ENERGY NORTHWEST

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10 CFR 50.54(f)

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

Subject: **COLUMBIA GENERATING STATION, DOCKET NO. 50-397 RESPONSE TO NRC BULLETIN 2012-01, DESIGN VULNERABILITY IN ELECTRIC POWER SYSTEM**

Reference: NRC Letter dated July 27, 2012, NRC Bulletin 2012-01, "Design Vulnerability in Electric Power System".

Dear Sir or Madam:

Pursuant to 10 CFR 50.54(f), this letter provides the Energy Northwest response to NRC Bulletin 2012-01, "Design Vulnerability in Electric Power System," dated July 27, 2012.

The NRC identified the following three objectives:

1. To notify the addressees that the NRC staff is 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 determine if further regulatory action is warranted.

2. To require that the addressees comprehensively verify their compliance with the regulatory requirements of General Design Criterion (GDC) 17, "Electric Power Systems," in Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 or the applicable principal design criteria in the updated final safety analysis report; and the design criteria for protection systems under 10 CFR 50.55a(h)(2) and 10 CFR 50.55a(h)(3).

3. To require that addressees respond to the NRC in writing, in accordance with 10 CFR 50.54(f).

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NRC Bulletin 2012-01 requested that within 90 days, licensees submit information confirming compliance with 10 CFR 50.55a(h)(2), 10 CFR 50.55a(h)(3), and Appendix A to 10 CFR 50, GDC 17 or principal design criteria specified in the updated final safety analysis report and address the two issues related to their electric power systems. Energy Northwest's 90-day response is provided in the attachment.

There are no new commitments contained in this letter. If you have any questions or require additional information, please contact ZK Dunham, Licensing Supervisor, at (509) 377-4735.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the date of this letter.

Respectfully,

AL Javorik
Vice President, Engineering

Attachments: Response to NRC Bulletin 2012-01, Design Vulnerability in Electrical Power System

cc: NRC Region IV Administrator
NRC NRR Project Manager
NRC Senior Resident Inspector/988C
AJ Rapacz – BPA/1399
WA Horin – Winston & Strawn

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 sources.

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 sources, 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.

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.

1. ***Given the requirements described in bulletin 2012-01, 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 sources.***

Response:

<u>Electrical Protection for the 4.16kV Engineered Safety Feature (ESF) buses (Protection System Description):</u>

The following describes the existing electrical protection system and how the protection scheme for ESF buses is designed as installed. Each ESF bus includes loss of voltage relay (LVR) and degraded voltage relay (DVR) protection. The original design of the ESF bus protection system did not include detection of an open phase in the offsite power supply interconnections as a design input. Therefore, an open phase condition in the offsite power supply was not included in the design criteria for the DVR or LVR ESF bus protection design.

Consistent with the current licensing basis (CLB) for Columbia Generating Station (Columbia) (including conformance to Power Systems Branch (PSB)-1 and General Design Criteria (GDC)-17 as described in the Final Safety Analysis Report (FSAR)), the existing as installed ESF bus protection system will separate the ESF bus from a failed source automatically. The separation is initiated from a loss of voltage or sustained degraded voltage condition on a credited GDC-17 offsite power circuit. Overcurrent protective relays are provided on the incoming line to each ESF bus that would isolate all power sources to that switchgear bus upon detection of a bus fault.

For each 4.16kV ESF bus this includes each offsite power source configuration (see Figure-1, Columbia Simplified One Line Diagram, showing the connection along the preferred power circuit path from E-TR-S and backup power from E-TR-B to the ESF buses) and associated on-site power source alignment.

At Columbia (see Figure-1), the on-site power alignment to the critical 4.16kV ESF bus includes:

(1) A *preferred source* connection to E-SM-7, E-SM-4 and E-SM-8 from either:

(i) the unit auxiliary transformer E-TR-N1 is the normal preferred power source per Figure-1, when the main generator is operating. Power is normally provided to all 4.16 kV ESF buses when the main generator is tied to the grid by a 25kV/4.16kV unit auxiliary transformer (E-TR-N1) fed from the main generator 25kV isolated phase bus.

or,

(ii) the startup transformer E-TR-S (that is sourced from the 230kV bus at Ashe) when the plant is starting up or the plant is proceeding to shutdown. The startup transformer is the preferred offsite power source per Figure-1 to all 4.16 kV ESF buses (E-SM-7, E-SM-8 and E-SM-4) when the main generator is not tied to the grid.

(2) A *backup source* connection from E-TR-B (that is sourced from a 115kV tapped line from Benton to DOE 451B) to E-SM-7 or E-SM-8 (there is no source from E-TR-B to E-SM-4) when power is not available from either the preferred offsite or normal source.

(3) An *emergency source* connection from associated emergency diesel generators supplying power to E-SM-7, E-SM-4 and E-SM-8 when power is not available from the main generator or offsite power source. The on-site standby power source for each 4.16kV ESF bus is provided by a dedicated Emergency Diesel Generator.

The preferred offsite circuit path is from the 230 kV Ashe substation along a ½ mile tie line interconnection to the 70 MVA E-TR-S startup transformer, which steps the 230 kV voltage down to 4.16 kV for ESF buses (E-SM-7, E-SM-8, and E-SM-4) and balance of plant (BOP) auxiliary load buses (E-SM-1, E-SM-2 and E-SM-3) and 6.9 kV for non-critical Reactor Recirculation (RRC) load buses. From the secondary of E-TR-S, the 4.16 kV circuit path to the Class-1E ESF switchgear buses E-SM-7, E-SM-8 and E-SM-4 must first pass through the non-Class 1E 4.16 kV switchgear buses, E-SM-1, E-SM-3, and E-SM-2, respectively.

E-TR-S is a 70 MVA four-winding power transformer with a solidly-grounded Y connected winding on the 230kV primary, two secondary high resistance grounded Y connected windings at 4.16kV and 6.9kV and a third secondary delta connected buried tertiary winding.

The 4.16 kV AC power high resistance grounded system (secondary winding of E-TR-S) is designed to limit ground fault current to 12.5 amps (maximum). An overcurrent relay is connected to a current transformer in the neutral of the resistance grounded Y connected secondary of the transformer for ground indication. This means a high impedance ground on the 4.16 kV AC power system is limited by design to safe levels that would not result in voltage imbalance deleterious to plant loads connected to the power system.

An automatic transfer feature is provided for Divisions 1 and 2 ESF switchgear buses such that if power is lost to a 4.16 kV ESF bus (E-SM-7 and/or E-SM-8) due to a loss of its preferred power supply from E-TR-S, the source feeder breaker to the ESF bus (E-SM-7 or E-SM-8) will trip and E-TR-B supply breaker to the bus will automatically close after a prescribed time delay to restore power (Figure-2). For a loss of preferred offsite power to E-SM-4, a similar transfer feature would align this bus instead to the emergency on-site source provided by the associated emergency diesel generator, EDG-3.

Automatic transfer capability is provided so that failure of the auxiliary transformer power supply from E-TR-N1 causes immediate tripping of the auxiliary transformer supply breakers (N breakers) and simultaneous closing of E-TR-S supply breakers (S breakers) to the non-safety related 4.16kV switchgear buses E-SM-1, E-SM-3 and E-SM-2 supplying ESF buses E-SM-7, E-SM-8 and E-SM-4 respectively. This shifts the power source for station auxiliary loads connected to the 4.16kV non-safety related and safety related buses from the main generator to the preferred offsite power source taken from the 230 kV bus at the Ashe substation through E-TR-S. Each E-TR-S breaker (S breaker) is interlocked to close only if the associated unit auxiliary transformer supply breaker (N breaker) is not locked out thus preventing closing onto a fault. This describes the source sequencing from E-TR-N1 to E-TR-S as part of the preferred source to the 4.16kV ESF bus.

Following initiation of an accident signal, certain safety related Division 1 and Division 2 plant loads used to mitigate an accident are started in a predetermined sequence in order to prevent overloading E-TR-S supplying offsite power to the safety related 4.16kV ESF switchgear buses (load sequencing).

The backup offsite power circuit path is from the 115 kV Benton substation tapped line interconnection that is stepped down through the station's backup transformer, E-TR-B, to provide a backup offsite power supply to E-SM-7 (Division 1) and E-SM-8 (Division 2), only. There is no backup offsite power source provided to E-SM-4 (Division 3).

