STP Nuclear Operating Company
South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

October 25, 2012
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10 CFR 50.4
10 CFR 2.202

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

South Texas Project
Units 1&2
Docket Nos. STN 50-498, STN 50-499
<u>STP Response to NRC Bulletin 2012-01: Design Vulnerability in Electrical Power System</u>

Reference: NRC Bulletin 2012-01: Design Vulnerability in Electrical Power System, Dated July 27, 2012 (ML12074A115)

The Nuclear Regulatory Commission (NRC) issued Bulletin 2012-01, "Design Vulnerability in Electrical Power System" (Reference) to all power reactor licensees and holders of combined licenses for nuclear power reactors on July 27, 2012. The Bulletin requires that each licensee provide a response to the Requested Action within 90 days of the date of this Bulletin. The Enclosure to this letter provides the Required Response to the Requested Actions of Bulletin 2012-01.

There are no regulatory commitments contained in this letter or the Enclosure.

If there are any questions regarding this letter, please contact Jim Morris at (361) 972-8652 or me at (361) 972-7566.

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

Executed on: October 25, 2012

Gerald T. Powell
Vice President-Generation

Enclosure: NRC Bulletin 2012-01, "Design Vulnerability in Electric Power System" Required Responses for the South Texas Project Units 1 & 2

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Enclosure

NRC Bulletin 2012-01 "Design Vulnerability in Electric Power System" Required Response for the South Texas Project Units 1 & 2

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NRC Bulletin Requested Action

To confirm that licensees comply with 10 CFR 50.55a(h)(2), 10 CFR 50.55a(h)(3), and Appendix A to 10 CFR Part 50, GDC 17, or principal design criteria specified in the updated final safety analysis report, the NRC requests that licensees address the following two issues related to their electric power systems within 90 days of the date of this bulletin:

1. Given the requirements above, describe how the protection scheme for ESF buses (Class 1E for current operating plants or non-Class 1E for passive plants) is designed to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on a credited off-site power circuit or another power source. Also, include the following information:

a. The sensitivity of protective devices to detect abnormal operating conditions and the basis for the protective device setpoint(s).

b. The differences (if any) of the consequences of a loaded (i.e., ESF bus normally aligned to offsite power transformer) or unloaded (e.g., ESF buses normally aligned to unit auxiliary transformer) power source.

c. If the design does not detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on a credited offsite power circuit or another power source, describe the consequences of such an event and the plant response.

d. Describe the offsite power transformer (e.g., start-up, reserve, station auxiliary) winding and grounding configurations.

STP Response to 1

Single Phase Open Circuit Discussion

Consistent with the current licensing basis and GDC 17, existing protective circuitry will separate the Engineered Safety Feature (ESF) buses from a connected failed offsite source due to a loss of voltage or a sustained degraded grid voltage with or without certain concurrent design basis accidents. Although the relay schemes were not specifically described in the UFSAR as having been designed to detect or respond to an open single phase of a three phase system, the undervoltage relay coincidence logic used from all three phases of the ESF buses resulted in a design that will detect and respond to the large majority of postulated loss of phase scenarios (refer to response to question 2, normal alignments scenarios). However, because the relay schemes were not specifically described to provide protection for a single-open phase, detection of and response to a single-open phase condition is considered to be beyond the currently approved design and licensing basis of the station.

In addition to the credited offsite power sources, South Texas Project also has an Emergency Transformer that can provide power to one ESF bus from each Unit. The Emergency Transformer is not a credited offsite power source. However, as part of defense in depth, the Emergency Transformer provides another possible source of offsite power to the ESF buses for use in emergency situations. Since this source is not credited, it is not discussed further in this response.

Preliminary analysis has shown the following for each of the credited offsite power circuits. (Refer to Attachment 3 for additional technical analysis.)

Main Transformer Back Feed Alignment Single-Phase Open Circuit Event

For a single-phase open circuit event on the grid side of a Main Transformer, the feed from the Main Transformer and the associated Unit Auxiliary Transformer (UAT) does not affect the safety-related or non-safety related loads since the wye-delta configuration of the Main Transformers recreates the lost phase (open-circuited phase). Also, the Main Transformers can carry the increased load on the remaining two phases due to MVA capacity of the Main Transformer being large relative to the combined safety-related and non-safety related loads on the UAT. Thus, following an expected unit trip due to unbalanced power flow from the Main Generator due to the loss of one phase, a single-phase open circuit event on the high side of the Main Transformers will not result in the loss of accident mitigating functions of the associated ESF buses powered by the UAT. Therefore, the safety-related loads fed by the Main Transformers and associated UAT are not affected by a single-phase open circuit event on the grid side of a Main Transformer. A single-phase open circuit without ground fault or short circuit on the plant side of the Main Transformers and UAT cannot occur without also initiating a ground fault or short circuit, because the conductors are enclosed isolated phase bus, enclosed non-segregated bus, or medium voltage cables in tray, duct banks, or conduit. Conductor failures in these circuits are expected to result in a fault that would be immediately cleared by installed protective relaying.

Standby Transformer Single-Phase Open Circuit Event

For a single-phase open circuit event on the grid side of a Standby Transformer (SBT), the feeds from the Standby Transformers are affected because of the wye-wye configuration of the Standby Transformers. Depending on which phase is open-circuited, the 13.8 kV bus undervoltage relays may drop out and trip the 13.8 kV buses, which would cause the associated 4.16 kV safety-related bus to separate from the offsite power source and be powered by its Standby Diesel Generator. This bus undervoltage relay scheme on the non-safety related 13.8 kV switchgear is set up to measure the voltage using bus potential transformers connected in an 'A' phase to 'B' phase and 'B' phase to 'C' phase configuration with a 2 out of 2 trip logic. Under normal operating conditions, the Standby Transformers are continuously loaded. Depending on the loading on the Standby Transformers, a single-phase open circuit on the primary side of the transformer may or may not be detected by the degraded voltage or undervoltage protection scheme. In most cases, with some loading on a Standby Transformer, at least one 13.8 kV bus undervoltage relay will drop out. However, there is no action or alarm if only one of the two relays actuates. Also, it should be noted that on an unloaded Standby Transformer, it is questionable if either 13.8 kV bus undervoltage relays will drop out. Therefore, depending on which phase is open-circuited and the loading on the Standby Transformers, the 13.8 kV bus undervoltage relaying may, or may not, drop out and trip the 13.8 kV buses.

In addition to the 13.8 kV bus undervoltage relays, the 4.16 kV safety-related ESF buses which are powered from the 13.8 kV buses, have bus undervoltage relays (both loss-of-voltage relays and degraded voltage relays). These loss-of-voltage and degraded voltage relays monitor all three phases and are connected to 2 out of 4 coincidence logic to separate the ESF buses from offsite power and realign them to the standby diesel generators upon detection of an unacceptable undervoltage or degraded voltage condition. The loss of voltage and degraded voltage relay schemes on the 4.16 kV switchgear are set up to measure the voltage using bus potential transformers connected in an 'A' phase to 'B' phase and 'B' phase to 'C' phase configuration. The drop out setpoint for the loss of voltage relays is approximately 75% of 4.16 kV. The drop out setpoint for the degraded voltage relays is approximately 92.2% of 4.16 kV. The loss of voltage relay time delay is set at 1.75 seconds and the degraded voltage relay time delays include a 35 second delay with a safety injection signal and a 50 second delay without a safety injection signal.

Given the 4.16 kV safety-related bus loss of voltage relay and degraded voltage relay drop out setpoints, associated time delay settings, and 2 out of 4 logic, this undervoltage protection scheme will automatically separate the associated 4.16 kV safety-related bus from the offsite power circuit for the large majority of postulated single-phase open circuit events (where normal load is present on the SBT). This protection scheme may not detect only a small subset of postulated single-phase open circuit events that could possibly occur during periods when the SBT is unloaded or very lightly loaded, such as during train swaps or planned maintenance periods. In order to detect this small subset of possible single-phase open circuit events, a corrective action is required. A corrective action to add a visual inspection of the 345 kV feeders to the SBTs to normal Operator rounds for the transformers that are conducted each shift has been entered into the STP Corrective Action Program. These inspections can identify a degraded or dropped phase connection well within the 72 hour LCO window for one offsite power circuit being inoperable, thus further reducing the probability and consequences of a possible single loss of phase event.

