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September 4, 2013
U7-C-NINA-NRC-130053

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Revised Response to Request for Additional Information

Reference: Letter, Scott Head to Document Control Desk, "Response to Request for Additional Information," U7-C-NINA-NRC-130002, dated January 3, 2013 (ML13008A237)

Nuclear Innovation North America, LLC (NINA) has revised the response to the NRC staff question in Request for Additional Information (RAI) letter number 419, related to Combined License Application (COLA) Part 2, Tier 2, Section 8.2, "Offsite Power Systems." NINA submitted the original response to this RAI with the referenced letter. The changes to the response to this RAI incorporate information discussed with the NRC during a public meeting on August 21, 2013 and are identified by revision bars in the right margin. The attachment to this letter contains the revised response to RAI question:

08.02-25

When a change to the COLA is required, it will be incorporated into the next routine revision of the COLA following NRC acceptance of the RAI response.

There are no commitments in this letter.

If you have any questions, please contact me at (979) 316-3011 or Bill Mookhoek at (979) 316-3014.

DO91
MRO

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 9/4/13



Scott Head
Manager, Regulatory Affairs
NINA STP Units 3 & 4

rhb

Attachment: RAI 08.02-25 Revision 1

cc: w/o attachment except*
(paper copy)

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RAI 08.02-25

QUESTION:

On July 27, 2012, the NRC issued Bulletin 2012-01, "Design Vulnerability in Electric Power System," (Agency wide Documents Access and Management System (ADAMS) Accession No. ML12074A115) to all holders of operating licenses and combined licenses for nuclear power reactors requesting information about the facilities' electric power system designs, in light of the recent operating experience that involved the loss of one of the three phases of the offsite power circuit (single-phase open circuit condition) at Byron Station, Unit 2 to verify compliance with applicable regulations and to determine if further regulatory action is warranted.

In order to verify the applicants of new reactors have addressed the design vulnerability identified at Byron in accordance with the requirements specified in General Design Criterion (GDC) 17, "Electric Power Systems," in Appendix A, "General Design Criteria for Nuclear Power Plants," and the design criteria for protection systems under 10 CFR 50.55a(h)(3), please provide the following information:

- Describe the protection scheme design for important to safety buses (non-safety or safety-related) to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on credited offsite power circuits.
- If the important to safety buses are not powered by offsite power sources during at power condition, explain how the surveillance tests are performed to verify that a single-phase open circuit condition or high impedance ground fault condition on an off-site power circuit is detected.
- Describe the plant operating procedures, including off-normal operating procedures, that specifically call for verification of the voltages on all three phases of the Class 1E Safety buses.

REVISED RESPONSE:

This response provides the results of analyses of the design that is provided in COLA revision 9, and does not propose or rely upon any design features that are not included in COLA revision 9. The protection scheme for the onsite power system is described primarily in DCD Section 8.3, and is not changed significantly by the limited departures related to electric power system. The changes to this response incorporate information discussed with the NRC during a public meeting on August 21, 2013 and are identified by revision bars in the right margin.

Item 1: Single Phase Open Circuit Discussion

Loss of a single phase on a Class 1E bus is specifically addressed in the certified ABWR design. As a result of loss of a single phase, the undervoltage protective circuitry will separate the Class 1E Safety buses from a connected failed offsite source due to loss of voltage or sustained degraded grid voltage with or without concurrent design basis accidents.

In the FSAR, Section 8.3.1 'AC Power Systems', the undervoltage schemes for detecting loss of voltage and degraded voltage are provided as follows:

'The loss of voltage condition and the degraded voltage condition are sensed by independent sets of three undervoltage relays (one on each phase of the 4.16 kV bus) which are configured such that two-out-of-three trip states will initiate circuitry for transferring power from offsite power to the onsite diesel generator (after a time delay for the degraded voltage condition). The primary side of each of the instrument potential transformers (PTs) is connected phase-to-phase (i.e., a "delta" configuration) such that a loss of a single phase will cause two of the three undervoltage relays to trip, thus satisfying the two-out-of-three logic. (For more information on the degraded voltage condition and associated time delays, etc., see Subsection (8) of 8.3.1.1.7.)'

The loss of voltage and degraded voltage schemes are required to be operational by the Technical Specifications:

LCO 3.3.1.4 The ESF Actuation Instrumentation for each Function in Table 3.3.1.4-1 shall be OPERABLE.