The Electric Power Research Institute (EPRI) has conducted initial confirmatory research of representative transformer configurations based upon the Byron event January 2012 on behalf of the industry that is described in EPRI report 1025772, "Analysis of Station Auxiliary Transformer Response to Open Phase Condition". This industry report notes a transformer (such as E-TR-S or E-TR-B) with a buried delta tertiary secondary winding will tend to mask or hold up the secondary voltage with an open phase condition on the primary. The EPRI analysis also notes that during a lightly loaded condition voltage monitoring alone may not detect an open-conductor condition.

This means with E-TR-S in standby with the plant's auxiliary power system aligned to the main generator output through E-TR-N1, the as-installed voltage monitoring capability from the ESF bus or upstream on the secondary of the E-TR-S winding may not reliably detect an open phase condition. This issue is being addressed in accordance with Columbia's Corrective Action Program (CAP) and the solution/remedy to mitigate the effects of an open phase condition on the offsite power supply is being tracked by AR 259724 and AR EVAL 261654.

The following summarizes a basic comparison of the configuration of Byron and Columbia offsite power systems:

Byron Vulnerability	Columbia configuration	Evaluation summary
Single offsite power source for two trains of safety related power	Preferred offsite power source through TR-S supplies all three 4.16kV ESF switchgear buses	The 230kV tie line is a single point of failure in the off-site power supply to ESF buses
Auxiliary power to ESF buses is provided by offsite power	Preferred offsite power source through E-TR-S is normally in standby with plant auxiliary buses powered from the main generator through E-TR-N1 and E-TR-N2	Low LOOP/LOCA susceptibility upon fast transfer to E-TR-S to coincident open phase condition provided ESF motor can withstand higher negative sequence current burden (magnitude and duration) without lockout and system voltage drops below degraded voltage relay settings to permit separation of degraded offsite source within analysis acceptable times
System Auxiliary Transformer (SAT) design makes station more susceptible to effects of open phase event	E-TR-S and E-TR-B are similar in design	Columbia's station service transformers (ie., preferred offsite power through startup transformer E-TR-S and backup power through E-TR-B) include a buried delta tertiery winding configuration that will tend

		to hold up secondary voltage under light load as monitored by ESF bus voltage relays with an open phase on the primary. This effect tends to mask an open phase under light load from medium voltge bus protection systems

- Non-Class 1E portion of the power circuit path to ESF buses.

<u>E-TR-S and E-TR-B High Voltage Indication and Alarm Monitoring</u>

The primary of E-TR-S has voltage indication available for all three phases. The primary of E-TR-B has voltage indication for all three phases and a low voltage alarm is available for phase A only.

Note: As a result of the initial review of the applicability of the Byron event to Columbia, additional alarm capability is being evaluated as a near term action for monitoring of all three phases of E-TR-S and E-TR-B high voltage connections. Voltage relays installed in the transformer bushing potential device secondary could augment an existing TR-S and TR-B trouble alarm circuit in the main control room as a defense in depth measure.

<u>E-TR-S and E-TR-B Primary Side Protection</u>

Preliminary evaluation of the electrical protection package for E-TR-S and E-TR-B (differential phase current, phase overcurrent and neutral overcurrent relays) indicates existing protective relays are either not sensitive enough and/or are not suited to detect a non-fault current component failure and so will not respond to an open circuit condition on the transmission tie line high voltage interconnection.

Bonneville Power Administration's (BPA) [the station's transmission operator (TO)] protective relay package covering the 230kV tie line from the substation bus includes overcurrent fault detection, line protection, and directional overcurrent for ground fault protection of the transmission lines; all of which depends upon fault current duty to detect a fault. There are no open phase detection features in the existing electrical protection scheme for the 230kV or 115kV tie lines to Columbia.

E-TR-S Secondary Protection

On the secondary side of E-TR-S in the preferred offsite circuit path to the non-safety related 4.16 kV switchgear (E-SM-1, E-SM-2 and E-SM-3), undervoltage relay 27YS and companion 27 undervoltage relays each monitoring E-SM-1, E-SM-2 and E-SM-3 voltage, would not detect an open C phase between Ashe substation and E-TR-S. The E-TR-S 4.16 kV Y-winding and the non-safety related switchgear bus connections would not detect an open C-phase as these relays are connected across phases A and B. The 27YS relay, located at the E-TR-S Y-winding, would normally operate on loss of voltage to prevent fast transfer of the E-TR-N1 auxiliary transformer power source to E-TR-S.

E-TR-B Secondary Protection

The secondary of E-TR-B that is part of the backup offsite circuit path to the two 4.16kV ESF buses E-SM-7 and E-SM-8 is connected via separate cables with each circuit monitored by a 27 undervoltage relay to the backup source incoming line breaker B-7 (supplying E-SM-7) or B-8 (supplying E-SM-8) to each 4.16kV ESF bus. There is only a single undervoltage relay connected A-B in each circuit. This configuration would not detect an open (C-phase) circuit in the backup offsite power supply interconnection through the E-TR-B secondary. These undervoltage relays in E-TR-B secondary will trip their respective B-7 (supplying E-SM-7) and B-8 (supplying E-SM-8) breakers for loss of voltage.

Safety Related 4.16kV ESF Bus Voltage Monitoring and Protection Features

ESF Bus Voltage Indication and Alarms

Each critical 4.16kV ESF bus has voltage indication on all three phases in the main control and an existing plant oscillograph recorder alarm from loss of voltage.

ESF Bus Voltage Protection

The DVR protection system for E-SM-7 (Figure-3) and E-SM-8 has three undervoltage sensors connected A-B, B-C and A-C on the secondary of the PT connected to the switchgear bus. These DVRs operate in a two-out-of-three trip logic scheme.

Although this scheme may be capable of detecting an open phase condition if resulting voltage degrades below the relay setting, the resulting unbalanced voltage provided by the remaining distribution network connections with those operating induction motors may be sufficient to maintain voltage in the plant's power system across the affected phase at or very near the existing degraded voltage relay setting. As described in the EPRI report and white paper from Basler Electric Company (Western Protective Relay Conference, October 2002), an open phase on the high voltage side of station service transformers does not readily present a loss of voltage where the affected phase voltage goes to zero (e.g. under light load conditions). Therefore, with an open circuit condition and with little or no fault current in the preferred or backup power source path to the critical 4.16 kV ESF switchgear bus, the automatic performance of the electrical protection system is not dependable to preclude potential consequence or impact to ESF motor performance. This issue has been entered into Columbia's CAP and is being tracked by AR 259724 and AR EVAL 261654.

The degraded voltage protection system for E-SM-4 has two undervoltage relay sensors in the secondary of a PT on the preferred circuit path on the incoming line breaker for E-SM-4, which is connected A-B and B-C. This protection system operates in a two-out-of-two trip logic scheme similar to Byron. With the relay connected A-B showing normal voltage the trip logic would not be satisfied for an open C-phase condition. With this design configuration, the trip logic will not be satisfied for a single open phase condition in the offsite power source circuit path such that no protective trip signals will be generated to automatically separate the Division 3 ESF safety bus from the offsite power source. This issue has been entered into Columbia's CAP and is being tracked by AR EVAL 263975.

As experienced at Byron and noted in applicable industry literature, running motors may trip on overcurrent due to increased running current from the voltage imbalance and standby motors may not automatically start due to insufficient torque from an open phase in the motor's AC power supply.

In this way, an open phase failure in the offsite to onsite power system circuit path results in two important considerations impacting availability of ESF/ECCS motors through performance of the electrical protection system. They are:

(i) running motors may trip on overcurrent and standby motors may not start, and,

(ii) due to configuration of the transformers E-TR-S and E-TR-B, the degraded (or loss of) voltage protection system may not generate protective trip signals because existing protection settings are not reached or there are not enough sensors monitoring all three phases to automatically separate the ESF safety buses from the offsite source and to initiate transfer to another source of power to the critical safety related bus.

<u>Summary of existing as-installed protection system design</u>:

As described above (i.e. assessing the response of the existing electrical protection system to a hypothical design input not included in the original design of the station); at various points in the AC power system along the GDC-17 qualified circuit path, the existing high voltage tie line protection system, the transformer E-TR-S and E-TR-B secondary protection, and safety related 4.16kV ESF bus loss of voltage or degraded voltage protection system may not reliably respond to an open phase condition in the offsite power supply.