During normal power operation, the safety related 4.16 kV ESF bus power supplies are split between the UAT source and the SBT source. The "A" and "C" ESF buses are normally fed from the UAT via the F and H Standby buses and their associated ESF transformers, and the "B" ESF bus is normally supplied from the applicable SBT via the G Standby bus and its associated ESF transformer. It is important to note that although the 4.16 kV safety-related bus undervoltage protection scheme may not separate the associated 4.16 kV safety-related bus from the SBT for a small subset of possible single-phase open circuit events on the high side of the transformer, this condition would only impact the 4.16 kV safety-related buses being powered by the Standby Transformer. In STP's Normal Lineup, only safety-related ESF Bus Train "B" is powered by a Standby Transformer. Therefore, only safety-related Train "B" would be impacted by this condition, and the other two safety-related Trains would not be impacted. Consequently, the design and operation of STP's electrical distribution system is such that at least one safety-related train will remain unaffected by a single-phase open circuit event, even in the unlikely event that it were to occur during an alternate authorized alignment and go undetected.

High Impedance Ground Discussion:

The electrical analyses for offsite power circuits have been reviewed with regard to high impedance grounds. The effect of a high impedance ground has been analyzed to be dependent on where the high impedance ground is located and the magnitude of current flowing to the high impedance ground.

If a high impedance ground were located on the low side of a large power transformer that provides offsite power to the ESF loads (Unit Auxiliary Transformers and Standby Transformers) 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 ESF bus(es). Consequently, the affected 4.16 kV ESF bus(es) would then be powered by its associated Emergency Diesel Generator.

The design of the STP power distribution system is to allow single phase high impedance grounds to occur and the system stay operational. To achieve this feature, neutral grounding resistors are installed on the low side of each transformer winding to limit the ground fault current.

If a high impedance ground 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 high impedance ground would not be expected to prevent ESF 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 high impedance ground were located on the high side of the UAT or Standby Transformer, the high impedance ground 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 LOOP for the affected ESF buse(s) which would then automatically realign to the Emergency Diesel Generator(s).

STP Response to 1a

Consistent with the current licensing basis and GDC 17, existing electrical protective devices are sufficiently sensitive to detect design basis conditions like a loss of voltage or a degraded voltage. Although not specifically described in the UFSAR as having been designed to detect or respond to an open single phase of a three phase system, the coincidence logic used from all three phases of the ESF buses resulted in a design that will detect and respond to the large majority of postulated loss of phase scenarios. Refer to the following table for undervoltage protective devices and the basis for the device setpoint(s).

Existing electrical protective devices are also sufficiently sensitive to detect a ground fault. The following table lists ground fault protection on the applicable portions of the STP electrical distribution system and the basis for the device setpoint(s). Specifically, the table below provides the ground fault protection on the high side and low side of the offsite power source large power transformers (Main Transformers and Standby Transformers).

Ground Fault Protection on High Side and Low Side of Offsite Power Transformers

Protection Zone	Protective Device	UV Logic	Setpoint (Nominal)	Basis for Setpoint
4.16 kV ESF Bus	Loss of Voltage Relays	2 of 4	3107 V (74.7% of 4160 V)	To actuate upon complete loss of ESF Bus voltage condition in accordance with previously approved station Technical Specifications.
4.16 kV ESF Bus	Degraded Grid Voltage Relays	2 of 4	3835 V (92.2% of 4160V)	To actuate upon degraded ESF Bus voltage condition in accordance with previously approved station Technical Specifications.
13.8 kV Neutral Grounding System	Neutral Overcurrent Relays (51 N)	N/A	1.8 A	To actuate upon detecting a ground fault on the neutral of the 13.8 kV system.
13.8 kV feeders to 13.8 kV/4.16 kV ESF Transformer	Ground Fault Protection Relay (50G)	N/A	0.5 A	To actuate upon detecting a current imbalance which could be a ground fault or load imbalance and is set at the minimum pickup value.
Main Generator Windings	Ground Fault Protection Relay (64S)	N/A	7 V	To actuate upon detecting a ground fault during plant startup and is set at the minimum pickup value.
Main Generator Windings, Isolated Phase Bus Duct, Main Generator Circuit Breaker, and 25 kV Windings of Transformers	Ground Fault Protection Relay (64R)	N/A	5.4 V	To actuate upon detecting a ground fault during normal operation and is set at the minimum pickup value without spurious tripping.
Main Generator Windings, Isolated Phase Bus Duct, and 25 kV Windings of Transformers	Ground Fault Protection Relay (64B)	N/A	16 V	To actuate upon detecting a ground fault when the main generator circuit breaker is open and is set at the minimum pickup value. When the main generator is connected to the system, this relay provides backup ground fault protection to the 64R relay on the main generator.
Two 345 kV Switchyard Circuit Breakers that connect the Main Transformers to the 345 kV Switchyard and Main Transformer High Side Bushings	Main Transformer Circuit Connection Current Differential Relay System (Primary and Secondary Relay System)	N/A	5 A	To actuate upon detecting either phase or ground faults in the zone of protection. There is a primary and secondary relay system. The primary relay is connected in conjunction with an auxiliary relay to form a pilot wire differential protection, instantaneous transferred tripping relay system. The secondary relay system and pilot wire relaying is a duplicate of the primary relay system.

Protection Zone	Protective Device	UV Logic	Setpoint (Nominal)	Basis for Setpoint
345 kV Switchyard Circuit Breakers adjacent to 345 kV Switchyard Bus, associated Switchyard Bus 345 kV Shunt Reactor and Standby Transformer High Side Bushings	345 kV Switchyard Bus and Standby Transformer Current Differential Relay System (Primary and Secondary)	N/A	5 A	To actuate upon detecting either phase or ground faults in the zone of protection. There is a primary and secondary relay system. The primary relay is connected in conjunction with auxiliary relays and pilot wire relaying to form a differential protection, instantaneous auxiliary tripping, and transferred tripping relay system. The secondary relay system is a duplicate of the primary relay system.

STP Response to 1b

Although not specifically described in the UFSAR as having been designed to detect or respond to an open single phase of a three phase system, the coincidence logic used from all three phases of the ESF buses resulted in a design that will detect and respond to the large majority of postulated loss of phase scenarios. Existing loss of voltage and degraded voltage relays can respond depending on load and possible grounds.

At STP, under normal operating conditions, the electrical distribution system is configured in such a way that all offsite power sources (large power transformers providing offsite power to ESF buses) are continuously loaded, and there is no fast bus transfer scheme in place. For a simplified single line diagram, refer to Attachment 2, Onsite Power System Diagram (Normal Line Up.

Main Transformers

For a single-phase open circuit event on the grid side of a Main Transformer, regardless of loading, the feed from the Main Transformer and the associated Unit Auxiliary Transformer does not affect the safety-related or non-safety related loads since the wye-delta configuration of the Main Transformers recreates the lost phase (open-circuited phase). Also, the Main Transformers can carry the increased load on the remaining two phases due to MVA capacity of the Main Transformer being large relative to the combined safety-related and non-safety related loads on the UAT. Thus, following an expected unit trip due to unbalanced power flow from the Main Generator due to the loss of one phase, a single-phase open circuit event on the high side of the Main Transformers will not result in the loss of accident mitigating functions of the associated ESF buses powered by the UAT. Therefore, the safety-related loads fed by the Main Transformers and associated UAT are not affected by a single-phase open circuit event on the grid side of a Main Transformer.