Diesel Generator Actuation (Table 3.3.1.4-1)

5.a, Division I, II, & III Loss of Voltage –4.16 kV, and

5.b, Division I, II, & III Degraded Voltage –4.16 kV

Requires all phase sensor channel functions to be Operable in all 5 Modes.

Setpoints for the loss of voltage and degraded voltage functions are determined in accordance with Technical Specification 5.5.2.11, Setpoint Control Program (SCP).

Based on the above, the loss of voltage and degraded voltage relay schemes on each of the Class 1E Safety buses detect and respond to the postulated loss of phase scenarios on a Class 1E Safety bus that could prevent the Class 1E bus from performing its required safety function. The loss of voltage and degraded voltage functions start the EDGs, disconnect the affected Class 1E bus from the degraded offsite source and connect the EDG to the affected Class 1E bus.

Two of the three Class 1E Safety buses are normally aligned to one of the two required offsite sources through the Main Transformer (MT) via Unit Auxiliary Transformers (UATs) and one of the three Class 1E Safety buses is normally aligned to the second offsite source through a Reserve Auxiliary Transformer (RAT). Refer to Item 2 below and FSAR Figure 8.3-1 for the normal Class 1E bus lineups. Figure 1 at the end of this response provides a simplified version of FSAR Figure 8.3-1.

Loss of a single phase on an offsite circuit affects a Class 1E Safety bus differently depending on whether the offsite circuit supplies the Class 1E Safety bus via the MT and a UAT or via a RAT. The expected response for each of the credited offsite power circuit paths is described below: (Refer to Attachment 1 for additional technical analysis and see FSAR Figure 8.3-1 for plant transformer configuration and transformer ratings.)

Main Transformer Back Feed Alignment Single-Phase Open Circuit Event

For a single-phase open circuit event on the grid side of the MT, the feed from the MT and each of the associated UATs does not affect the safety-related or non-safety related loads since the wye-delta configuration of the MT regenerates the lost phase (open-circuited phase). Also, the MT can carry the increased load on the remaining two phases because the MVA capacity of the MT is large relative to the combined safety-related and non-safety related loads on the UATs. Therefore, the important to safety loads fed by the MT and associated UATs are not affected by a single-phase open circuit event on the grid side of the MT. A single-phase open circuit without ground fault or short circuit on the plant side of the MT and UAT cannot occur because the conductors are enclosed isolated phase bus, enclosed non-segregated bus, or enclosed medium voltage cables in tray, duct bank, or conduit. Conductor failures in these circuits are expected to result in a fault that would be immediately cleared by installed protective relaying.

Reserve Auxiliary Transformer Single-Phase Open Circuit Event

For a single-phase open circuit event on the grid side of a RAT, the feeds from the RATs are affected because of the wye-wye configuration of the RATs. As stated above, the 4.16 kV Class 1E Safety buses have both loss-of-voltage and degraded voltage relays. These loss-of-voltage and degraded voltage relays monitor all three phases and are connected to a 2 out of 3 coincidence logic to separate the Class 1E Safety buses from offsite power and realign them to the emergency diesel generators (EDGs) upon detection of an unacceptable undervoltage or degraded voltage condition. The loss of a single phase on the high side of the transformer will drop voltage low enough for the degraded undervoltage relays to detect and trip the feed.

Ground Fault Discussion:

The offsite power circuits have been reviewed with regard to ground faults. The effect of a ground fault has been analyzed to be dependent on where the ground fault is located and the magnitude of current flowing to the ground fault.

If a ground fault were located on the low side of a large power transformer that provides offsite power to the Class 1E Safety loads (UATs and RATs) and the magnitude of ground current is above the ground protection relay setpoint, then the ground protection relaying would actuate and lockout the transformer tripping all of the powered buses including the offsite power source feed to the associated 4.16 kV Class 1E Safety bus(es). Consequently, the affected 4.16 kV Class 1E Safety bus(es) would then be powered by its associated EDG.

The design of the power distribution system allows the system to stay operational if a single phase ground fault occurs. See FSAR Figure 8.3-1. To achieve this feature, neutral grounding resistors are installed on the low side of each transformer winding to limit the ground fault current (reference FSAR section 8.3.1.0.6.2 'Grounding Methods').

If a ground fault were located on the low side of any of the aforementioned large power transformers and the magnitude of ground current is below the ground protection relay setpoint, then the ground protection relays would not actuate. However, this very low magnitude current ground fault would not be expected to prevent Class 1E Safety loads from performing their

design function while staying connected to their associated offsite power source, because the magnitude of the current to the ground fault is ultimately limited to an acceptable value by the neutral grounding resistor at the source transformer.