Cause or Vulnerability	Protection System Barrier	Description of Consequece	Action Plan
Failure to detect open phase conductor in the off-site power supply tie lines to the plant	High Voltage line protection does not include open phase or downed conductor protection features	Off-site power supply with open phase conductor failure can be aligned to the station	Investigate utilizing new protection scheme or supplementing existing protection schemes to effectively block connection of the 230kV or 115kV source if an open phase condition occurs on the high voltage side of E-TR-S or E-TR-B (AR- EVAL 261654) To aid operator diagnosis of an open phase condition in the offsite power supply install additional voltage or loss of phase monitors in the E-TR-S and E-TR-B HV trouble alarm circuits (AR 259724-07 and AR-EVAL 261653 for E-TR-B and, AR-EVAL 261688 for E-TR-S)

Cause or Vulnerability	Protection System Barrier	Description of Consequece	Action Plan
On-site electrical protection system did not protect 4.16kV ESF buses from prolonged effects of an open phase in the offsite power supply connection	Electrical protection minimizes exposure to degraded power supply when connected to offsite power	Onsite protection system design did not initiate protection signals due to inadequate number of sensors in the existing conincident logic two-out-of-two trip scheme or sensor not installed to monitor all phases in the power system Configuration of the E-TR-S and E-TR-B transformers together with the effects of running motors may not allow existing protection systems to detect an open phase conductor in the offsite power supply under light load conditions within the plant's AC power system	Address gaps in the existing electrical protection scheme by installing an additional protective relay to change to a two-out-of-three trip scheme for E-SM-4 degraded voltage protection (AR-EVAL 263975) Address improvements in the protection system for E-TR-S secondary circuit path to E-SM-1, E-SM-2 and SM-3 (AR-EVAL 263977). Address improvements in the protection system for E-TR-B secondary circuit path to E-SM-7 & E-SM-8 (AR-EVAL 266747) Address the effects of E-TR-S and E-TR-B winding configuration and effects of running motors on performance of the protection scheme and impact to plant equipment: From applicable techncial considerations develop plan to throughly review and study Columbia's design basis and conduct plant power system specific computer modelling to characterize the electrical fault signature and response of plant power systems and equipment to an open phase component failure in the offsite power supply connections to the plant. (AR 257993-15, AR 257993-16 and AR-EVAL 261654)

Monitoring and Protection System

The primary of E-TR-S has voltage meter indication available for all three phases. E-TR-B has voltage meter indication for all three phases and an alarm is available for phase A loss of voltage only. Additional loss of voltage sensors, loss of phase or unbalance voltage detection relays can be installed on the primary side of E-TR-S and E-TR-B to initiate the existing E-TR-S or E-TR-B trouble alarm in the main control room.

A gap exists in the as-installed E-SM-4 Secondary Undervoltage (i.e., the Degraded Voltage) electrical protection scheme. E-SM-4 has only two undervoltage relays in this degraded voltage protection design with a two-out-of-two coincident trip logic which would not permit reliable protection for an open circuit (in this case a C-phase open) failure in the offsite power supply to this ESF bus. An additional undervoltage relay configured in a two-out-of-three trip logic (similar to the trip logic used for E-SM-7 and E-SM-8) will allow the protection system to initiate a trip for loss of a single phase in the offsite power supply to E-SM-4 where resulting voltage is below the trip setting of the relays. This issue has been entered into Columbia's CAP and is being tracked by AR-EVAL 263975.

The E-TR-S secondary 4.16kV Y-Winding undervoltage protection scheme:

> On the Y-winding E-TR-S secondary there is only one undervoltage relay which monitors the voltage across phases A and B (i.e., either undervoltage relay 27YS or companion 27 undervoltage relays monitoring individual non-safety related 4.16kV bus E-SM-1, E-SM-2 and E-SM-3 feeder connections from E-TR-S). This configuration would not detect an open circuit (C-phase) on this portion of the 4.16kV circuit path. The stated FSAR design function for the electrical protection covering the E-TR-S secondary Y-winding along the feeder circuits to non-safety related 4.16kV switchgear buses is to trip the associated S-breakers for a loss of voltage. This issue has been entered into Columbia's CAP and is being tracked by AR EVAL 263977.

The as-installed TR-B secondary 4.16kV undervoltage protection scheme:

> The secondary of E-TR-B that is part of the backup offsite circuit path is split up going to the two 4.16kV ESF buses E-SM-7 and E-SM-8 via separate cables. There is only a single undervoltage relay connected A-B in each circuit. This relay configuration would not detect an open circuit (C-phase) in the backup offsite power supply interconnection through the E-TR-B secondary. The stated FSAR design function of the installed undervoltage relays in E-TR-B secondary circuit path is to trip their respective B-7 (supplying E-SM-7) and B-8 (supplying E-SM-8) breakers for a loss of voltage. This issue has been entered into Columbia's CAP and is being tracked by AR EVAL 266747.

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

Response:

<u>Electrical Protection for the 4.16kV ESF buses (Protection Features and Setting Basis):</u>

The Electrical Protection for the 4.16kV ESF buses, including protection features and setting basis is summarized in Table-1 and Table-2 and associated figures (Figure-3, Figure-4 and Figure-5). Table-1 provides the protective relay description and settings for the two offsite sources, E-TR-S and E-TR-B, which power the 4.16 ESF buses. Figure-4 and Figure-5 provide excerpts from associated plant one line drawings. Table-2 provides the relay description and settings for the 4.16kV buses, including the ESF buses. Figure-3 provides excerpts from plant one line drawings for ESF bus, E-SM-7.

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.

Response:

<u>Electrical Protection for the 4.16kV ESF buses (Consequences):</u>

EPRI issued report 1025772, "Analysis of Station Auxiliary Transformer Response to Open Phase Condition" (June 2012). This industry report notes a transformer (such as E-TR-S or E-TR-B) with a buried delta tertiary secondary winding will tend to mask or hold up the secondary voltage with an open phase condition on the primary. E-TR-B is a three-winding transformer which also includes a secondary delta connected buried tertiary winding. E-TR-S is a four-winding transformer which also includes a secondary delta connected buried tertiary winding

The EPRI analysis also notes that during a lightly loaded condition voltage monitoring alone may not detect an open-conductor condition. This means with E-TR-S in standby with the plant's auxiliary power system aligned to the main generator output through E-TR-N1, the as-installed voltage monitoring capability from the ESF bus or upstream on the secondary of the E-TR-S winding may not reliably detect the open phase condition.

With the 4.16kV ESF buses aligned to the main generator output E-TR-N1, the existing ESF bus electrical protection system voltage monitors will not detect an open phase condition on the offsite power supply.

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 sources, describe the consequences of such an event and the plant response.

Response:

Electrical Protection for the 4.16kV ESF buses (Consequences):

A high impedance ground on the 230kV line side or winding side will have no immediate effect on plant operation. If the ground is sufficiently large to affect plant operation, protective relaying will isolate the ground automatically. The line side fault should be detected by the impedance relays and the winding side fault should be detected by the differential relay depending upon the magnitude of the fault.

Columbia did not credit in the current licensing basis that the Class 1E protection scheme for ESF buses was designed to detect and automatically respond to a single-phase open circuit condition on the credited off-site power source.

Since Columbia 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 scheme. Since open phase detection was not credited in the Columbia design or licensing basis, no design basis calculations or design documents exist that considered this condition.

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, which is a generic overview.

The difficulty in applying these documents to the Columbia specific response is that these are generic assessments and cannot be formally credited as a basis for an accurate 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 Columbia specific Class 1E electric distribution system). This issue has been entered into Columbia's CAP and is being tracked by AR EVAL 261654.

Consequences are described above in response to Question 1.

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

Response:

<u>Electrical Power System - offsite power transformers (Component Description):</u>

E-TR-S has the capacity to supply full startup, normal running, and ESF shutdown loads for Divisions 1, 2, and 3. Transformer primary (high-voltage) winding is wye connected with a solid connection to ground. An intermediate delta connected winding is provided between the single wye connected primary and dual wye connected secondary windings. This 230/6.9/4.16-kV transformer is rated 42/56/70 MVA. The 6.9-kV secondary winding is rated 18/24/70 MVA and the 4.16-kV secondary winding is rated 24/32/40 MVA.