A single-phase open circuit without ground fault or short circuit on the plant side of the Main Transformers and UAT cannot occur without also initiating a ground fault or short circuit, because the conductors are enclosed isolated phase bus, enclosed non-segregated bus, or medium voltage cables in tray, duct banks, or conduit. Conductor failures in these circuits are expected to result in a fault that would be immediately cleared by installed protective relaying.

Standby Transformers

Under normal operating conditions, the Standby Transformers are continuously loaded. Depending on the loading on the Standby Transformers, a single-phase open circuit on the primary side of the transformer may or may not be detected by the degraded voltage or undervoltage protection scheme. In most cases, with some loading on a Standby Transformer, at least one 13.8 kV bus undervoltage relay will drop out. However, there is no action or alarm if only one of the two relays actuates. Also, it should be noted that on an unloaded Standby Transformer, it is questionable if either 13.8 kV bus undervoltage relays will drop out. Therefore, depending on which phase is open-circuited and the loading on the Standby Transformers, the 13.8 kV bus undervoltage relaying may, or may not, drop out and trip the 13.8 kV buses.

In addition to the 13.8 kV bus undervoltage relays, the 4.16 kV safety-related ESF buses which are powered from the 13.8 kV buses, have bus undervoltage relays (both loss-of-voltage relays and degraded voltage relays). These loss-of-voltage and degraded voltage relays monitor all three phases and are connected to 2 out of 4 coincidence logic to separate the ESF buses from offsite power and realign them to the standby diesel generators upon detection of an unacceptable undervoltage or degraded voltage condition.

For a single-phase open circuit on the primary side of the Standby Transformer, the 4.16 kV safety-related ESF bus undervoltage relays (both loss-of-voltage relays and degraded voltage relays) would actuate and provide protection to ESF loads.

However, the plant response for a loaded Standby Transformer cannot be calculated without specifying the amount of loading and the specific loads involved.

For a high impedance ground with a loaded bus or unloaded ESF bus, it is important to know the magnitude of ground current. Regardless of loading, if the ground current is greater than or equal to the ground protection relay setpoint, then the ground protection relay will actuate and protect the ESF loads. However, if the ground current is less than the ground protection relay setpoint, then the ground protection relay will not actuate. However, this very low magnitude current, high impedance ground would not be expected to prevent ESF loads from performing their design function while staying connected to their associated offsite power source, because once the very low magnitude current, high impedance ground increases in current magnitude, it will actuate the ground protection relaying.

STP Response to 1c

1. The South Texas Project did not credit in the Current Licensing Basis (CLB) that the Class 1E protection scheme (for the emergency safety features (ESF) buses) was designed to detect and automatically respond to a single phase open circuit condition on a credited offsite power source as described in the UFSAR and Technical Specifications.

   The offsite power circuits at the South Texas Project consists of three independent circuits from the high side of Standby Transformer 1, Standby Transformer 2, or Main Transformers to the feeder breakers to the Class 1E ESF Buses. It should be noted that when the Main Generator trips via the Main Generator Circuit Breaker, offsite power continues to be provided from the 345 kV switchyard to the associated ESF buses through a back feed from the Main Transformers and associated Unit Auxiliary Transformer without a fast bus transfer. For a simplified single line diagram, refer to Attachment 1, Offsite Power System Diagram.

2. Since the South Texas Project did not credit the ESF bus protection scheme as being capable of detecting and automatically responding to a single-phase open circuit condition, an open phase fault was not included in the design criteria for either the loss of voltage or the degraded voltage relay (DVR) scheme. Since open phase detection was not credited in the South Texas Project design or licensing basis, no design basis calculations or design documents exist that previously considered this condition.

3. Without formalized engineering calculations or engineering evaluations, the electrical consequences of such an open phase event (including plant response), can only be evaluated to the extent of what has already been published by EPRI and Basler; which is a generic overview. The difficulty in applying these documents to the South Texas Project specific response is that these are generic assessments and cannot be formally credited as a basis for a technically complete response. The primary reason is that detailed plant specific models would need to be developed (e.g., transformer magnetic circuit models, electric distribution models, motor models; including positive, negative, and zero sequence impedances (voltage and currents), and the models would need to be compiled and analyzed for the South Texas Project specific Class 1E electric distribution system (EDS)).

Nonetheless, as a corrective action to detect the small subset of possible single-phase open circuit events that the 4.16 kV safety-related bus undervoltage protection scheme is unable to detect on the high side of the Standby Transformers (such as during infrequent unloaded transformer occurrences during switching/scheduled maintenance), an action item has been entered into the STP Corrective Action Program for Operations to perform a periodic visual inspection of the transmission lines and electrical connections between the Standby Transformers and the 345 kV switchyard. This Operations visual inspection will occur during normal Operator rounds for the Standby Transformers and will ensure that the Limiting Condition for Operation (LCO) action statement time requirement (72 hours) associated with the Technical Specification requirement (3.8.1.1) for the loss of one offsite power source is not exceeded should a problem with the lines or connections be identified.

Furthermore, to improve Operator awareness regarding the symptoms and potential impacts of a single loss of phase event, the following action items have been entered into the STP Corrective Action Program:

1. Provide a summary of the Byron 2 Event, the resulting electrical system transient, and the corrective action that adds inspections of the overhead lines to the Standby Transformers and switchyard rounds to all licensed and non-licensed operators. This event summary should include a description of the indications evident in the Byron 2 event to assist the control room operators in their diagnosis if such an event occurred at STP. (Condition Report:12-22996 Action Item 2)
2. Add this event to the normal Operations Training Cycle. This training should include the event indications, operational response, potential impact to STP, and the corrective action that adds inspections of the overhead lines between the Standby Transformers and the switchyard during operator rounds. (Condition Report:12-22996 Action Item 3)

No additional design changes are planned at this time, the design and operational alignments for STP limit the possible impact of a postulated loss of phase event on either of the two offsite power circuits to a low overall risk to the station.

The probability is low, because there is no single point in the offsite power supply where the loss of a single phase can impact both offsite power circuits. Only one of the offsite power circuits is susceptible to the loss of phase event impacting the safety related ESF buses, and the addition of visual inspection of the susceptible circuit to normal operator rounds makes it more likely that degradation of the conductors or supporting insulators and hardware will be detected before failure.

The consequences are low, because a loss of phase or malfunction of one offsite power circuit cannot impact all three safety related buses for either unit. Consequently, the design and operation of STP's electrical distribution system is such that at least one safety-related train will remain unaffected by a single-phase open circuit event, even in the unlikely event that it were to occur during an alternate authorized alignment and go undetected. In addition, the safety-related ESF bus loss-of-voltage and degraded voltage relays monitor all three phases and are connected to 2 out of 4 coincidence logic to separate the ESF buses from offsite power and realign them to the standby diesel generators upon detection of an unacceptable undervoltage or degraded voltage condition. This relay scheme will automatically detect the vast majority of possible loss of phase events. Only a small subset of postulated single-phase open circuit events that could possibly occur during periods when the SBT is unloaded or very lightly loaded, could go undetected by the degraded voltage relay scheme. In order to detect this small subset of possible single-phase open circuit events, a periodic visual inspection (operator rounds) corrective action has been entered into the STP Corrective Action Program to identify a degraded or dropped phase connection well within the 72 hour LCO window for one offsite power circuit being inoperable. (Condition Report: 12-22996 Action Item 1)

STP Response to 1d

Below is a listing of the offsite power transformer winding and grounding configurations.