If a ground fault were located on the high side of the UATs or RATs, the ground fault would be expected to either burn off and clear or rapidly propagate to a ground fault that would actuate the protective relaying and disconnect the transformer from offsite power. This would result in a Loss of Preferred Power (LOPP) for the affected Class 1E Safety bus(es) which would then automatically realign to the EDG(s).

Below is a listing of the offsite power transformer winding and grounding configurations based on information from FSAR Figure 8.3-1.

Offsite Power Transformer Winding and Grounding Configurations

Transformer	Winding Configuration (High Side / Low Side)	Grounding Configuration (High Side / Low Side)
Main Transformer	Wye / Delta	Solidly Grounded / Ungrounded
Two of the Unit Auxiliary Transformers	Delta / Wye – Wye	Ungrounded / Low Resistance Grounded – Low Resistance Grounded
Third Unit Auxiliary Transformer	Delta / Wye	Ungrounded / Low Resistance Grounded
Reserve Auxiliary Transformers A & B	Wye / Wye – Wye	Solidly Grounded / Low Resistance Grounded – Low Resistance Grounded

Item 2: Offsite Power Sources During at Power Conditions

The Class 1E Safety buses are normally powered by offsite power sources. Note 9 on FSAR Figure 8.3-1, sheet 1 states “During normal plant operations all of the non-class 1E buses and two of the Class 1E buses are supplied with power from the main turbine generator through the unit auxiliary transformers. The remaining Class 1E bus is supplied from RAT (B). This division is immediately available without a bus transfer if [normally preferred power] is lost to the other two divisions.” Figure 8.3-1 sheet 1 also shows that there is a generator circuit breaker between the main generator and the main and auxiliary transformers. This allows an automatic back feed through the MT on trip of the main turbine generator.

Item 3: Plant Operating Procedures

Plant operating and off-normal procedures for onsite electrical distribution will be developed as described in FSAR 13.5, Plant Procedures, after the detailed design is complete and the equipment, including monitoring instrumentation, is procured. A combination of monitoring instrumentation, procedural requirements (including Channel Checks described in the Bases for

Surveillance Requirement 3.3.1.4.1), and operator training will be used to provide a high degree of assurance that required voltage is maintained on all three phases and that off normal conditions, including failures affecting a single phase, are detected promptly.

Licensing Strategy

As described in this response, NINA has demonstrated that loss of a single phase in an offsite circuit either has no effect on STP 3 & 4 Class 1E electrical bus safety functions or will be detected by existing Technical Specification undervoltage and/or degraded voltage functions which will disconnect the affected offsite circuit and power affected Class 1E buses from an EDG. This conclusion will be confirmed for the ‘as-built’ plant by the ITAAC proposed below.

In addition, NINA will evaluate Nuclear Strategic Issues Advisory Committee (NSIAC) initiatives to ensure that STP 3 & 4 design and procedures remain consistent with industry accepted practices.

To ensure that the ‘as-built’ design of the STP 3 & 4 Electrical Power Distributions (EPD) System is appropriately protected for a lost phase, with or without a ground fault, on credited offsite power circuits supplying the MT and RATs, NINA will revise COLA, Part 9, Section 3.0, Site-Specific ITAAC, to include the following:

Table 3.0-29 Detection of Single Phase Events

Design Requirement	Inspections, Tests, Analyses	Acceptance Criteria
1. A lost phase, with or without a ground, on credited offsite power circuits supplying the Main Transformer is re-created such that ESF bus voltage is greater than the ESF bus undervoltage and degraded voltage setpoints.	1. An analysis for the as-built EPD System demonstrates a lost phase, with or without a ground, on credited offsite power circuits supplying the Main Transformer is re-created such that ESF bus voltage is greater than the ESF bus undervoltage and degraded voltage setpoints.	1. An analysis exists for the as-built EPD System that demonstrates that a lost phase, with or without a ground, on credited offsite power circuits supplying the Main Transformer is re-created such that ESF bus voltage is greater than the ESF bus undervoltage and degraded voltage setpoints.
2. A lost phase, with or without a ground, on credited offsite power circuits supplying the Reserve Auxiliary Transformers actuates the ESF bus degraded voltage relay protection.	2. An analysis for the as-built EPD System demonstrates a lost phase, with or without a ground, on credited offsite power circuits supplying the Reserve Auxiliary Transformers actuates the ESF bus degraded voltage relay protection.	2. An analysis exists for the as-built EPD System that demonstrates that a lost phase, with or without a ground, on credited offsite power circuits supplying the Reserve Auxiliary Transformers actuates the ESF bus degraded voltage relay protection.