E-TR-B has the capability of supplying the full power requirements of the ESF systems for both Division 1 and Division 2. Transformer primary (high-voltage) winding is wye connected with a solid connection to ground. An intermediate delta connected winding is provided between the wye connected primary and secondary winding. This 115/4.16-kV transformer is rated 14 MVA.

Transformer	Power Rating	Voltage Rating	Winding Configuration	Grounding Configuration
E-TR-S	70 MVA 40 MVA (4.16kV) 30 MVA (6.9 kV)	230kV / 4.16kV /6.9kV	Y-Y four winding; 230kV primary with 4.16kV and 6.9kV secondary and a delta connected buried tertiary winding	Solid grounded 230kV primary with both medium voltage secondary high resistance grounded
E-TR-B	14 MVA	115kV / 4.16kV	Y-Y three winding; 115kV primary with 4.16kV secondary and a delta connected buried tertiary winding	Solid grounded 115kV primary with medium voltage secondary high resistance grounded

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).

Response:

<u>Electrical Power System – operating configuration of the ESF buses at power (Operating Description):</u>

At Columbia (see Figure-1), the on-site power alignment to the critical 4.16kV ESF bus includes:

(1) A *<u>preferred source</u>* connection to E-SM-7, E-SM-4 and E-SM-8 from either:

(i) the unit auxiliary transformer E-TR-N1 is the normal preferred power source per Figure-1, when the main generator is operating. Power is normally provided to all 4.16 kV ESF buses when the main generator is tied to the grid by a 25kV/4.16kV unit auxiliary transformer (E-TR-N1) fed from the main generator 25kV isolated phase bus. When the Class 1E buses E-SM-7 and E-SM-8 are being fed from the turbine generator, the possibility of sustained undervoltage is not considered credible due to response characteristics of the voltage regulator and protection equipment for the unit.

or,

(ii) the startup transformer E-TR-S (that is sourced from the 230kV bus at Ashe) when the plant is starting up or the plant is proceeding to shutdown. The startup transformer is the preferred offsite power source per Figure-1 to all 4.16 kV ESF buses (E-SM-7, E-SM-8 and E-SM-4) when the main generator is not tied to the grid.

(2) A *<u>backup source</u>* connection from E-TR-B (that is sourced from a 115kV tapped line from Benton to DOE 451B) to E-SM-7 or E-SM-8 (there is no source from E-TR-B to E-SM-4) when power is not available from either the preferred offsite or normal source.

(3) An *<u>emergency source</u>* connection from associated emergency diesel generators supplying power to E-SM-7, E-SM-4 and E-SM-8 when power is not available from the main generator or offsite power source. The on-site standby power source for each 4.16kV ESF bus is provided by a dedicated Emergency Diesel Generator.

During normal operating conditions, when the main generator is supplying power to the grid, the connection is to the 500 kV grid. In this normal operational line up, power is provided to all the 4.16 kV ESF buses by a 25 kV/4.16 kV normal auxiliary transformer

(E-TR-N1) fed from the main generator 25 kV isolated phase bus. However, this power source is not credited with meeting the requirements of LCO 3.8.1.a, because it does not come from an offsite circuit. Columbia Technical Specification LCO 3.8.1, "AC Sources - Operating," specifies requirements for the Electrical Power System AC sources.

E-TR-S is used while the 25-kV main generator is being started and synchronized with the system. When this is accomplished, all auxiliary load is transferred (live load transfer) to the normal auxiliary transformers (E-TR-N1 and E-TR-N2). E-TR-S remains energized from the 230-kV offsite power line to permit the auxiliary load to be automatically transferred back to it if power from either normal auxiliary transformer is lost. It is possible to operate the plant with auxiliary loads carried by E-TR-S.

The 4.16-kV non-Class 1E switchgear buses E-SM-1, E-SM-2, and E-SM-3 are fed from the secondary windings of the dual secondary winding normal auxiliary transformer (E-TR-N1) or from the 4.16-kV "Y" winding of the dual secondary winding startup transformer (E-TR-S).

Automatic transfer capability is provided so that failure of the E-TR-N1 supply causes immediate tripping of the normal auxiliary transformer supply breakers and simultaneous closing of the E-TR-S auxiliary switchgear breakers to supply the balance of plant (BOP) and ESF buses. Each E-TR-S supply breaker is interlocked to close only if the associated normal auxiliary transformer supply breaker is not locked out, thus preventing closing onto a fault or connecting a credited source to a non-credited source. Manual live transfer capability of power between the normal auxiliary transformer source and the startup and backup (Division 1 and Division 2 only) transformer sources is also provided.

From the transformer yard, two qualified, electrically and physically separated circuits are available to provide AC power to the Division 1 and Division 2, 4.16 kV ESF buses (E-SM-7 and E-SM-8). One qualified circuit is available to provide AC power to the Division 3, 4.16 kV ESF bus (E-SM-4).

One qualified circuit is powered from the 230 kV Ashe Substation stepped down through the 230 kV/4.16 kV windings of a 230 kV/6.9 kV/4.16 kV transformer (E-TR-S) through connecting switchgear to all 4.16 kV ESF buses.

The other qualified circuit (Division 1 and Division 2, 4.16 kV ESF buses only) is powered from the 115 kV Benton Substation stepped down through a 115 kV/4.16 kV transformer (E-TR-B).

A qualified offsite circuit consists of breakers, transformers, switches, interrupting devices, cabling, and controls required to transmit power from the offsite transmission network to the onsite Class 1E ESF buses. E-TR-S normally provides power to the 4.16 kV ESF buses when the main generator is not connected to the grid.

An automatic transfer feature is provided for the ESF divisions. If power is lost to the Division 1 and Division 2 4.16 kV ESF buses (E-SM-7 and E-SM-8) due to a loss of E-TR-S, the E-TR-B supply breaker to the bus will automatically close and provide power.

The onsite power system is designed to supply the power requirements of all auxiliary plant loads during normal operation and to ESF loads when required. Sufficient instrumentation and protective control devices are provided to maximize operational reliability and availability of the supply system.

Those portions of the onsite power system required for the distribution of power to ESF electrical components are designed to provide reliable availability of power essential to shut down and maintain the unit in a safe condition and/or limit the release of radioactivity to the environment following a design basis accident (DBA). The physical events that accompany such an accident will not interfere with the ability of the system to mitigate the consequences of that accident within the acceptable limits, even assuming a single, simultaneous failure in the electrical system.

Two immediate access (offsite) power sources are provided for the Division 1 and Division 2 ESF systems; one immediate access (offsite) power source is provided for the Division 3 (HPCS) system.

Additionally, one independent Class 1E 4.16-kV diesel generator and one independent Class 1E 125-V dc system are provided for each division load group.

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

Response:

<u>Electrical Power System – ESF buses aligned to offsite power (Operating Description):</u>

The critical 4.16kV ESF buses are not normally aligned to an offsite power supply with the unit at power (normal operating condition).

E-TR-S is aligned to the ESF buses while the 25-kV main generator is being started and synchronized with the system. When this is accomplished, all auxiliary load is transferred (live load transfer) to the normal auxiliary transformers.

There are also some surveillance and testing procedures that may temporarily align offsite power (E-TR-S or E-TR-B) to provide power to an ESF bus. Reference Figure-2.

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.

<u>Electrical Power System – ESF power sources operating surveillances (Operating Description and Requirements):</u>

Columbia's weekly surveillance procedure OSP-ELEC-W101 for the offsite power sources from the 230kV and 115kV network interconnections checks the voltage at the substation bus through conversation with Munro Control Center (voltage is based upon SCADA inputs measuring Ashe and Benton substation bus voltage). Both the 230kV and 115kV offsite power source are typically in standby with the plant auxiliary power system connected to the main generator output. This line up and monitoring technique may not detect an open circuit condition on the applicable offsite power circuit. This has been entered into Columbia's CAP and is being tracked by AR259724-10.