Offsite Power Transformer Winding and Grounding Configurations

Transformer	Winding Configuration (High Side – Low Side)	Grounding Configuration (High Side – Low Side)
Unit 1 Main Transformer MT001A	Wye – Delta	Solidly Grounded – Ungrounded
Unit 1 Main Transformer MT001B	Wye – Delta	Solidly Grounded – Ungrounded
Unit 1 Unit Auxiliary Transformer	Delta – Wye – Wye	Ungrounded – Low Resistance Grounded – Low Resistance Grounded
Unit 2 Main Transformer MT001A	Wye – Delta	Solidly Grounded – Ungrounded
Unit 2 Main Transformer MT001B	Wye – Delta	Solidly Grounded – Ungrounded
Unit 2 Unit Auxiliary Transformer	Delta – Wye – Wye	Ungrounded – Low Resistance Grounded – Low Resistance Grounded
Standby Transformer 1	Wye – Wye – Wye	Solidly Grounded – Low Resistance Grounded – Low Resistance Grounded
Standby Transformer 2	Wye – Wye – Wye	Solidly Grounded – Low Resistance Grounded – Low Resistance Grounded

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2. Briefly describe the operating configuration of the ESF buses (Class 1E for current operating plants or non-Class 1E for passive plants) at power (normal operating condition). Include the following details:

a. Are the ESF buses powered by offsite power sources? If so, explain what major loads are connected to the buses including their ratings.

b. If the ESF buses are not powered by offsite power sources, 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.

c. Confirm that the operating configuration of the ESF buses is consistent with the current licensing basis. Describe any changes in offsite power source alignment to the ESF buses from the original plant licensing.

d. Do the plant operating procedures, including off-normal operating procedures, specifically call for verification of the voltages on all three phases of the ESF buses?

e. If a common or single offsite circuit is used to supply redundant ESF buses, explain why a failure, such as a single-phase open circuit or high impedance ground fault condition, would not adversely affect redundant ESF buses.

STP Response to 2

For STP, power feeds from the switchyard for each unit are normally via a Standby Transformer, and a back feed through the respective unit's Main and Unit Auxiliary Transformers. The Unit Auxiliary Transformer (UAT) and both Standby Transformers (SBT) can supply power to the 13.8kV Standby buses (F, G, and H). Standby buses F, G, and H in turn feed the 13.8 / 4.16kV ESF transformers. During normal power operation, the safety related 4.16 kV ESF bus power supplies are split between the UAT source and the SBT source. The "A" and "C" ESF buses are normally fed from the UAT via the F and H Standby buses and their associated ESF transformers, and the "B" ESF bus is normally supplied from the applicable SBT via the G Standby bus and its associated ESF transformer. For a simplified single line diagram, refer to Attachment 2.

It should be noted that when the Main Generator trips via the Main Generator Circuit Breaker, offsite power continues to be provided from the 345 kV switchyard to the associated ESF buses through a back feed from the Main Transformers and associated Unit Auxiliary Transformer without a fast bus transfer. For a simplified single line diagram, refer to Attachment 1, Offsite Power System Diagram.

At STP, under normal operating conditions, the electrical distribution system is configured in such a way that all offsite power sources (large power transformers providing offsite power to ESF buses) are continuously loaded, and there is no fast bus transfer scheme in place.

STP Response to 2a

For at power (normal operating condition) configurations, ESF buses are powered by offsite power sources.

Below is a listing of major loads connected to the 4.16 kV ESF buses.

Unit 1 Major Loads Connected to ESF Buses

ESF Bus	Load	Voltage Level (V)	Rating
E1A	High Head Safety Injection Pump	4160	1000 hp
E1A	Low Head Safety Injection Pump	4160	400 hp
E1A	Essential Cooling Water Pump	4160	800 hp
E1A	Auxiliary Feed Water Pump	4160	800 hp
E1A	Centrifugal Charging Pump	4160	600 hp
E1A	Containment Spray	4160	400 hp
E1A	Component Cooling Water Pump	4160	800 hp
E1A	EAB Essential A/C Chiller	4160	500 hp
E1A	Load Center Transformer E1A1	4160	1333 kVA
E1A	Load Center Transformer E1A2	4160	1333 kVA
E1B	High Head Safety Injection Pump	4160	1000 hp
E1B	Low Head Safety Injection Pump	4160	400 hp
E1B	Essential Cooling Water Pump	4160	800 hp
E1B	Auxiliary Feed Water Pump	4160	800 hp
E1B	Containment Spray	4160	400 hp
E1B	Component Cooling Water Pump	4160	800 hp
E1B	EAB Essential A/C Chiller	4160	500 hp
E1B	Load Center Transformer E1B1	4160	1333 kVA
E1B	Load Center Transformer E1B2	4160	1333 kVA
E1C	High Head Safety Injection Pump	4160	1000 hp
E1C	Low Head Safety Injection Pump	4160	400 hp
E1C	Essential Cooling Water Pump	4160	800 hp
E1C	Auxiliary Feed Water Pump	4160	800 hp
E1C	Centrifugal Charging Pump	4160	600 hp
E1C	Containment Spray	4160	400 hp
E1C	Component Cooling Water Pump	4160	800 hp
E1C	EAB Essential A/C Chiller	4160	500 hp
E1C	Load Center Transformer E1C1	4160	1333 kVA
E1C	Load Center Transformer E1C2	4160	1333 kVA

EAB- Electrical Auxiliary Building

Unit 2 Major Loads Connected to ESF Buses

ESF Bus	Load	Voltage Level (V)	Rating
E2A	High Head Safety Injection Pump	4160	1000 hp
E2A	Low Head Safety Injection Pump	4160	400 hp
E2A	Essential Cooling Water Pump	4160	800 hp
E2A	Auxiliary Feed Water Pump	4160	800 hp
E2A	Centrifugal Charging Pump	4160	600 hp
E2A	Containment Spray	4160	400 hp
E2A	Component Cooling Water Pump	4160	800 hp
E2A	EAB Essential A/C Chiller	4160	500 hp
E2A	Load Center Transformer E2A1	4160	1333 kVA
E2A	Load Center Transformer E2A2	4160	1333 kVA
E2B	High Head Safety Injection Pump	4160	1000 hp
E2B	Low Head Safety Injection Pump	4160	400 hp
E2B	Essential Cooling Water Pump	4160	800 hp
E2B	Auxiliary Feed Water Pump	4160	800 hp
E2B	Containment Spray	4160	400 hp
E2B	Component Cooling Water Pump	4160	800 hp
E2B	EAB Essential A/C Chiller	4160	500 hp
E2B	Load Center Transformer E2B1	4160	1333 kVA
E2B	Load Center Transformer E2B2	4160	1333 kVA
E2C	High Head Safety Injection Pump	4160	1000 hp
E2C	Low Head Safety Injection Pump	4160	400 hp
E2C	Essential Cooling Water Pump	4160	800 hp
E2C	Auxiliary Feed Water Pump	4160	800 hp
E2C	Centrifugal Charging Pump	4160	600 hp
E2C	Containment Spray	4160	400 hp
E2C	Component Cooling Water Pump	4160	800 hp
E2C	EAB Essential A/C Chiller	4160	500 hp
E2C	Load Center Transformer E2C1	4160	1333 kVA
E2C	Load Center Transformer E2C2	4160	1333 kVA

EAB- Electrical Auxiliary Building

STP Response to 2b

Not Applicable – The ESF buses at South Texas Project are normally powered by offsite power sources.

STP Response to 2c

The South Texas Project was originally licensed in such a way that multiple alternate electrical alignments were allowed. However, a particular alignment has been specified as the normal alignment by the station one line drawing throughout the history of the station. The normal alignment has changed several times as described below since original licensing to manage projected switchyard voltage limitations resulting from interfaces with transmission distribution service providers.

The current at power (normal operating condition) configuration has been confirmed to be consistent with the current licensing basis and is as follows. (For a simplified single line diagram, refer to Attachment 2.)