Attachment

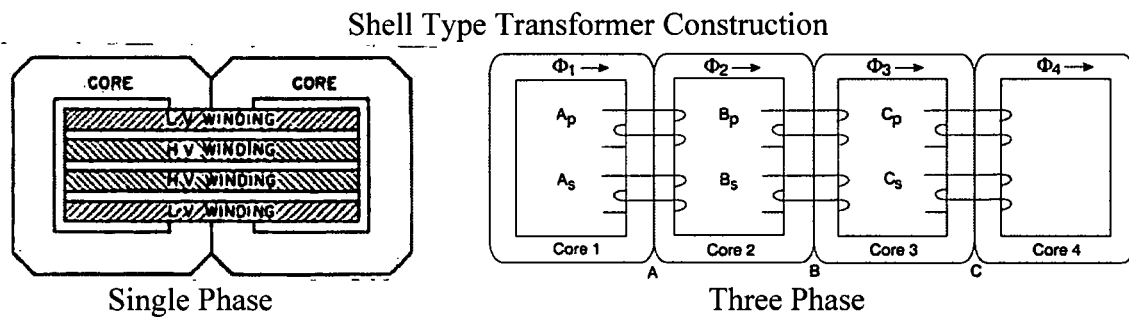
1. Byron Event Technical Analysis for Impact at the South Texas Project, Units 3 and 4.

**Attachment - Byron Event Technical Analysis for Impact at
South Texas Project Units 3 and 4**

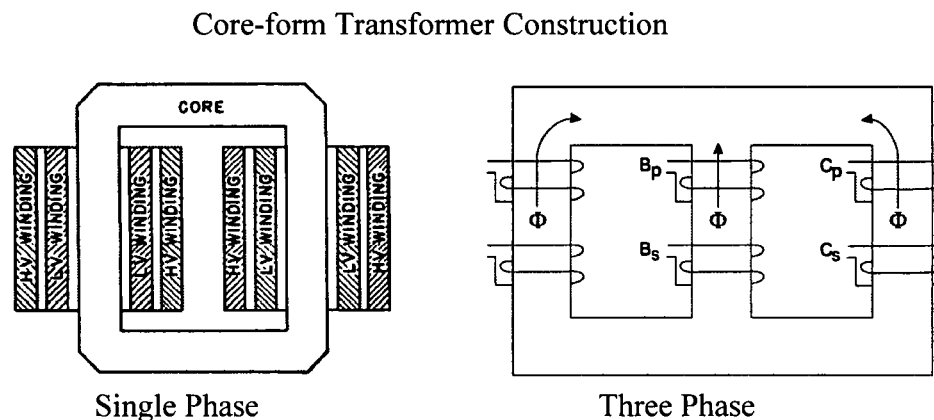
Transformer Construction:

The following is an example of typical transformer construction for the reader's reference.

Shell-form construction for single-phase transformers consists of all windings formed into a single ring, with magnetic punchings assembled so as to encircle each side of the winding ring as shown below. The mean length of turn is usually longer than for a comparable core-form design, while the iron path is shorter.



Core-form construction for a single-phase transformer consists of magnetic steel punchings arranged to provide a single-path magnetic circuit. High- and low-voltage coils are grouped together on each main or vertical leg of the core, as shown below. In general, the mean length of turn for the winding is comparatively short in the core form design, while the magnetic path is long.

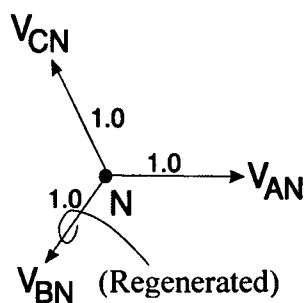


Main Transformer

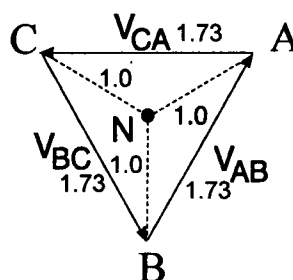
The MT is comprised of 3 single phase, 537.5 MVA 345/26kV transformers that are connected wye-ground/delta. The wye side is connected to the 345kV switchyard and the delta side is connected to the 26kV main generator and three (3) UATs. See FSAR Figure 8.3-1.

