Entergy Operations, Inc.
17265 River Road
Killona, LA 70057-3093
Tel 504-739-6660
Fax 504-739-6678
djacob2@entergy.com

Donna Jacobs
Vice President - Operations
Waterford 3

10 CFR 50.54(f)

W3F1-2012-0091

October 25, 2012

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Subject: 90-Day Response to NRC Bulletin 2012-01,
"Design Vulnerability in Electric Power System."
Waterford Steam Electric Station, Unit 3 (Waterford 3)
Docket No. 50-382
License No. NPF-38

Reference: 1. NRC letter to Entergy, Bulletin 2012-01, "Design Vulnerability in Electric Power System," dated July 27, 2012 (ADAMS Accession Number ML12074A115)

Dear Sir or Madam:

On July 27, 2012, the NRC issued Bulletin 2012-01 (Reference 1), requesting that each licensee submit a written response in accordance with 10 CFR 50.54(f) within 90 days of the bulletin to provide requested information. This letter provides Entergy Operations, Inc. 90-day response to Reference 1 for Waterford Steam Electric Station, Unit 3 (Waterford 3) in the attachment.

There are no new commitments contained in this submittal. Please contact Michael Mason, Licensing Manager (acting), at (504) 739-6673 if you have questions regarding this information.

I declare under penalty of perjury that the foregoing is true and correct. Executed on October 25, 2012.

Sincerely,

DJ/WH

Attachment: 90-Day Response to NRC Bulletin 2012-01

cc: Director, Office of Nuclear Reactor Regulation
U. S. NRC
RidsNrrMailCenter@nrc.gov

Mr. Elmo E. Collins, Jr., Regional Administrator
U. S. NRC, Region IV
RidsRgn4MailCenter@nrc.gov

NRC Program Manager for Waterford 3
Kaly.Kalyanam@nrc.gov

NRC Senior Resident Inspector for Waterford 3
Marlone.Davis@nrc.gov

Attachment to

W3F1-2012-0091

90-Day Response to NRC Bulletin 2012-01

NRC Bulletin 2012-01 Response – Waterford 3

Overview:

- System Description - Items 2., 1.d, 2.a, 2.c
- System Protection - 1., 1.a, 2.b, 2.d
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- Figure 1: Simplified One-Line Diagram
- Tables
    - Table 1 - ESF Buses Continuously Powered From Offsite Power Source(s)
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    - Table 4 - Offsite Power Transformers
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System Description

Items 2, 1.d, 2.a, and 2.c request system information and will be addressed in this section:

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).

See Figure 1 for a Simplified One-Line Diagram.

The ESF buses are normally powered from the main generator via the Unit Auxiliary Transformers during normal operation.

The two 4.16 kV ESF buses 3A3-S and 3B3-S supply equipment essential for safe shutdown of the plant. These two buses receive power either from the non-safety related buses 3A2 and 3B2 or from the Emergency Diesel Generators (one per train). A third 4.16 kV bus, 3AB3-S, can receive power from either bus 3A3-S or 3B3-S, but not from both simultaneously. This swing bus supplies power to equipment which is standby to equipment on the other buses. Either bus 3A3-S or 3B3-S can supply sufficient power to shut down the plant and to maintain the plant in a safe condition, under normal and design basis accident conditions.

The 480V auxiliary system receives power from the 4.16 kV system through dry type, three-phase indoor and outdoor transformers. The 480V ESF auxiliary system consists of three safety-related power centers (plus two nonsafety-related power centers), 17 motor control centers (MCCs) (including four non-safety-related MCCs), the safety-related loads and interconnecting cables. Each of the two safety-related power centers 3A31-S, and 3B31-S, and two non-safety-related power centers, 3A32 and 3B32, consists of a 4160-480V, three-phase, delta-wye, indoor, dry-type transformer. The remaining safety related power center, 3AB31-S, can receive power from either power center 3A31-S or 3B31-S, but not from both simultaneously.