Columbia's weekly surveillance procedure OSP-ELEC-W102 checks the electrical distribution system breaker alignment and power availability. Within this procedure the voltage at the 4.16kV ESF buses are recorded. However, with the plant's AC Power System aligned to E-TR-N1, this voltage measurement with installed instrumentation is not recording all three phase voltages available at the ESF from the offsite power source.

Plant procedure PPM 3.1.10, Operating Data and Logs, requires Operations check E-TR-S and E-TR-B voltages on all three phases once a shift.

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.

Electrical Power System – power source alignment to ESF buses (Operating Description):

ESF Bus	ESF Description	Operating Configuration	Technical Specifications applicable	ESF bus operation consistent with current licensing basis (yes/no)
E-SM-7 (Division 1)	LPCS/LPCI	Preferred power supply from E-TR-N1 is aligned to ESF bus during normal operating condition. Offsite power from E-TR-S aligned to ESF bus during plant startup or shutdown operating condition	3.8.1 AC Sources Operating 3.3.8.1 Loss of Power Instrumentation	yes
E-SM-8 (Division 2)	LPCI	Preferred power supply from E-TR-N1 is aligned to ESF bus during normal operating condition. Offsite power from E-TR-S aligned to ESF bus during plant startup or shutdown operating condition	3.8.1 AC Sources Operating 3.3.8.1 Loss of Power Instrumentation	yes
E-SM-4 (Division 3)	HPCS	Preferred power supply from E-TR-N1 aligned to ESF bus during normal operating condition. Offsite power from E-TR-S aligned to ESF bus during plant startup or shutdown operating condition	3.8.1 AC Sources Operating 3.3.8.1 Loss of Power Instrumentation	yes

The operating configuration of the ESF buses is consistent with the current licensing basis. There have been no 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?

Response:

<u>Electrical Power System – verify adequacy of voltage to ESF buses (Operating Procedures):</u>

> Plant procedure PPM 3.1.10, Operating Data and Logs, requires Operations check E-TR-S and E-TR-B voltages on all three phases once a shift.
>
> Plant abnormal procedure ABN-ELEC-GRID requires Operations check E-TR-S and E-TR-B voltages on all three phases.

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.

<u>Electrical Power System – Failure Effects on Redundant ESF Buses (Consequenses):</u>

During normal operations, power is provided to all the 4.16 kV ESF buses by a 25 kV/4.16 kV normal auxiliary transformer (E-TR-N1) fed from the main generator 25 kV isolated phase bus; therefore, a single-phase open circuit or high impedance ground fault condition, would not immediately have an adverse effect on redundant ESF buses. If a fast transfer from E-TR-N1 to E-TR-S, in which all three ESF buses are aligned to E-TR-S, the susceptibility is expected to be low due to the sequencing of Emergency Core Cooling Systems (ECCS) loads to the ESF buses. The EPRI report shows that since the AC power system is loaded, the voltage on the open phase cannot be supported, which allows the degraded voltage relays to actuate (pick up) and initiate source transfer to another viable power source prior to all ECCS loads being added to the ESF buses.