Based on Reference 1, a lost phase on a wye-grounded / delta transformer does not impact voltages on the secondary of the transformer. This is because the lost phase voltage is regenerated in the delta windings of the transformer. The three phase load on the secondary of the transformer will only be carried by the two connected phases on the high side of the transformer. This is within the capability of the MT, which has a combined rating of about 1612 MVA, because the load on the UATs is about 90 MVA with all the BOP motors running.

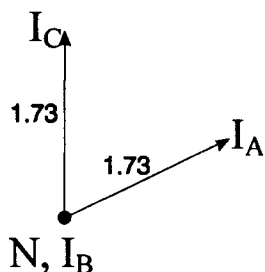
The following phasor diagrams represent the voltages and currents for the loss of “B” phase (Reference 1).



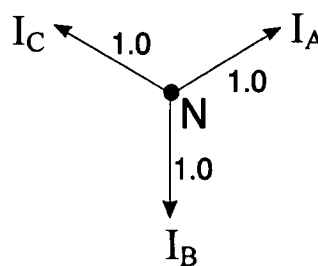
Primary Voltage



Secondary Voltage



Primary Currents



Secondary Currents

As can be seen, the lost phase voltage (B phase) on the primary is regenerated and the secondary voltage is equivalent to the expected phase to phase voltage. It should also be noted that the primary current of the remaining high side phases of the MT is the $\sqrt{3}$ (1.73) larger.

To confirm that the results predicted in Reference 1 are applicable to the MT for STP Units 3 and 4, STP modeled the response of the secondary voltage of the MT to the loss of a single phase on an offsite circuit using the computer software, ETAP, Version 12, under both light loading (shutdown loads on the balance of plant and Class 1E buses) and design loading (operating loads on the balance of plant and accident loads on the Class 1E buses). As shown from the results below, the ETAP analysis results are consistent with the conclusions from Reference 1. Specifically, ETAP confirms that loss of a single phase on the high voltage side of the MT will not result in a significant decrease in secondary side voltage for any phase. Therefore, loss of a single phase on the high voltage side of the MT will not significantly affect the voltage supplied to any phase on the high voltage side of the UATs and voltage at the Class 1E buses will remain within required limits. STP 3 & 4 detailed design and equipment purchase specifications are not

yet complete. The ITAAC described as part of this RAI response will ensure that equivalent results are achieved with the 'as-built' plant.

ETAP Study Results for Main Transformer expected Secondary Voltages

Wye-G/Delta, 3 x 1 Shell Form Transformer, B phase lost (Voltages in per unit)					
	High Side		Low Side		
Light loading (Shutdown loads on BOP and Class 1E buses)					
V _{AN}	1.00 ∠0	V _{AB}	1.01 ∠-30	DVR	Does not trip
V _{BN}	~0	V _{BC}	1.00 ∠-150	DVR	Does not trip
V _{CN}	1.00 ∠120	V _{CA}	0.999 ∠90	DVR	Does not trip
Design Loading (Operating loads and Accident loads on Class 1E buses)					
V _{AN}	1.00 ∠0	V _{AB}	0.993 ∠-33	DVR	Does not trip
V _{BN}	~0	V _{BC}	0.987 ∠-154	DVR	Does not trip
V _{CN}	1.00 ∠120	V _{CA}	0.96 ∠86	DVR	Does not trip

Unit Auxiliary Transformers:

Two of the UATs are three winding transformers, 26/13.8/4.16 kV and are connected delta/wye-ground (with resistor) - wye-ground (with resistor). The third UAT is a two winding transformer, 26/4.16 kV and is connected delta/wye-ground (with resistor). The UATs are fed by the MT or the Main Generator. Based on the ability of the MT to regenerate a lost phase, the UATs would have all phase voltages present. The loss of a phase on the Main Generator would cause a trip of the generator. See FSAR Figure 8.3-1.

Reserve Auxiliary Transformers:

The RATs are three winding transformers 345/13.8/4.16 kV and are connected wye-ground/wye-ground (with resistor) - wye-ground (with resistor) and are expected to be shell type construction. Based on Reference 1, the lost phase will not be completely regenerated in the secondary wye windings like they are for a wye-ground/delta transformer on a loaded or unloaded transformer. During normal operation, one RAT is connected to at least one of the three Class 1E safety related buses and is monitored by the undervoltage and degraded voltage functions for the Class 1 E bus.