Waterford 3 Offsite Power System is designed to comply with 10CFR50, Appendix A, General Design Criterion 17 (Electrical Power Systems) by having two electrically and physically independent transmission circuits from the grid to the plant distribution system. The two transmission lines are electrically separated by at least two circuit breakers in series at both the switchyard and the switching station. The transformer yard contains two Main Transformers (MT), two Startup Transformers (SUT) and two Unit Auxiliary Transformers (UAT). During normal plant operation, Waterford 3 in-house loads are powered from the two Unit Auxiliary Transformers and the two Startup Transformers are on standby (one per train). During normal plant operation, an open phase on the main transformer 230kV side would have no effect on the safety bus voltage. Since the UAT is tied directly to the generator terminals, it will continue to receive three phase voltage on its primary side for as long as the main generator remains online. If the main generator trips on negative sequence due to the open Main Transformer phase, the safety buses and the upstream balance of plant (BOP) buses 1A, 1B, 2A, and 2B will automatically transfer to their alternate source (SUT). Therefore, an open phase on the main transformer high side while the plant is in normal operation is not of concern.

An open phase on the UAT primary side while the generator isophase and main transformer connections remain intact is not credible due to the isophase bus connection arrangement, which makes it highly unlikely that a phase would open without also shorting to ground and tripping the generator.

During normal plant operation, an open single-phase on the SUT primary has no effect on safety bus voltage since the safety buses are powered from the UAT. During plant outages, the safety buses are power from the SUT. However, a loss of single phase would only affect one safety related train.

The following connections are associated with each of the transformers:

<u>Main Transformer (MT)</u>

High Side (230kV) – Overhead line connected to the transmission towers

Low Side (25kV) – Isophase bus connected to the main generator

<u>Startup Transformer (SUT)</u>

High Side (230kV) - Overhead line connected to the transmission towers

Low Sides (6.9kV and 4.16kV) – Calvert Cable Bus connected to the Switchgears

<u>Unit Auxiliary Transformer (UAT)</u>

High Side (25kV) - Isophase bus connected to the main generator

Low Sides (6.9kV and 4.16kV) – Calvert Cable Bus connected to the Switchgears

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

See Table 4 for offsite power transformer winding and grounding configurations.

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

For at power (normal operating condition) configurations, ESF buses are not powered by offsite sources. The ESF buses are normally powered directly from the main generator via the Unit Auxiliary Transformers during normal operation.

2.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.

The two 4.16 kV ESF buses 3A3-S and 3B3-S supply equipment essential for safe shutdown of the plant. These two buses receive power either from the non-safety related buses 3A2 and 3B2 or from the Emergency Diesel Generators (one per train). A third 4.16 kV bus, 3AB3-S, can receive power from either bus 3A3-S or 3B3-S, but not from both simultaneously. This swing bus supplies power to equipment which is standby to equipment on the other buses. Either bus 3A3-S or 3B3-S can supply sufficient power to shut down the plant and to maintain the plant in a safe condition, under normal and design basis accident conditions.

The 480V auxiliary system receives power from the 4.16 kV system through dry type, three-phase indoor and outdoor transformers. The 480V ESF auxiliary system consists of three safety-related power centers (plus two nonsafety-related power centers), 17 motor control centers (MCCs) (including four non-safety-related MCCs), the safety-related loads and interconnecting cables. Each of the two safety-related power centers 3A31-S, and 3B31-S, and two non-safety-related power centers, 3A32 and 3B32, consists of a 4160-480V, three-phase, delta-wye, indoor, dry-type transformer. The remaining safety related power center, 3AB31-S, can receive power from either power center 3A31-S or 3B31-S, but not from both simultaneously.

During normal operating condition 4.16 kV ESF buses are powered from the Main Generator via the Unit Auxiliary Transformers which have been confirmed to be consistent with the current licensing basis.

<u>System Protection</u>

Items 1, 1.a, 2.b, and 2.d request information regarding electrical system protection and will be addressed in this section:

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…. :**

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, balanced degraded grid voltage concurrent with certain design basis accidents. The relay systems were not specifically designed to detect and isolate an open single phase of a three phase system. Detection of a single-open phase condition is beyond the approved design and licensing basis of the plant.

ABB has performed a PSCAD/EMTDC program analysis on open phase at the Startup Transformer for Waterford 3. Based on the analysis, it has been determined that Waterford 3 does not have a protective relaying scheme that can adequately detect an open circuit (without a ground fault) for the Startup Transformers during normal plant operation. Hence, Waterford 3 is susceptible to similar events discussed in the NRC Bulletin. However, Waterford 3 relaying schemes are expected to detect and automatically separate the offsite power system from the safety related onsite power system if the open phase was solidly grounded either at the transformer high side or at the switchyard side.