4160 V ESF Bus	Offsite Power Source
Unit 1 - E1A	345 kV switchyard (Unit 1 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 1 - E1B	345 kV switchyard (Standby Transformer 1) Includes ESF On Load LTC Transformer
Unit 1 - E1C	345 kV switchyard (Unit 1 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 2 - E2A	345 kV switchyard (Unit 2 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 2 - E2B	345 kV switchyard (Standby Transformer 2) Includes ESF On Load LTC Transformer
Unit 2 - E2C	345 kV switchyard (Unit 2 Main Transformers and Unit Auxiliary Transformer with On Load LTC)

The original at power (normal operating condition) configuration was as follows.

4160 V ESF Bus	Offsite Power Source
Unit 1 - E1A	345 kV switchyard (Unit 1 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 1 - E1B	345 kV switchyard (Standby Transformer 1)
Unit 1 - E1C	345 kV switchyard (Standby Transformer 1)
Unit 2 - E2A	345 kV switchyard (Unit 2 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 2 - E2B	345 kV switchyard (Standby Transformer 2)
Unit 2 - E2C	345 kV switchyard (Standby Transformer 2)

The 2007 changes were as follows (changes in italics):

4160 V ESF Bus	Offsite Power Source
Unit 1 - E1A	345 kV switchyard (Unit 1 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 1 - E1B	*345 kV switchyard* *(Unit 1 Main Transformers and* *Unit Auxiliary Transformer with On Load LTC)*
Unit 1 - E1C	345 kV switchyard (Standby Transformer 1)
Unit 2 - E2A	*345 kV switchyard* *(Standby Transformer 2)*
Unit 2 - E2B	*345 kV switchyard* *(Unit 2 Main Transformers and* *Unit Auxiliary Transformer with On Load LTC)*
Unit 2 - E2C	*345 kV switchyard* *(Unit 2 Main Transformers and* *Unit Auxiliary Transformer with On Load LTC)*

The 2009 changes were as follows (changes in italics):

4160 V ESF Bus	Offsite Power Source
Unit 1 - E1A	345 kV switchyard (Unit 1 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 1 - E1B	*345 kV switchyard* *(Standby Transformer 1)* *Added ESF On Load LTC Transformer*
Unit 1 - E1C	*345 kV switchyard* *(Unit 1 Main Transformers and* *Unit Auxiliary Transformer with On Load LTC)*
Unit 2 - E2A	345 kV switchyard (Standby Transformer 2)
Unit 2 - E2B	345 kV switchyard (Unit 2 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 2 - E2C	345 kV switchyard (Unit 2 Main Transformers and Unit Auxiliary Transformer with On Load LTC)

The 2010 changes were as follows (changes in italics):

4160 V ESF Bus	Offsite Power Source
Unit 1 - E1A	345 kV switchyard (Unit 1 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 1 - E1B	345 kV switchyard (Standby Transformer 1)
Unit 1 - E1C	345 kV switchyard (Unit 1 Main Transformers and Unit Auxiliary Transformer with On Load LTC)
Unit 2 - E2A	*345 kV switchyard* *(Unit 2 Main Transformers and Unit Auxiliary Transformer with On Load LTC)*
Unit 2 - E2B	*345 kV switchyard* *(Standby Transformer 2)* *Added ESF On Load LTC Transformer*
Unit 2 - E2C	345 kV switchyard (Unit 2 Main Transformers and Unit Auxiliary Transformer with On Load LTC)

STP Response to 2d

Plant operating procedures (with the exception of Generator synchronization) do not call for verification of the voltages on all three phases of the ESF buses. Although some operating procedures do not specifically instruct operators to verify all three phases of ESF bus voltage, STP operators are trained to check all three phases. The South Texas Project has entered actions into the Corrective Action Program to evaluate this condition and revise the appropriate operating procedures to include verifying the voltages on all three phases of the ESF bus. (Condition Report: 12-26977 Action Items 2 -8)

STP Response to 2e

Consistent with the current licensing basis and GDC 17, existing protective circuitry will separate the ESF buses from a connected failed offsite source due to a loss of voltage or a sustained degraded grid voltage with or without certain concurrent design basis accidents. Although the relay schemes were not specifically described in the UFSAR as having been designed to detect or respond to an open single phase of a three phase system, the undervoltage relay coincidence logic used from all three phases of the ESF buses resulted in a design that will detect and respond to the large majority of postulated loss of phase scenarios. However, because the relay schemes were not specifically described to provide protection for a single-open phase, detection of and response to a single-open phase condition is considered to be beyond the currently approved design and licensing basis of the station. No formal calculations for the single-open phase scenario have been performed at the South Texas Project.

In accordance with the current station design, protective circuitry will protect from a ground fault condition with all three phases intact.

As a result of the STP design, and authorized alignments, there is no single point in the offsite power supply where the loss of a single phase or a high impedance ground fault condition can impact all offsite power circuits, and a loss of phase or malfunction of one offsite power circuit cannot impact all three safety related buses for either unit. Consequently, the design and operation of STP's electrical distribution system is such that at least one safety-related train will remain unaffected by a single-phase open circuit or high impedance ground fault condition, even in the unlikely event that it were to occur during an alternate authorized alignment and go undetected. It should be noted that only one train of safety-related equipment is required to safely shut down and cool down an operating unit.

For STP, power feeds from the switchyard for each unit are normally via a Standby Transformer, and a back feed through the respective unit's Main and Unit Auxiliary Transformers. The Unit Auxiliary Transformer (UAT) and both Standby Transformers (SBT) can supply power to the 13.8kV Standby buses (F, G, and H). Standby buses F, G, and H in turn feed the 13.8 / 4.16kV ESF transformers. During normal power operation, the safety related 4.16 kV ESF bus power supplies are split between the UAT source and the SBT source. The "A" and "C" ESF buses are normally fed from the UAT via the F and H Standby buses and their associated ESF transformers, and the "B" ESF bus is normally supplied from the applicable SBT via the G Standby bus and its associated ESF transformer. For a simplified single line diagram, refer to Attachment 2, Onsite Power System Diagram (Normal Line Up). An allowed alternate lineup for each unit is to feed the standby buses from both SBT 1 and SBT 2. It is not allowed by procedure to have all three ESF buses for one unit fed by one SBT or UAT.

As stated above, in the normal alignment, both "A" and "C" ESF buses are fed from the UAT. As previously stated, for a single-phase open circuit event on the grid side of a Main Transformer, regardless of loading, the feed from the Main Transformer and the associated Unit Auxiliary Transformer does not affect the safety-related or non-safety related loads since the wye-delta configuration of the Main Transformers recreates the lost phase (open-circuited phase). Also, the Main Transformers can carry the increased load on the remaining two phases due to MVA capacity of the Main Transformer being large relative to the combined safety-related and non-safety related loads on the UAT. Thus, following an expected unit trip due to unbalanced power flow from the Main Generator due to the loss of one phase, a single-phase open circuit event on the high side of the Main Transformers will not result in the loss of accident mitigating functions of the associated ESF buses powered by the UAT. Therefore, the safety-related loads fed by the Main Transformers and associated UAT, which in the normal alignment would be all "A" and "C" train safety-related loads, are not affected by a single-phase open circuit event on the grid side of a Main Transformer. Refer to Attachment 3 for additional technical analysis.

A single-phase open circuit without ground fault or short circuit on the plant side of the Main Transformers and UAT cannot occur without also initiating a ground fault or short circuit, because the conductors are enclosed isolated phase bus, enclosed non-segregated bus, or medium voltage cables in tray, duct banks, or conduit. Conductor failures in these circuits are expected to result in a fault that would be immediately cleared by installed protective relaying.

The offsite power circuits are protected by ground fault and short circuit protective relaying that will isolate affected portions of the circuits upon detection of ground faults or short circuits in accordance with generally accepted protective relaying design standards.