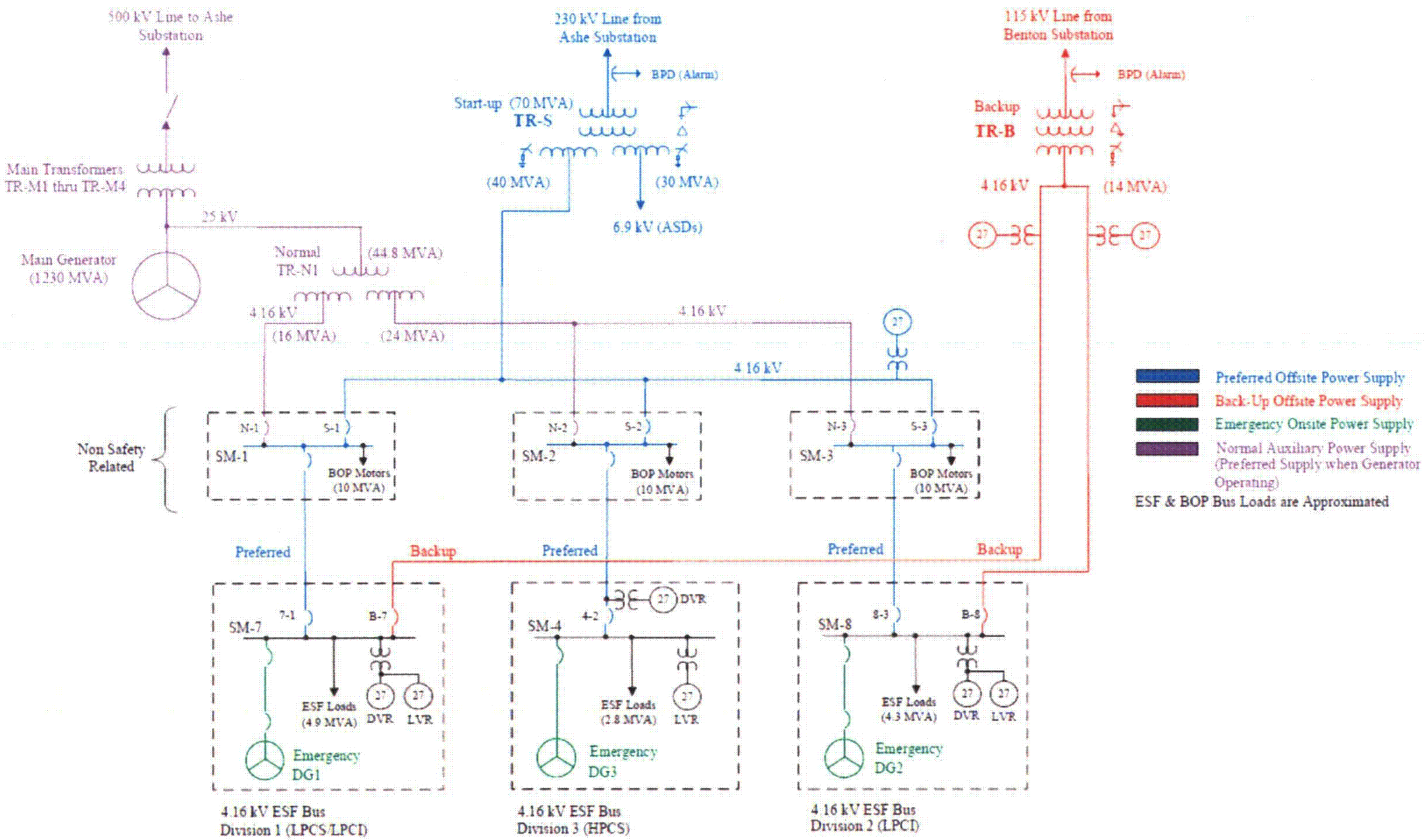

Figure-1: Columbia AC Power System Simplified One Line Diagram

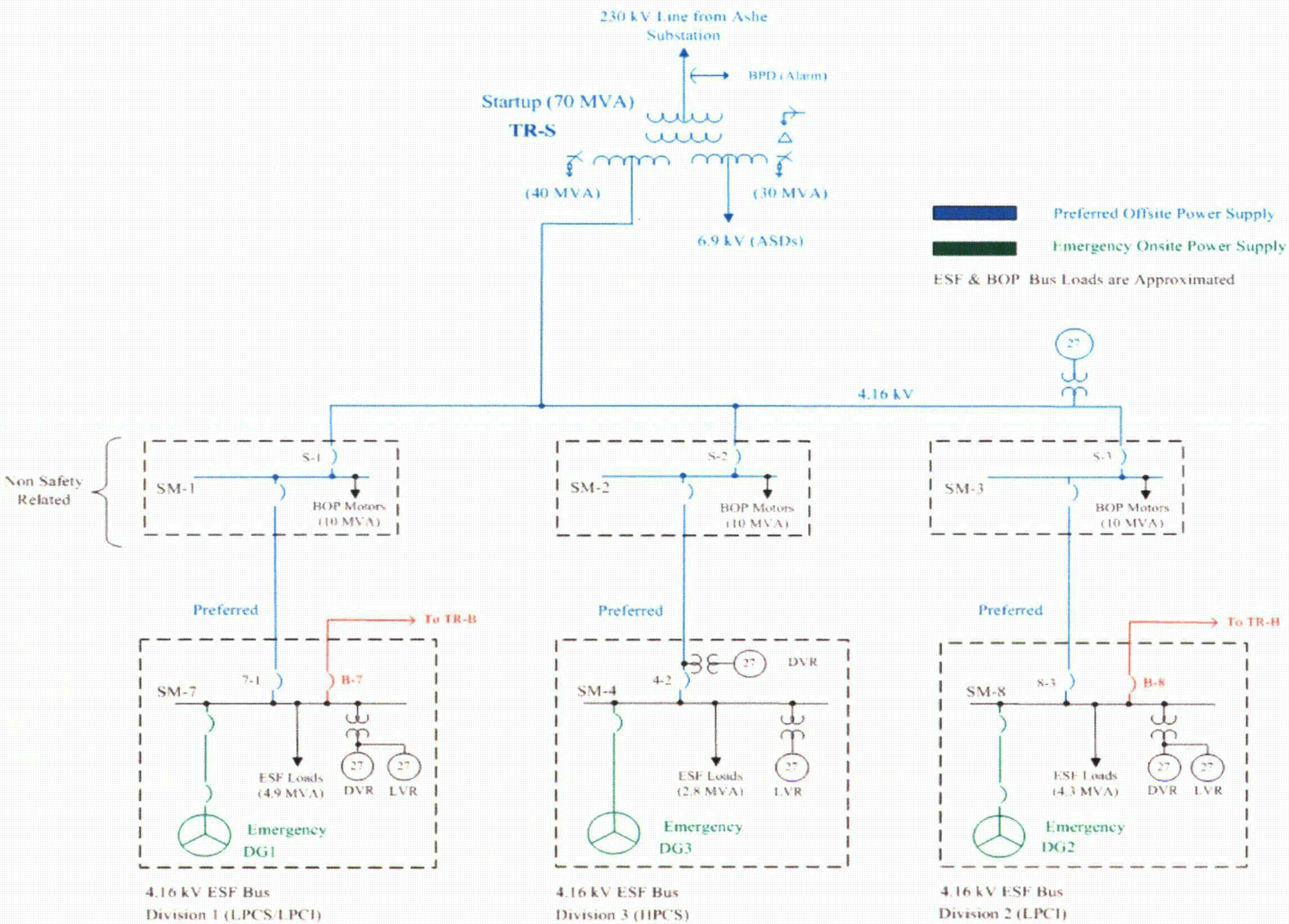

Figure-2: AC Power System alignment from TR-S (230kV offsite source interconnection)

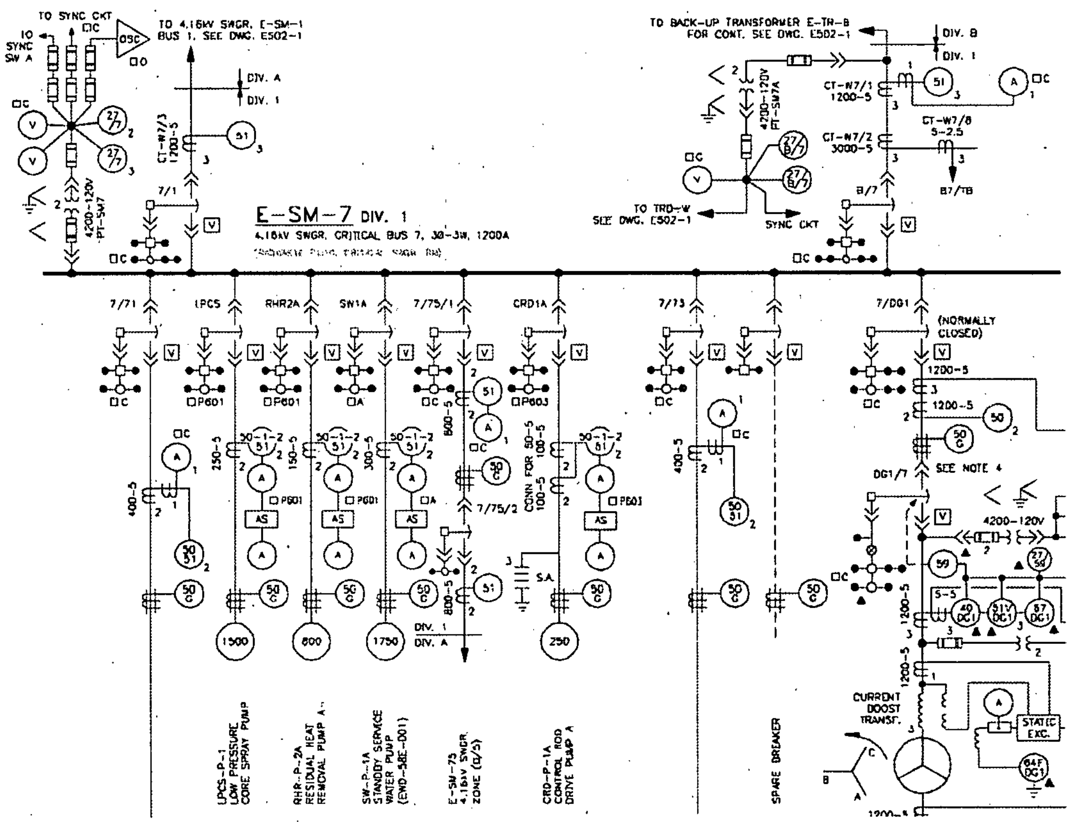

Figure-3: Excerpt from Columbia's One Line Diagram E502-2 for SM-7

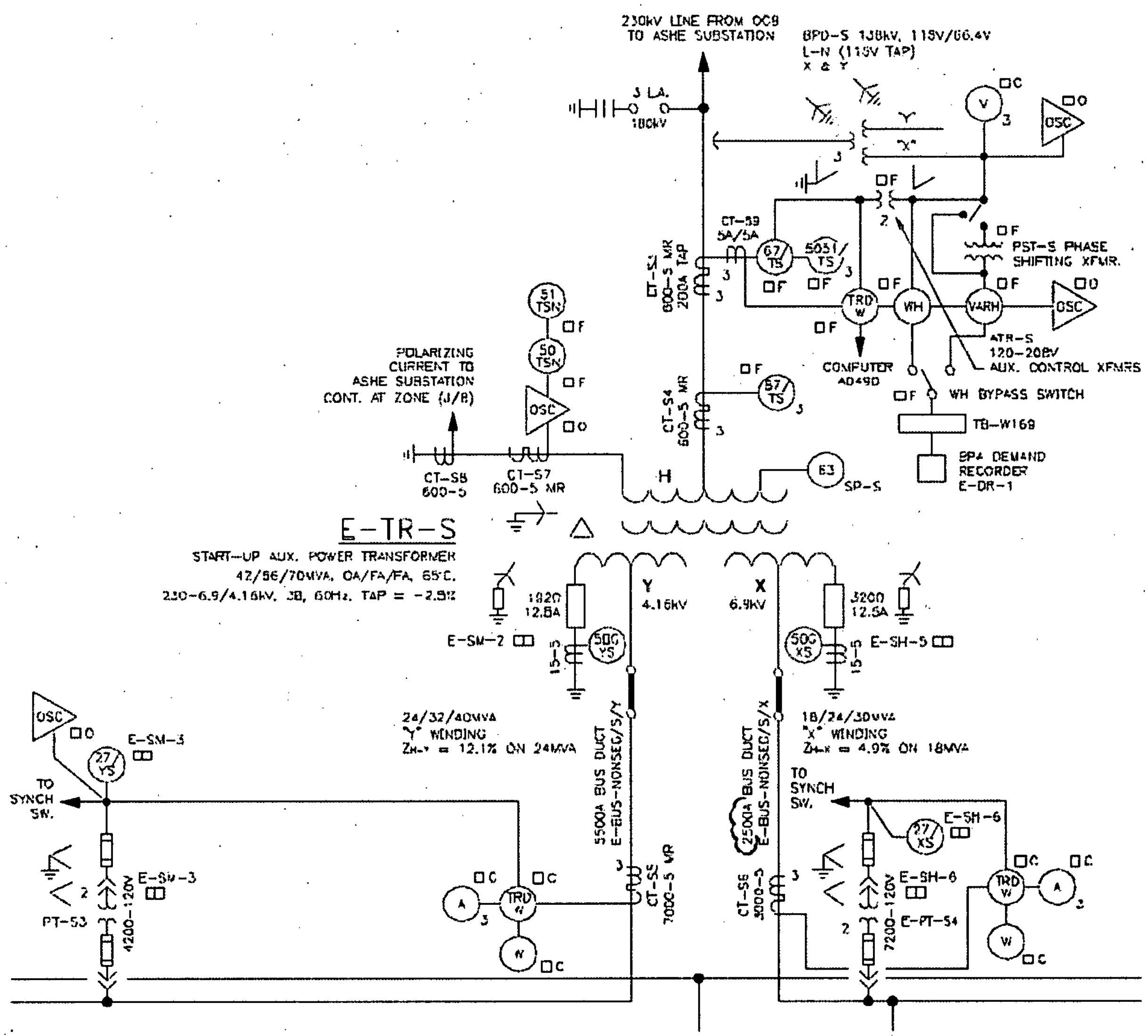

Figure-4: E-TR-S Protection Relays (Excerpt from E502-1)