The impact of the open phase fault depends on type and location of failure along with the transformer core and winding configuration (WYE-WYE, WYE-Delta etc). There is a tendency to assume that the associated phase voltage collapses to zero when a loss of a phase occurs at the transformer. This is not always the case. There are multiple elements in the power system providing paths and mechanisms to re-energize the lost phase from the remaining two phases which make detection of the phase loss condition difficult. Due to the complexity of the coupling voltage generated within the windings of the transformer recreating the lost phase, ABB performed a PSCAD/EMTDC program analysis on the Waterford 3 Startup Transformer to determine the exact voltage and current responses resulting from a loss of phase on the primary side. Waterford 3 startup transformers have 230kV Wye (ground) – 7.2 kV Delta – 4.36kV Delta winding configuration. The results of the analysis from ABB were evaluated and used as input to generate responses to the NRC Bulletin. The single phasing event may be classified in three postulated scenarios that are discussed below:

<u>Scenario #1 – Open circuit with a ground fault on the switchyard side (Byron Event #2)</u>

If one of the transmission lines failed open and grounded on the switchyard side, the associated switchyard breakers on the 230kV Waterford 3 Switchyard (East and West busses) and the associated Generator Output breaker (GOB) will open due to high ground fault current. During normal plant operation, Waterford 3 continues to operate via the Unit Auxiliary Transformers and supplies power to the grid as the redundant transmission line and its equipments are designed for 100% power rating. If the Waterford 3 in-house loads are fed from the Startup Transformers, a loss of offsite power on the train associated with the failed startup transformer would actuate the undervoltage/degraded voltage relays to initiate the transfer from off-site power source to the Emergency Diesel Generator source.

<u>Scenario #2 – Open circuit with a ground fault on the transformer high side (Byron Event #1)</u>

An open phase at the transmission lines with a solid ground fault on the transformer high side will generate a ground fault current of approximately 1000 amps at the transformer high side which is expected to actuate the Startup Transformer ground overcurrent relay. The ground overcurrent relay initiates the associated startup transformer lockout relay which isolates offsite power to the affected startup transformer resulting in actuation of the undervoltage/degraded voltage relays to initiate the transfer from off-site power source to the Emergency Diesel Generator source. In addition to the high ground fault current generated at the transformer neutral, the voltage on one phase of the secondary windings degrades to less than 35% nominal which is expected to initiate an alarm in the control room via the Startup Transformers undervoltage monitoring relays. Additionally, a blown fuse alarm on the ESF bus may actuate in the control room due to one or more of the undervoltage/degraded relay actuated. The startup transformer differential relays are not expected to actuate during this event.

The magnitude of the degraded voltage on the affected phase and the overcurrent on the neutral of the startup transformer high voltage winding are similar for transformer load ranging from 0% to 100%.

<u>Scenario #3 – Open circuit without a ground fault</u>

The PSCAD/EMTDC analysis shows that if one phase is lost on the WYE source (230kV high side), the lost phase is recreated on the WYE phase by back-feed from the DELTA winding (7.2 kV or 4.36 kV low side). Hence, the voltages on the 7.2 kV and 4.36 kV are maintained at all three phases which make it impossible to detect an open phase with undervoltage relays during normal plant operation while the Startup Transformers are on standby. Although the voltage on the lost phase is recreated, the voltages on all three phases are not maintained at 100% which create an unbalance voltage at the secondary windings when the Startup Transformers are loaded. The percent of unbalance voltage depends on the percent of loadings on the startup transformer. For example, at 0% load, the voltages on all three phases are balanced and maintained at nominal voltages. However, as load increases on the startup transformer, the secondary voltages (7.2 kV and 4.36 kV) and currents on the three phases are unbalanced, up to 10%. During an unbalanced voltage condition, negative sequence current is produced that creates magnetic flux that rotates in the reverse rotation of the rotor of the motors. The reverse rotation of the magnetic flux could cause rapid heating in the rotor, which may result in motor insulation failure. In accordance with Motor Standard MG-1, an unbalance voltage of 5% can reduce the motor output by 25%. Although the voltage on the lost phase is re-generated to more than 90% nominal, it is not acceptable to continuously operate the motor under this unbalanced condition as the negative sequence current could cause permanent damage to the motor.

