum Allowable Value.

8.1.1.6 Voltage Setpoint

4160 V Switchgear buses 141 (Div. 11), 142 (Div. 12), 241 (Div. 21), and 242 (Div. 22).

The Total Negative Error and Total Positive Error in the base calculation is based on a nominal relay setpoint near 110V. The low degraded voltage relay will be set near 90V and therefore these errors are recalculated.

The calibration error is recalculated for a nominal relay setpoint near 90V in accordance with Section IX.B.2 of the base calculation:

2*σ reference accuracy = ± 0.2% of reading + 10 least significant digits, where each digit corresponds to 0.01V

(10*0.01V) / 90V = 0.111%

The 2*σ reference accuracy is 0.2% + 0.111% = 0.311%

Thus, σ for calibration error is 0.156%

The relay setting tolerance is recalculated for a nominal relay setpoint near 90V in accordance with Sections VI.A.1 and IX.B.5 of the base calculation:

For a ± 0.2V setting tolerance, the random error is 0.2V/90V = 0.222%

Thus, σ for the setting tolerance is 0.111%

The Total Error is recalculated in accordance with Section IX.C of the base revision using the new calibration instrument error and relay setting tolerance values calculated above:

$$\text{Random Error} = \sqrt{(0.05\%)^2 + (0.156\%)^2 + (0.111\%)^2} = 0.198\%$$

The base calculation determined the negative and positive non-random error to be 1.055% and 0.544%, respectively.

The Total Error is calculated using the following equation:

Total = Non-Random + 2*Random

Total Negative Error (TNE) = 1.06% + 2*0.198% = 1.46%
Total Positive Error (TPE) = 0.54% + 2*0.198% = 0.94%

Nominal Relay Dropout Setpoint = Minimum Relay Dropout (MRD) + Total Negative Error (in percent of nominal relay dropout setpoint). The minimum allowable value as determined in Section 8.1.1.5 is 3113.8V. Therefore, the MRD = 3113.8V/35 = 88.97V

Nominal Relay Dropout = MRD / (1-TNE)

= 88.97V / (1-0.0146)

= 90.29V

This equates to 90.29V*35 (PT Ratio) = 3160.15V.

EC 377631 (Ref. 6.10) determined that no damage will result to permanently connected Class 1E loads as a result of operation at degraded voltage conditions for the maximum allowable duration of the transients as specified in the Technical Specifications (340 seconds) at a 4.16 kV Switchgear bus voltage of 3120V (75%). Therefore, the new LDVR setpoint of 3160.15V/35 = 90.29V is acceptable.

8.1.1.7 Time Delay Setting

The LDVR time delay setting needs to be long enough to prevent spurious tripping, and short enough to protect the motors from overload tripping and lockout due to prolonged exposure to low bus voltage (low degraded voltage). The LDVR should trip before overload relays for a sustained low bus voltage condition.

Minimum Setting Criteria

Section 8.3 of the Byron UFSAR states that the 4160 V ESF Switchgear are protected from faults via relays (Westinghouse CO series overcurrent relays, UFSAR Table 8.3-6) to disconnect faults with minimum system disturbance. Thus, the initial time delay associated with the LDVRs should allow the overcurrent relays to clear faults prior to tripping the bus. Appendix D of this calculation determines the maximum fault clearing time for a 4.16 kV circuit breaker based on a high impedance fault on a 480V bus fed from a protected 4.16 kV ESF bus. The longest fault clearing time has been determined to be approximately 2 seconds, with additional margin of 1 second to establish the nominal setpoint (3 seconds) and allow time for the bus voltage to recover. The contacts of the new LDVR that are part of the trip circuit are connected in series with a new NTS time delay relay connected to prevent spurious 4.16 kV bus trips when repowering a dead bus (References 6.11 & 6.12).

The total time delay setpoint for the LDVR and NTS time delay relay is 3 seconds. The LDVRs will have a time delay of 0.5 second and the NTS time delay relays will have a time delay of 2.5 seconds.

The time delay tolerance is taken from Sections 5.1.5 and 5.1.6 and the total time delay error is calculated below:

TPE = TNE = (LDVR time delay * tolerance) + (NTS time delay * tolerance)

= 0.5s * 10% + 2.5s * 2% = 0.1s

Maximum Setting Criteria

The 4.16 kV and 480V ESF motors are protected from damage, due to

overcurrent, by thermal overload (TOL) relays and phase overcurrent relays. The maximum LDVR time delay is evaluated below to ensure coordination with the motor overcurrent protection.