The following table provides the results of an analysis from Reference 1 and shows what the resultant voltages would be for lost phases. The first table is for a transformer without any load on it.

Wye-G/Wye-G, 5 Legged Shell Form Xfmr, completely opened phase (No load), primary and secondary voltages					
B phase lost (middle phase)					
V _{AN}	1.00 ∠0	V _{AB}	~0.764 ∠19.1	V _{0,LN}	0.167 ∠60
V _{BN}	~0.5 ∠-120	V _{BC}	~0.764 ∠-79.1	V _{1,LN}	0.833 ∠30
V _{CN}	1.00 ∠120	V _{CA}	1.000 ∠150	V _{2,LN}	0.167 ∠-60
C phase lost (outside phase)					
V _{AN}	1.00 ∠0	V _{AB}	1.000 ∠30	V _{0,LN}	0.193 ∠-30
V _{BN}	1.00 ∠-120	V _{BC}	0.882 ∠-109	V _{1,LN}	0.839 ∠-6.6
V _{CN}	0.577 ∠90	V _{CA}	0.666 ∠150	V _{2,LN}	0.193 ∠90

The following table shows the expected resulting voltages of the RAT with the loss of one phase and some phase to neutral loading.

Wye-G/Wye-G, 5 Legged Shell Form Xfmr, opened phase, some Ph-N loading					
B phase lost (middle phase)					
V _{AN}	1.00 ∠0	V _{AB}	1.000 ∠30	V _{0,LN}	0.333 ∠-60
V _{BN}	~0	V _{BC}	0.578 ∠-120	V _{1,LN}	0.667 ∠0
V _{CN}	1.00 ∠120	V _{CA}	0.578 ∠180	V _{2,LN}	0.333 ∠60
C phase lost (outside phase)					
V _{AN}	1.00 ∠0	V _{AB}	1.000 ∠30	V _{0,LN}	0.333 ∠-60
V _{BN}	1.00 ∠-120	V _{BC}	0.578 ∠-120	V _{1,LN}	0.667 ∠0
V _{CN}	~0	V _{CA}	0.578 ∠180	V _{2,LN}	0.333 ∠60

The following table shows the expected resulting voltages of the RAT with the loss of one phase and phase to phase loading.

Wye-G/Wye-G, 5 Legged Shell Form Xfmr (similar to 3 single phase transformers based on analysis), opened phase, Ph-Ph load back-feed to lost phase; primary and secondary voltages					
B phase lost (middle phase)					
V _{AN}	1.00 ∠0	V _{AB}	<0.500 ∠-30	V _{0,LN}	0.500 ∠60
V _{BN}	< 0.5 ∠60	V _{BC}	<0.500 ∠ -30	V _{1,LN}	0.500 ∠0
V _{CN}	< 1.00 ∠120	V _{CA}	1.000 ∠150	V _{2,LN}	0.500 ∠-60

The loss of voltage and degraded voltage relays are fed from bus PTs that are connected phase to phase in a delta configuration. The output of the relays use a 2 out 3 logic to initiate circuitry for transferring power from offsite power to the onsite EDG. As shown in the table, if one phase is lost, two of the secondary voltages will be below the degraded voltage relay settings, and the degraded voltage relays drop out. The degraded voltage relay setting is nominally 90% (reference FSAR section 8.3.1.1.7 (8)).

To confirm that the results predicted in Reference 1 are applicable to the RATs for STP Units 3 and 4, STP modeled the response of the secondary voltage of a RAT to the loss of a single phase on an offsite circuit using the computer software, ETAP, Version 12, under both light loading (approximately 1 MW of load on one Class 1E bus) and design loading (accident load on one Class 1E bus). As shown from the results below, the ETAP analysis results are consistent with the conclusions from Reference 1. Specifically, ETAP confirms that loss of a single phase on the high voltage side of the RAT will result in a decrease in secondary side voltage for at least one phase. Loss of a single phase on the high voltage side of the RAT will significantly affect the voltage supplied to at least one phase on the low voltage side of the RAT resulting in actuation of two channels of the low voltage and degraded voltage trip function on the Class 1E safety bus. STP 3 & 4 detailed design and equipment purchase specifications are not yet complete. The ITAAC described as part of this RAI response will ensure that equivalent results are achieved with the 'as-built' plant.