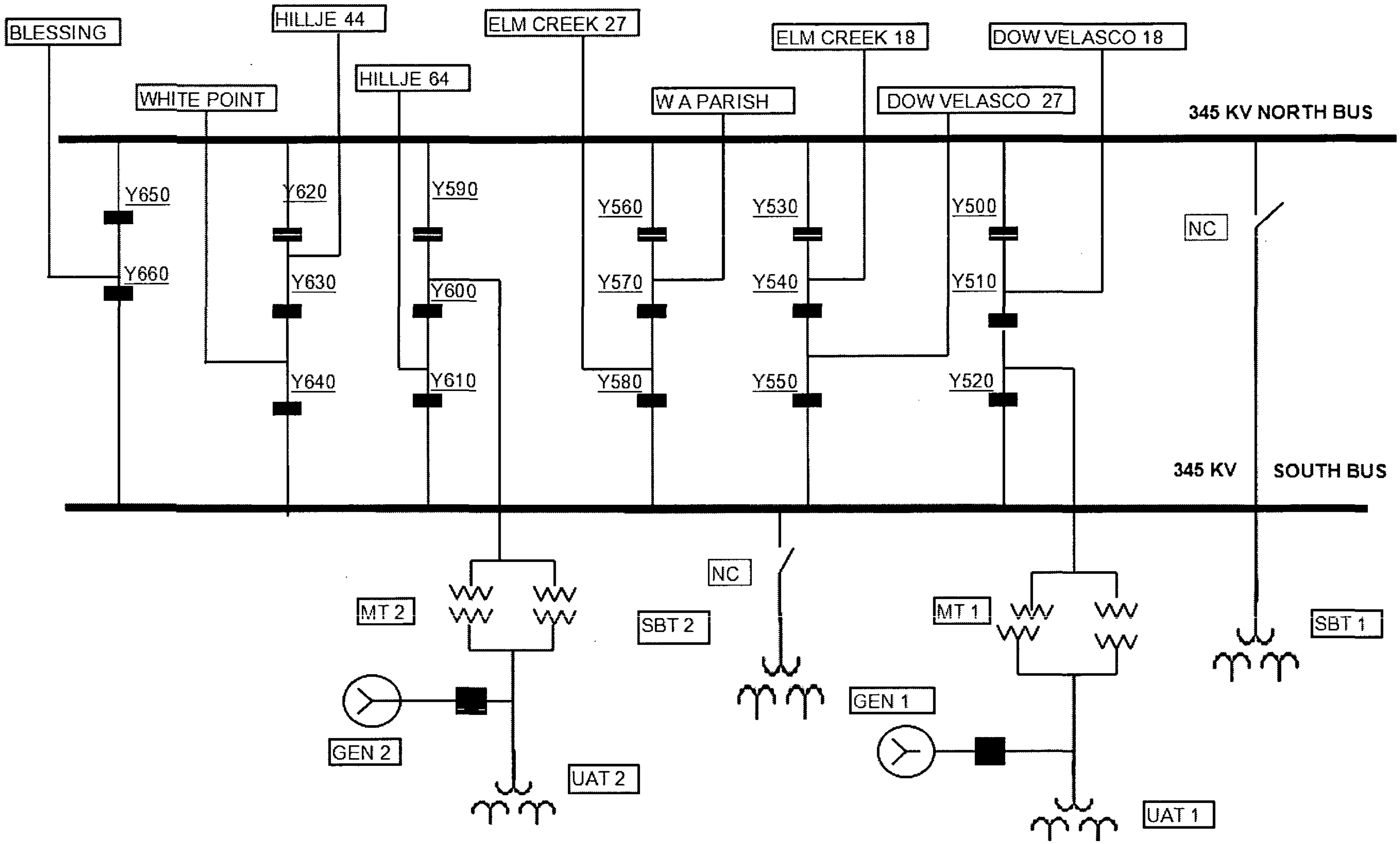
The safety-related 4.16kV ESF buses have loss-of-voltage and degraded voltage protective relaying. These loss-of-voltage and degraded voltage relays monitor all three phases and are connected to 2 out of 4 coincidence logic to separate the ESF buses from offsite power and realign them to the standby diesel generators upon detection of an unacceptable undervoltage or degraded voltage condition. The loss of voltage time delay is set at 1.75 seconds and the degraded voltage time delays include a 35 second delay with a safety injection signal and a 50 second delay without a safety injection signal.

In addition, individual motor load protective relaying uses a conventional inverse time overcurrent and instantaneous overcurrent protection scheme via electromechanical and solid state relays. These relays will trip most of the motors at 3.5 to 4 seconds at full voltage and locked rotor current. A few motors like the reactor coolant pumps are delayed to about 12 seconds at full voltage and locked rotor current because of the amount of time it takes to accelerate these particular motors. In all cases, running and starting, the motors are protected from damage by the overcurrent protection scheme.

References

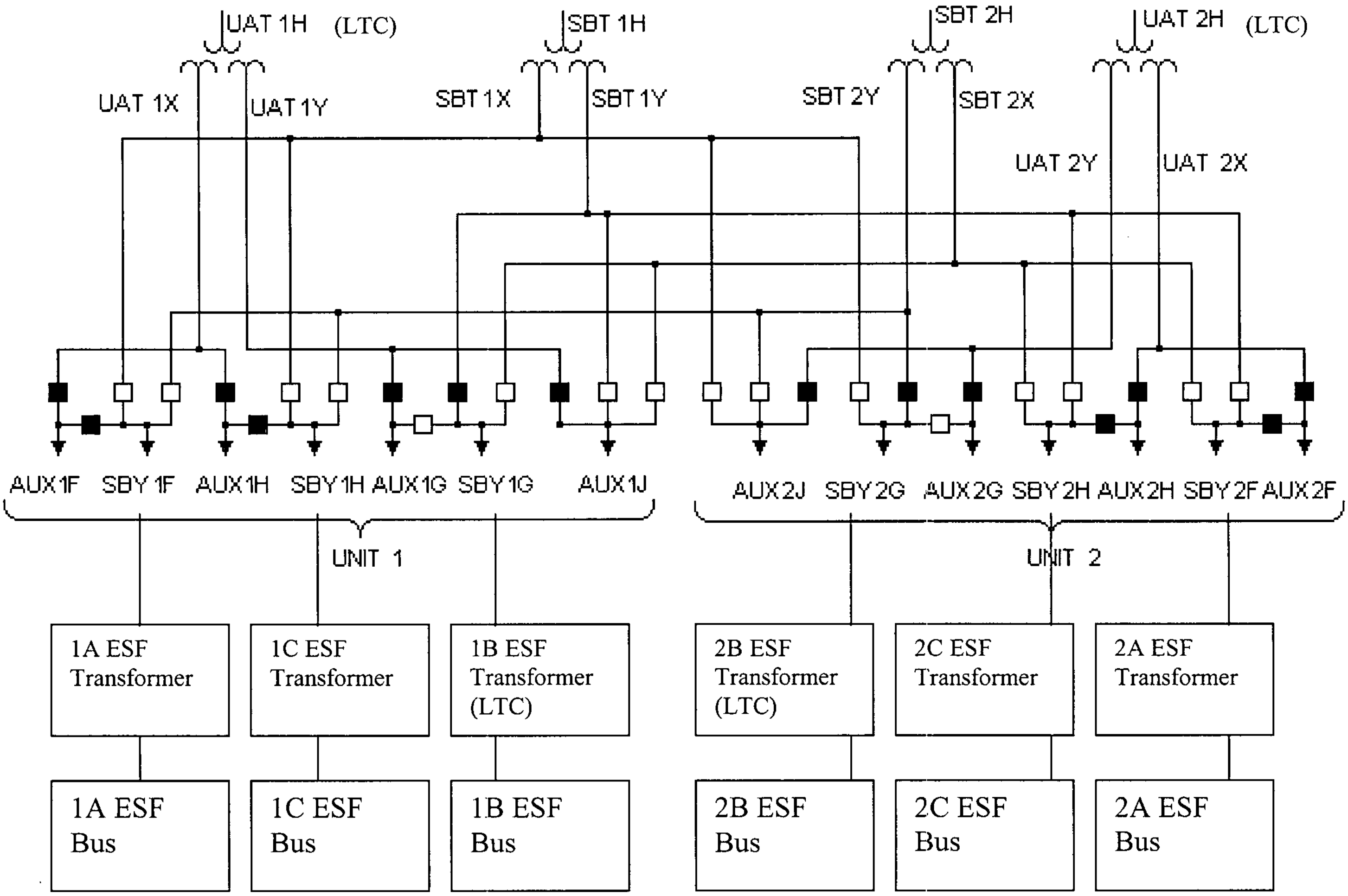
1. "A Practical Guide for Detecting Single-Phasing on a Three-Phase Power System" by John Horak and Gerald F. Johnson (Basler)