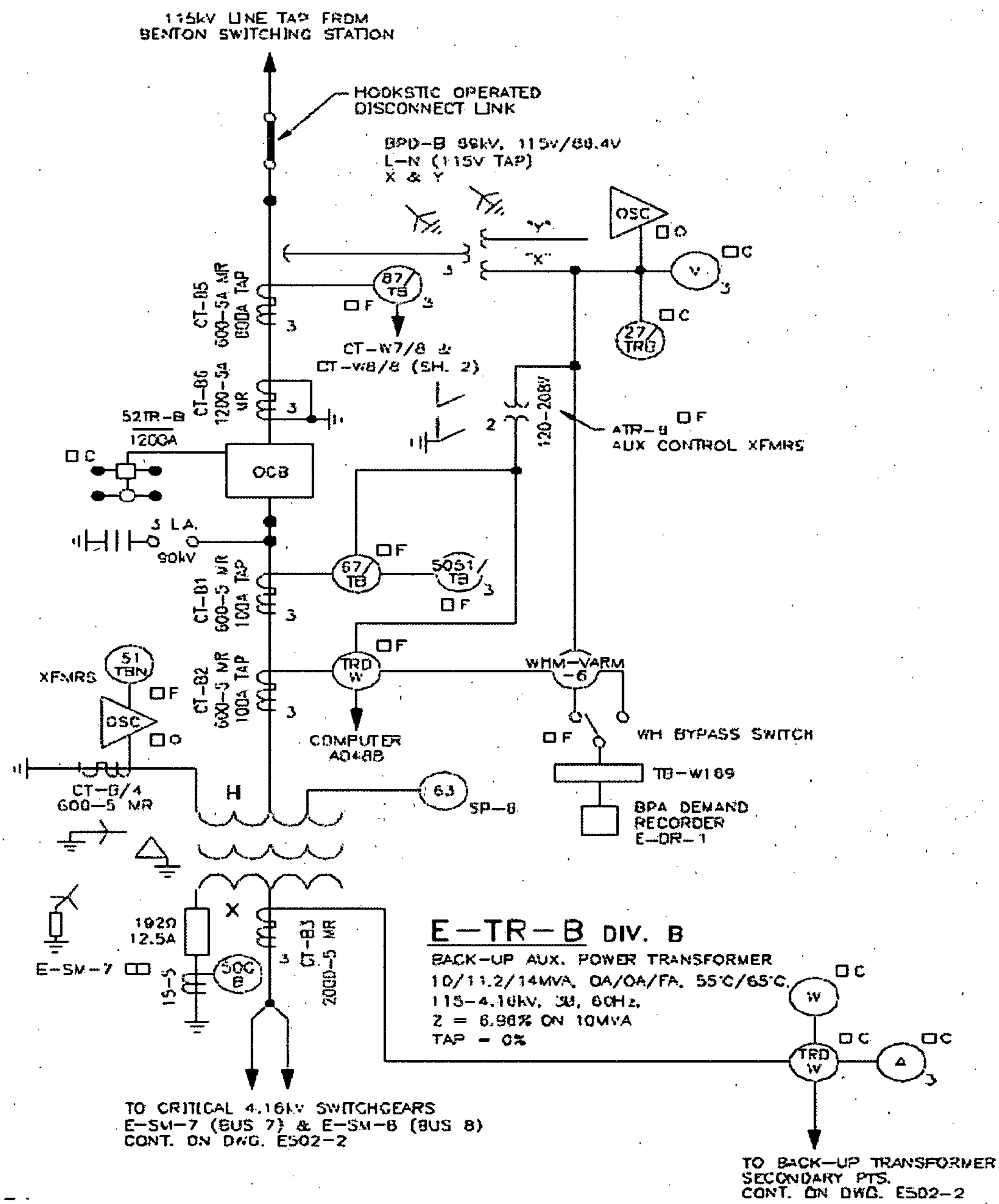

Figure-5: E-TR-B Protection Relays (Excerpt from E502-1)

Table-1: E-TR-S and TR-B Protective Relay Description and Settings

E-TR-S, 230kV HIGH SIDE					
ANSI Device/Equipment Part Number	Function Performed	Calculation	Setting Drawing	OEM Instruction (Model)	Comments
OSC (BPD-S)	OSCILLOGRAPH TR-S UNDERVOLTAGE SENSOR	E/I-02-85-06	E514-27	H-1020 (8534901)	FROM TR-S BUSHING POTENTIAL DEVICE (BPD)
VOLTAGE INDICATOR (BPD-S)	BUSHING POTENTIAL DEVICE CONTROL ROOM METER	N/A	N/A	N/A	THREE PHASES METERED
E-RLY-67TS	STARTUP TRANSFORMER TR-S REVERSE POWER RELAY	E/I-02-84-03	E514-17	GEH-2056D (GE ICW52A)	REVERSE POWER RELAY SENTS ALARM SIGNAL
E-RLY-5051/TS/A, B, C	TR-S OVERCURRENT 51TS BD-F (OVERCURRENT SETTING)	E/I-02-92-17	E514-16	GEK-34053A (IAC51B806A)	TAP 5A WITH CTR OF 40=200A
E-RLY-87/TS/A, B, C	TR-S DIFF RLY 87TS ON BD-F	2.12.06	E514-16	GEI-98349B & GEH-2057A (GE, BDD17B1A)	DIFFERENTIAL RELAY FOR GROUND DETECTION IN PROTECTION ZONE
OSC	OSCILLOGRAPH TR-S NEUTRAL CURRENT SENSOR	E/I-02-85-06	E514-27	H-1017 (8504301)	OSCILLOGRAPH INDICATION
E-RLY-50TSN	AUX PWR TR-S INSTANTANEOUS NEUTRAL OVERCURRENT 50TSN ON BD-F	2.12.41	E514-16	GEI-28803B (GE PJC11)	INSTANTANEOUS NEUTRAL OVERCURRENT, INTENDED FOR NEUTRAL DETECTION
E-RLY-51TSN	AUX PWR TR-S NEUTRAL OVERCURRENT RLY 51 BD-F	2.12.40	E514-16	GEK-34053A (GE 12IAC51)	NEUTRAL OVERCURRENT, INTENDED FOR NEUTRAL DETECTION
E-RLY-63/SPS	AUX PWR TR-S SUDDEN PRESSURE RELAY	N/A	N/A	N/A	SUDDEN PRESSURE RELAY, NO CALCULATION OR SETTING
E-TR-S, Y-WINDING SECONDARY SIDE					
ANSI Device number	Function Performed	Calculation	Setting Drawing	OEM instruction	Comments
E-RLY-50GYS	AUX PWR TR-S GND CURR 50GYS	2.12.10	E514-16	WEST ITH	GROUND ALARM ON Y WINDING
E-RLY-27/YS (PT S3)	TR-S, Y WINDING UNDERVOLTAGE RELAY 27YS	2.12.17	E514-11	IL41-201J	ONE RELAY BETWEEN A AND B PHASE ONLY, ALARM, ANN-C/C4 (EWD-46E-104) SEE EWD-46E-104A FOR TRIP AND BLOCK FUNCTION.