The WO MCR chillers are the only normally running 4.16 kV loads running on Buses 141, 142, 241, and 242 that lockout following a trip. The 480V MCC motor loads have thermal overload relays that lockout following a trip. The remaining 4.16 kV loads and 480V switchgear loads will restart if tripped on overcurrent prior to the LDVRs disconnecting the associated bus (References 6.11 and 6.12).

Calculation 19-AN-3, Rev. 16G (Ref. 6.31) establishes that the WO MCR Chiller motor overcurrent relay, with a pickup of 146 % of full load current, does not trip at the LDVR minimum allowable value. For a sustained undervoltage at the Loss of Voltage Relay allowable value of 65.6% (Section 3.3.5.2 of Ref. 6.16), full load current for the motors would be 1/(65.6%) = 152.4%. (Note that the WO MCR Chiller motor is conservatively modeled running at 340 HP, which is the motor input power per Ref. 6.31. The brake horsepower of this motor at full load is 321 HP per Ref. 6.31) Even at a full load current of 250%, the WO MCR chiller motor CO-5 relay would trip in approximately 5 seconds. The TOL trip curves for the 480V MCC loads show a cold start minimum trip time of approximately 25 seconds for 250% of the trip rating. Therefore, the LDVR setting should not be any higher than 5 seconds.

LDVR Time Delay Setting

In order to have margin between the maximum allowable value and the setpoint for the time delay, the maximum allowable value is set at 3.5 seconds. The maximum allowable value of 3.5 seconds is greater than the nominal setpoint (3 seconds) plus the total positive error (0.1 seconds). The LDVR setting of 3.5 seconds is acceptable because it is above the minimum setting and below the maximum setting, with margin for timing tolerances.

8.1.2 Maximum Relay Reset

The maximum reset voltage is calculated from the maximum dropout voltage and PU/DO ratio as shown in Section 5.1.5. The TPE was calculated in Section 8.1.1.6.

Max. Relay Dropout = Nominal Relay Dropout (DO) + TPE (in % of DO)

= 90.29 * (1.0 + 0.0094)

= 91.14V

Max. Relay Pickup = Max. Relay Dropout / PU/DO ratio

= 91.14V / 0.995 = 91.60V

Max. Reset Bus Voltage = 91.60V * 35 = 3206V

8.2 Results

With the new LDVR set at 90.29V and 3 seconds, this calculation determined that the LDVRs will actuate prior to any normally running safety-related motors stalling. This satisfies the first acceptance criterion.

Motor protection is analyzed with the LDVRs set at 90.29V and 3 seconds in ECs 389241 and 389242 (References 6.11 and 6.12) and in Calc 19-AN-3 Rev. 16G (Reference 6.31). The analyses determined that the motor protection, for loads that will lockout following a trip, will not trip on the normally running, safety-related motors during a degraded voltage condition and that normally running safety-related motors will not be damaged prior to the DVR 5-minute timer transferring the safety-related loads to the emergency diesel generator. This satisfies the second acceptance criterion.

Block starting of ESF motors following an SI initiation is analyzed with the LDVRs set at 90.29V and 3 seconds in ECs 389241 and 389242 (References 6.11 and 6.12). The analyses determined that the LDVRs will not trip due to the voltage transient caused by the block start of ESF motors. This satisfies the third acceptance criterion.

This calculation determined that the LDVR time delay setpoint of 3 seconds is long enough to prevent spurious tripping during faults and to allow the overcurrent protective devices to clear faults prior to tripping the bus on low degraded voltage. This satisfies the fourth acceptance criterion.

This calculation determined that the LDVR time delay setpoint of 3 seconds is short enough to protect the motors with protective devices requiring manual reset from tripping on overload due to prolonged exposure to low bus voltage. This satisfies the fifth acceptance criterion.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 Low Degraded Voltage Relay Settings

Based on the acceptance criteria of Section 3.0 and the calculations of Section 8.0, the following relay settings are recommended:

Nom. Relay Dropout Setpoint	= 90.29V [3160.15V (primary side voltage)]
Nom. Relay Pickup (Reset) Setpoint	= 90.29V/ 0.995 = 90.74V
Time Delay Setpoint	= 0.5 seconds

9.2 Time Delay Relay Setting

Based on the acceptance criteria of Section 3.0 and the calculations of Section 8.0, the following relay setting is recommended:

Time Delay Setpoint	= 2.5 seconds

10.0 APPENDICES

A) ELMS-AC Plus Load Flow Reports
B) Calculation Input
C) ELMS-AC Station File Changes
D) High Impedance Fault Clearing Time
E) Input Changes Listing