ETAP Study Results for Reserve Auxiliary Transformer expected Secondary Voltages

Wye-G/Wye-low impedance, Shell Form transformer, B phase lost (Voltages in per unit)					
	High Side		Low Side		
Light loading (~1 MW of load on one Class 1E bus)					
V _{AN}	1.00 ∠0	V _{AB}	0.869 ∠6	DVR	Tripped
V _{BN}	~0	V _{BC}	0.599 ∠-91	DVR	Tripped
V _{CN}	1.00 ∠120	V _{CA}	0.995 ∠150	DVR	Does not trip
Design Loading (Accident load on one Class 1E bus)					
V _{AN}	1.00 ∠0	V _{AB}	0.875 ∠1	DVR	Tripped
V _{BN}	~0	V _{BC}	0.555 ∠-101	DVR	Tripped
V _{CN}	1.00 ∠120	V _{CA}	0.936 ∠145	DVR	Does not trip

Loss of Two Phases in an Offsite Source

In 2013, the Forsmark Nuclear Plant in Sweden was in an outage utilizing a feed from a 400 kV offsite power source. When the offsite source tripped, two phases opened and the third phase stayed closed. The Forsmark plant's onsite emergency diesel generators did not start automatically because the induced voltage on the open phases was higher than the undervoltage relay settings.

NINA evaluated the effect of loss of two phases in an offsite circuit that supplies the STP 3 & 4 MT or a RAT. Based on analyses described in Reference 1, NINA determined that loss of two phases on an offsite circuit that supplies either the MT or a RAT will result in actuation of the degraded voltage function for any affected Class 1E bus. Actuation of the degraded voltage function will disconnect the degraded offsite source from the affected Class 1E buses and start and connect the EDG. The expected secondary voltages based on Reference 1 are shown below:

STP Reserve Auxiliary Transformer
Expected Secondary Voltages following Loss of Two Phases*

Wye-G/Wye-G, 5 Legged Shell Form Xfmr, opened phase, some Ph-N loading (Voltages in per unit)					
	High Side		Low Side		
Loss of A and C Phases					
V _{AN}	~0	V _{AB}	0.578 ∠ 60	DVR	Tripped
V _{BN}	1.00 ∠ 0	V _{BC}	0.578 ∠ -120	DVR	Tripped
V _{CN}	~0	V _{CA}	0	DVR	Tripped
Loss of B and C Phases					
V _{AN}	1.00 ∠ 0	V _{AB}	0.578 ∠ 0	DVR	Tripped
V _{BN}	~0	V _{BC}	0	DVR	Tripped
V _{CN}	~0	V _{CA}	0.578 ∠ 180	DVR	Tripped

*Reference 1

STP Main Transformer
Expected Secondary Voltages following Loss of Two Phases*

Wye-G/Delta Transformer, B and C Phases Open (Voltages in per unit)					
Primary Voltages					
V _{AN}	1.00 ∠ 0	V _{AB}	0.867 ∠ 0		
V _{BN}	~0.5 ∠ 180	V _{BC}	~0		
V _{CN}	~0.5 ∠ 180	V _{CA}	0.867 ∠ 180		
Secondary Voltages					
V _{AN}	0.867 ∠ 0	V _{AB}	0.500 ∠ 0	DVR	Tripped
V _{BN}	~0	V _{BC}	0.500 ∠ 0	DVR	Tripped
V _{CN}	0.867 ∠ 180	V _{CA}	1.00 ∠ 180	DVR	Does not trip

*Reference 1

Conclusions:

Unlike Byron, the STP 3 & 4 electrical auxiliary system is configured and operated such that a failure or problem with one offsite source will not impact all three divisions of safety related equipment. At least one division will be available and able to shutdown the unit and at least one division will be immediately available to mitigate a design basis event.

For a single-open phase event on the grid side of the main power transformer, the safety related or non-safety related loads are not affected since the wye-ground/delta connection of the MT regenerates the lost phase. Also, the MT can carry the increased load on the remaining two phases because of its MVA capacity relative to the combined safety and non-safety loads. Thus, a single-open phase on the high side of the MT will not result in the loss of accident mitigating functions of the associated Class 1E Safety buses.

For a single-open phase event on the grid side of the RATs, the feeds from the RATs are affected by the single-open phase. Based on the analysis from Reference 1, the loss of a single phase will drop the voltage on two phases of the transformer's secondary. This drop in secondary voltage will be detected by the degraded undervoltage relaying on the Class 1E Safety buses.