Attachment 1 - Offsite Power System Diagram



Attachment 2- Onsite Power System Diagram (Normal Line Up)

OFFSITE POWER FROM: UAT 1 SBT 1 UAT 2 SBT 2
CIRCUIT BREAKER CLOSED ■
CIRCUIT BREAKER OPEN ☐

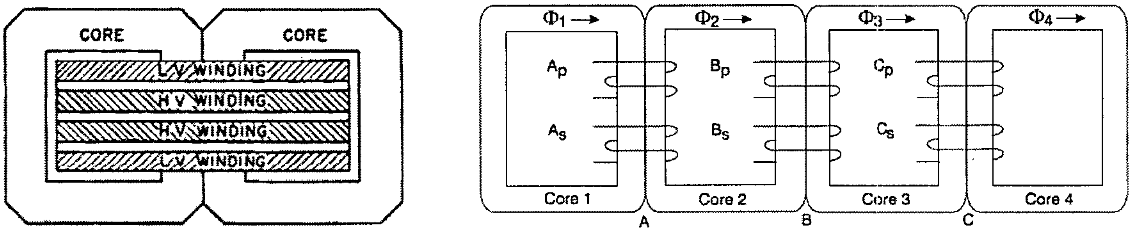


Attachment 3 - Byron Event Technical Analysis for Impact at the South Texas Project

Unit Main and Auxiliary Transformers:

Based on nameplate, test data and equipment purchase specifications, the unit Main transformers were purchased as a shell type transformer. The Unit Auxiliary transformers are core form type transformers. 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.

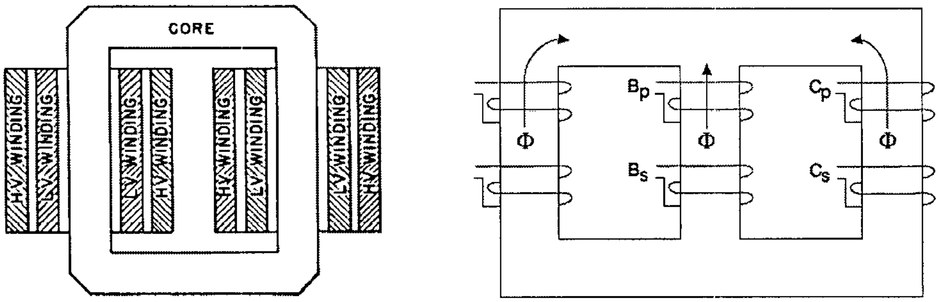
Shell Type Transformer Construction



Single Phase Three Phase

For your information, 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.

Core-form Transformer Construction

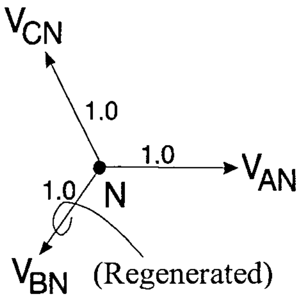


Single Phase Three Phase

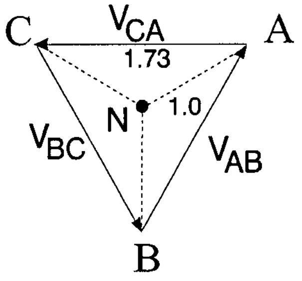
The Main transformers are paralleled 362.25/25kV and are connected wye-ground/delta. The wye side is connected to the 345kV switchyard and the delta side is connected to the 25kV main generator and Unit Auxiliary Transformer. The Unit Auxiliary Transformer is a three winding transformer, 25/13.8/13.8kV and is connected delta/wye-ground (with resistor)/ wye-ground (with resistor).

Based on a paper by John Horak and Gerald F. Johnson "A Practical Guide for Detecting Single-Phasing on a Three-Phase Power System" (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 reproduced 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 two Main transformers connected in parallel which have a combined base rating of about 1400 MVA because the load on the Unit Auxiliary Transformer is about 80 MVA.

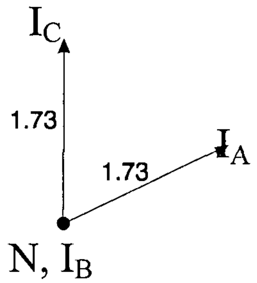
The following phasor diagrams represent the voltages and currents for the loss of "B" phase (reference 1).



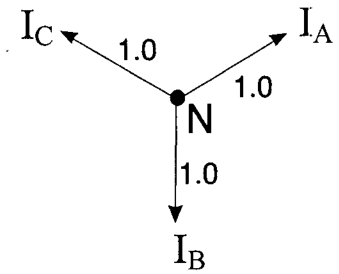
Primary Voltage



Secondary Voltage



Primary Currents



Secondary Currents

As can be seen, the lost phase voltage (B phase) on the primary is recreated 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 main transformers is the √3 (1.73) larger.

Even though the Main transformers reproduce a lost phase's voltage on the delta side of the transformer, there are voltage imbalances that are produced when the Main Generator is on line and operating at rated power. This is evident based on a Unit 2 trip that occurred March 1, 2001 (CR 01-3411).

In this STP event, Unit 2 was single phased due to a pole not closing on one of the 345 kV unit output switchyard circuit breakers because of a broken linkage. The other 345kV switchyard breaker had been opened as part of a clearance. After running a short time with one phase open, one of the circulating pump motors tripped on current imbalance (46 relay). Shortly after the first pump motor trip, a second circulating water pump motor tripped on current imbalance which caused a trip of the turbine and reactor. The current imbalance was due to a voltage imbalance caused by the loss of one phase at the unit output circuit breaker in the switchyard.

Following the unit trip, the Unit Auxiliary Transformer (UAT) continued to operate as designed because all three phase voltages which were reproduced by the Main transformer are present on high side of the UAT. Also, the Unit Auxiliary Transformer is connected to the Main transformers and generator circuit breaker via isolated phase bus duct. The undetected opening of one phase in the bus duct is very unlikely since the duct protects the bus, the connections are bolted and any failure of a main conductor would likely result in a line to ground fault to the grounded isolated phase bus outer shell.

Once the main generator trips, the Main and Unit Auxiliary transformers continue to supply power to the plant buses with nearly balanced three phase voltages to the 13.8kV and 4160V systems. The load on the Main transformer windings would be unequal but still well within the rating of the transformers.

Standby Transformers:

Based on nameplate, test data and equipment purchase specifications, the Standby transformers were purchased as a shell type transformer. The transformers are three winding transformers 362.25/13.8/13.8kV and are connected wye-ground/wye-ground (with resistor)/ wye-ground (with resistor). Based on a paper by John Horak and Gerald F. Johnson "A Practical Guide for Detecting Single-Phasing on a Three-Phase Power System" (reference 1), the lost phase will not be completely reproduced in the secondary wye windings like they are for a wye-ground/delta transformer on a loaded or unloaded transformer.