Table-1: E-TR-S and TR-B Protective Relay Description and Settings (Continued)

E-TR-B 115kV HIGH SIDE					
ANSI Device number	Function Performed	Calculation	Setting Drawing	OEM instruction	Comments
OSC (BPD-B)	OSCILLOGRAPH TR-B UNDER VOLTAGE SENSOR	E/I-02-85-06	E514-27	N/A	OSCILLOGRAPH INDICATION
E-RLY-27/TRB (BPD-8)	UNDERVOLTAGE RLY FOR TR-B ON BD-C	2.12.54	E514-17	GEH-1768B	ONE PHASE TRIPS 115KV OCB/ EWD-46E-047
E-RLY-87/TB/A, B, C	AUX TR-B DIFFERENTIAL RELAY 87TB	2.12.07	E514-17	GEH-2057A	DIFFERENTIAL,INTENDED FOR GROUND DETECTION IN PROTECTION ZONE
E-RLY-67/TBX	BACKUP TRANSF TR-B REVERSE PWR RLY	2.12.39	E514-17	GEI-21902D	REVERSE POWER
E-RLY-5051/TB/A, B, C	TR-B OVERCURRENT RELAY PHASE	E/I-02-92-17	E514-17	GEK-34053A	PRIMARY OVERCURRENT
OSC	OSCILLOGRAPH TR-B NEUTRAL CURRENT SENSOR	E/I-02-85-06	E514-27	H-1017 (8504301)	OSCILLOGRAPH INDICATION
E-RLY-51TBN (CT-8/4)	AUX TR-B TIME OVERCURRENT RLY51TBN	BPA	E514-17	GEK-34054A	OVERCURRENT, INTENDED FOR GROUND DETECTION IN TRANSFORMER PROTECTION ZONE
E-RLY-63/SPB	AUX TR-B SUDDEN PRESSURE RELAY	N/A	N/A	N/A	SUDDEN PRESSURE
E-TR-B X-WINDING 4.16kV SECONDARY SIDE					
ANSI Device number	Function Performed	Calculation	Setting Drawing	OEM instruction	Comments
E-RLY-50GB	E-TR-B NEUTRAL GND ALARM RELAY	2.12.11	E514-17	IL41-771G	ALARM
E-RLY- 27/B/7/1 (PT-SM7A)	E-TR-B BUS E-SM-7 PHASE A-B UNDV RELAY	2.12.18	E514-11	GEI-90805	Secondary of TR-B Undervoltage Relay
E-RLY- 27/B/7/2 (PT-SM7A)	E-TR-B BUS E-SM-7 PHASE B-C UNDV RELAY	N/A	E514-11A	IB18.4.7-2	See Note 1 on E514-11A for Setting Basis
E-RLY-51/B/7/A, B, C	OVERCURRENT RELAY PHASE-A, B, C FOR E-CB-B/7	E/I-02-92-17	E514-7	IL41-100	Overcurrent Protection on feeder, TR-B to SM-7
E-RLY-27/B/8/1 (PT-SM8A)	E-TR-B AT E-SM-8 PHASE B-C UV RELAY	2.12.18	E514-11	GEI-90805	Secondary of TR-B Undervoltage Relay
E-RLY-27/B/8/2 (PT-SM8A)	FEEDER BUS B-8 PHASE A-B UV RELAY	N/A	E514-11A	IB18.4.7-2	See Note 1 on E514-11A for Setting Basis
E-RLY-51/B/8/A, B, C	E-CB-B/8 OVERCURRENT RELAY PHASE-A, B, C	E/I-02-92-17	E514-8	IL41-100	Overcurrent Protection on feeder, TR-B to SM-8

Table-2: Bus Protective Relay Description and Settings

E-SM-1, 2 AND 3							
ANSI Device number	Function Performed	Calculation	Setting Drawing	OEM instruction	Comments	Voltage Trip Setting	Trip Setting (%)
E-RLY-27/1	SM-1 UNDERVOLTAGE RELAY	2.12.21	E514-11	IL41-201J	SM-1 Undervoltage Relay, West. CV-2	2870	69.0%
E-RLY-27/2	SM-2 UNDERVOLTAGE RELAY	2.12.21	E514-11	IL41-201J	SM-2 Undervoltage Relay, West. CV-2	2870	69.0%
E-RLY-27/3	SM-3 UNDERVOLTAGE RELAY	2.12.21	E514-11	IL41-201J	SM-3 Undervoltage Relay, West. CV-2	2870	69.0%
E-RLY-51/S1/A, B, C	OVERCURRENT RELAY, TR-S TO SM-1	E/I-02-92-17	E514-3	IL41-100		N/A	N/A
E-RLY-51/S2/A, B, C	OVERCURRENT RELAY, TR-S TO SM-2	E/I-02-92-17	E514-4	IL41-100		N/A	N/A
E-RLY-51/S3/A, B, C	OVERCURRENT RELAY, TR-S TO SM-3	E/I-02-92-17	E514-5	IL41-100		N/A	N/A

Table-2: Bus Protective Relay Description and Settings (Continued)

E-SM-4, 7 AND 8							
ANSI Device number	Function Performed	Calculation	Setting Drawing	OEM instruction	Comments	Voltage Trip Setting	Trip Setting (%)
E-RLY-27/4/S1	E-SM-4 PRIMARY UNDERVOLTAGE RELAY	2.12.18	E514-11	GEI-90805B	Primary Undervoltage Relay At SM-4	2870	69.0%
E-RLY-27/4/S2	E-SM-4 PRIMARY UNDERVOLTAGE RELAY	2.12.18	E514-11	GEI-90805B	Primary Undervoltage Relay At SM-4	2870	69.0%
E-RLY-2762/4/1	E-SM-4 SECONDARY UNDERVOLTAGE RELAY	2.12.58	E514-11	IB-7417-7	Secondary Undervoltage Relay at SM-4	3720.5	89.4%
E-RLY-2762/4/2	E-SM-4 SECONDARY UNDERVOLTAGE RELAY	2.12.58	E514-11	IB-7417-7	Secondary Undervoltage Relay at SM-4	3720.5	89.4%
E-RLY-27/7/1	E-SM-7 PHASE A-B PRIMARY UNDERVOLTAGE RELAY	2.12.18	E514-11	GEI-90805	Primary Undervoltage Relay At SM-7	2870	69.0%
E-RLY-27/7/2	E-SM-7 PHASE B-C PRIMARY UNDERVOLTAGE RELAY	2.12.18	E514-11	GEI-90805	Primary Undervoltage Relay At SM-7	2870	69.0%
E-RLY-27/7/3	E-SM-7 PHASE A-B UNDERVOLTAGE RELAY	2.12.58	E514-11A	IB7.4.1.7-7	Secondary Undervoltage Relay at SM-7	3720.5	89.4%
E-RLY-27/7/4	E-SM-7 PHASE B-C UNDERVOLTAGE RELAY	2.12.58	E514-11A	IB7.4.1.7-7	Secondary Undervoltage Relay at SM-7	3720.5	89.4%
E-RLY-27/7/5	E-SM-7 PHASE A-C UNDERVOLTAGE RELAY	2.12.58	E514-11A	IB7.4.1.7-7	Secondary Undervoltage Relay at SM-7	3720.5	89.4%
E-RLY-27/8/1	E-SM-8 PHASE A-B PRIMARY UNDERVOLTAGE RELAY	2.12.18	E514-11	GEI-90805	Primary Undervoltage Relay At SM-8	2870	69.0%
E-RLY-27/8/2	E-SM-8 PHASE B-C PRIMARY UNDERVOLTAGE RELAY	2.12.18	E514-11	GEI-90805	Primary Undervoltage Relay At SM-8	2870	69.0%
E-RLY-27/8/3	E-SM-8 PHASE A-B UNDERVOLTAGE RELAY	2.12.58	E514-11A	IB7.4.1.7-7	Secondary Undervoltage Relay at SM-8	3720.5	89.4%
E-RLY-27/8/4	E-SM-8 PHASE B-C UNDERVOLTAGE RELAY	2.12.58	E514-11A	IB7.4.1.7-7	Secondary Undervoltage Relay at SM-8	3720.5	89.4%
E-RLY-27/8/5	E-SM-8 PHASE A-C UNDERVOLTAGE RELAY	2.12.58	E514-11A	IB7.4.1.7-7	Secondary Undervoltage Relay at SM-8	3720.5	89.4%