For loss of two phases on an offsite circuit that supplies either the MT or the RAT, drop in secondary voltage will be detected by the degraded undervoltage relaying on the Class 1E Safety buses.

Reference

1. "A Practical Guide for Detecting Single-Phasing on a Three-Phase Power System" by John Horak and Gerald F. Johnson (Basler)

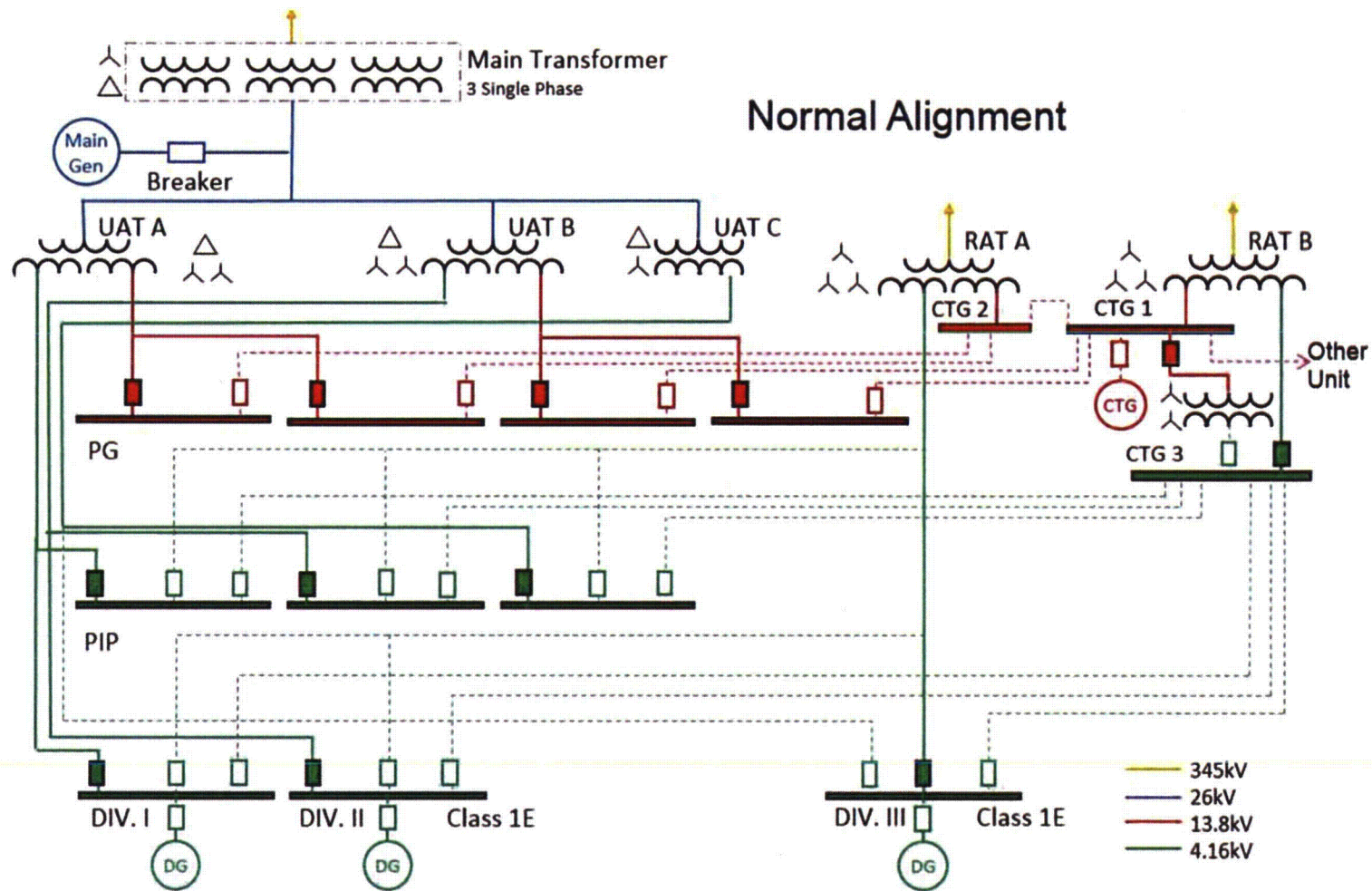


Figure 1: STP 3 & 4 On Site Electrical Distribution system