The following table provides the results of an analysis from reference 1. It does not represent STP's phasing; however, it does show 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 $\angle$ 0	V_{AB}	~0.764 $\angle$ 19.1	$V_{0,LN}$	0.167 $\angle$ 60
V_{BN}	~0.5 $\angle$ -120	V_{BC}	~0.764 $\angle$ -79.1	$V_{1,LN}$	0.833 $\angle$ 30
V_{CN}	1.00 $\angle$ 120	V_{CA}	1.000 $\angle$ 150	$V_{2,LN}$	0.167 $\angle$ -60
C phase lost (outside phase)					
V_{AN}	1.00 $\angle$ 0	V_{AB}	1.000 $\angle$ 30	$V_{0,LN}$	0.193 $\angle$ -30
V_{BN}	1.00 $\angle$ -120	V_{BC}	0.882 $\angle$ -109	$V_{1,LN}$	0.839 $\angle$ -6.6
V_{CN}	0.577 $\angle$ 90	V_{CA}	0.666 $\angle$ 150	$V_{2,LN}$	0.193 $\angle$ 90

The following table shows the expected resulting voltages of the standby transformer 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 $\angle$ 0	V_{AB}	1.000 $\angle$ 30	$V_{0,LN}$	0.333 $\angle$ -60
V_{BN}	~0	V_{BC}	0.578 $\angle$ -120	$V_{1,LN}$	0.667 $\angle$ 0
V_{CN}	1.00 $\angle$ 120	V_{CA}	0.578 $\angle$ 180	$V_{2,LN}$	0.333 $\angle$ 60
C phase lost (outside phase)					
V_{AN}	1.00 $\angle$ 0	V_{AB}	1.000 $\angle$ 30	$V_{0,LN}$	0.333 $\angle$ -60
V_{BN}	1.00 $\angle$ -120	V_{BC}	0.578 $\angle$ -120	$V_{1,LN}$	0.667 $\angle$ 0
V_{CN}	~0	V_{CA}	0.578 $\angle$ 180	$V_{2,LN}$	0.333 $\angle$ 60

The following table shows the expected resulting voltages of the standby transformer 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 $\angle$ 0	V_{AB}	<0.500 $\angle$ -30	$V_{0,LN}$	0.500 $\angle$ 60
V_{BN}	< 0.5 $\angle$ 60	V_{BC}	<0.500 $\angle$ -30	$V_{1,LN}$	0.500 $\angle$ 0
V_{CN}	< 1.00 $\angle$ 120	V_{CA}	1.000 $\angle$ 150	$V_{2,LN}$	0.500 $\angle$ -60

The bus undervoltage relay scheme on the non-safety related 13.8kV switchgear is set up to measure the voltage using bus potential transformers connected in an A-B and B-C configuration with a 2 out of 2 trip. There is no action or alarm if only one relay should actuate. Per STP calculation EC05028 'Protection 13.8kV Switchgear', the 13.8kV switchgear undervoltage voltage relays are set at approximately 79% of nominal voltage. Based on the tables above for light load conditions and phase to phase load conditions, at least one of these non-safety related 13.8 kV bus undervoltage relays (GE IAV) will drop out after a time delay. At 71% bus voltage, the relay will time out in about 22.5 seconds and at 57.8% voltage, the relay will time out in about 10 seconds. In addition, under no load conditions, the undervoltage relays (loss of voltage) may not drop out because the voltage may not go low enough. However, the loss of phase effect on the non-safety related 13.8kV switchgear will also cause undervoltage or degraded voltage conditions on the 4.16 kV ESF buses and these buses are supervised by additional undervoltage and degraded voltage relaying as described below.

ESF Transformers:

Based on nameplate, test data and equipment purchase specifications, the ESF transformers were purchased as a core type transformer. The transformers are two winding transformers 13.8/4.16kV and are connected delta/wye-ground (with resistor). Again, based on reference 1, the loss of a phase is not reproduced by the delta windings on the primary side of the transformer.

The following table shows the effects of the loss of a phase on a delta-wye transformer.

Delta/Wye-G Xfmr, B phase lost					
Primary (Delta) Voltages					
V_{AN}	$1.00\angle 0$	V_{AB}	$0.500\angle -30$	$V_{0,LN}$	$0.500\angle 60$
V_{BN}	$0.50\angle 60$	V_{BC}	$0.500\angle -30$	$V_{1,LN}$	$0.500\angle 0.0$
V_{CN}	$1.00\angle 120$	V_{CA}	$1.000\angle 150$	$V_{2,LN}$	$0.500\angle -60$
Secondary (Wye) Voltages					
V_{AN}	$1.00\angle -30$	V_{AB}	$0.866\angle -30$	$V_{0,LN}$	0
V_{BN}	$0.500\angle 150$	V_{BC}	0	$V_{1,LN}$	$0.500\angle -30$
V_{CN}	$0.500\angle 150$	V_{CA}	$0.866\angle 150$	$V_{2,LN}$	$0.500\angle -30$

The loss of voltage and degraded voltage relays are fed from bus PTs that are connect A-B and B-C twice. The outputs of the undervoltage time delay relays are connected to the sequencer which activates loss of voltage relay circuitry on a 2 out of 4 logic. As shown in the table, if one phase is lost, two of the secondary voltages will be above the loss of voltage relay settings but below the degraded voltage relay settings, and the degraded voltage relays drop out (nominal drop out setting is 92.2% of bus voltage per EC05052). The time delay for the degraded voltage relays is 35 seconds with a concurrent accident signal and 50 seconds without an accident signal.

During this period of time when the under voltage relay scheme is timing out, safety related motors that attempt to start will not develop adequate torque to accelerate which will cause their protective relays to trip. Also, other running motors that are experiencing the unbalanced currents due to the open phase may trip on overcurrent.

During an accident (with an SI signal), if a single phase event occurs on a phase that is only detected by the degraded voltage relays, then the 35 second time delay would cause the tripping of the over current relays on the safety related motors before the bus is tripped on under voltage. However, as previously described, this would not impact all of the ESF buses because at least two separate power sources are normally aligned to the three ESF buses.

The feeds to the ESF transformers are from the 13.8kV switchgear standby buses 1(2)F, 1(2)G and 1(2)H. Theses feeds are made up of insulated 15kV cable that have bolted connections on each end. The cable is routed in duct bank for most of the way and is not exposed directly to the elements. The more likely failure of these feeds is the cable insulation breaking down causing a line to ground fault. Such faults would be immediately detected by protective relaying.

An open phase on the high side of the standby transformer will produce approximately the same voltages on the secondary of the ESF transformers as on the secondary of the Standby transformer as shown above in the Standby transformer discussion.

Conclusions:

Unlike Byron, the STP 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 or mitigate a design basis event.

For a single-open phase event on the grid side of the main power transformer, the feed from the Main and Auxiliary does not affect the safety related or non-safety related loads since the wye-delta connection of the Main transformers recreates the lost phase. Also, the Main transformers can carry the increase load on the remaining two phases due to MVA capacity relative to the combined safety and non-safety loads. Thus, a single-open phase on the high side of the main transformers will, following an expected unit trip due to unbalanced power flow from the main generator, not result in the loss of accident mitigating functions of the associated ESF buses.

For a single-open phase event on the grid side of the Standby Transformer, the feeds from the Standby transformers are affected by the single-open phase. Depending on which phase is lost, will determine if both 13.8kV bus undervoltage relays will drop out and trip the buses. In most cases at least one 13.8kV bus undervoltage relay will drop out with some loading on a Standby Transformer. On an unloaded Standby Transformer, it is questionable if either undervoltage relay will drop out.

The loss (open circuit) of a phase at the grid upstream of the ESF transformer will likely be detected by the safety related bus degraded grid undervoltage relays. For the loss of two of the phases, the loss of voltage relays will drop out and time out to trip the safety buses in about 1.75 seconds. For the loss of one of the phases, the safety related bus will likely trip after the time delay for the degraded grid of 35 seconds with an SI signal or after 50 seconds if there is no SI signal. Before the under voltage trip occurs, the open phase condition will likely cause the tripping of running motors on over current and prevent the successful starting of safety related motors. This condition, however, does not impact all of the other trains of ESF buses.