The setpoint for the degraded voltage relays is set at 3875V (93%) and one or two relays may pickup during an open phase condition when load on the startup transformer is above 75%. However, the Waterford 3 undervoltage/degraded voltage schemes require a three-out-of-three logic to initiate the transfer from off-site power source to the Emergency Diesel Generator source. Therefore, automatic actions are not expected from the degraded voltage relaying scheme. There are several degraded/undervoltage alarms that may actuate during the open phase condition (w/o ground). The actuation of the alarm depends on the magnitude of re-generated voltage on the lost phase which is based on the percentage load on the Startup Transformer.

The 4.16 kV ESF buses 3A3-S and 3B3-S Low Voltage alarms may actuate depending on which phase is affected. The safety related 4kV busses have a degraded voltage alarm set at 3940V (94.7%). However, this degraded voltage alarm only monitors voltage on one phase (A-B). This relay only actuates when an open phase of the primary winding occurs that reduces the voltage on the A-B phase of the 4.36kV secondary winding below 3940V. Additionally, a blown fuse alarm on the ESF bus may actuate in the control room due to one or more of the undervoltage/degraded relay actuated.

As load on the startup transformer decreases, the re-generated voltage increases which make it impossible to detect the open phase via voltage and/or current detection schemes without concern of spurious actuations. In conclusion, Waterford 3 currently does not have a protective relay scheme that would adequately detect and isolate the open circuit (w/o ground) condition.

<u>High Impedance Ground</u>

The ABB PSCAD/EMTDC program analysis, performed for Waterford 3, does not include the evaluation for high impedance ground fault condition. A single phase high impedance fault (defined herein as those faults of sufficient impedance to remain below the setting level of the ground fault relays) on the primary winding with all three phases intact may not be detected by system protection relays. A single phase high impedance fault concurrent with the loss (i.e., "open") of the same phase is expected to respond similarly to the open circuit condition w/o a ground fault (Scenario #3 above). Waterford 3 has high impedance ground detection scheme installed on the 4.16 kV and 480 V ESF systems. High impedance grounding is used on the 4.16 kV and 480 V ESF systems so that ground fault currents will be too small (about 10 A) to require tripping of the affected breaker. Ground faults are detected and alarmed at the control room by ground detector relay connected to a current transformer.

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

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, but were not designed to detect a single phase open circuit condition while the Startup Transformers are unloaded. The 4.16kV buses, 3A3-s and 3B3-2, are provided with undervoltage relays which monitor the bus voltage during all plant conditions and provide protection for safety related equipment. The degraded voltage protections provided on the ESF buses are set such that it will not be activated upon starting the Heater Drain Pump (largest motor). See Table 5 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. Table 5 lists ground alarm on the ESF buses and the basis for the device setpoint(s).

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.

An interim compensatory action is in place to perform a daily visual walkdown inspection of switchyard connections to the Startup Transformers and verify all three phases are physically intact. The visual inspection of overhead lines is included in this inspection. Based on the PSCAD/EMTDC analysis, an open phase circuit with a ground fault is expected to result in automatic actuation of the affected relays (overcurrent and/or undervoltage relays). Loss of offsite power on the affected train occurs and EDG is expected to start and provide power to the safety related buses. Currently (during normal plant operation), for the open phase without a ground or with a high impedance ground, there is no detection device available and visual walkdown inspection of the switchyard connections is the only known acceptable method.

2.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?

The Waterford 3 plant operating procedures and/or operations logs specifically call for verification of the voltages on all three phase to phase connections of the ESF buses. Operators record the lowest phase voltage.

<u>Consequences</u>

Items 1.b, 1.c, and 2.e request information regarding the electrical consequences of an event and will be addressed in this section:

1.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.

Installed relays were not designed to detect single phase open circuit conditions. Existing loss of voltage and degraded voltage relays will not detect single phase open circuit conditions because the monitored ESF buses are normally aligned to the Unit Auxiliary Transformers. At Waterford 3, there will be no plant response for an unloaded (e.g., ESF buses normally aligned to unit auxiliary transformer) power source in the event of a single-phase open circuit (without ground fault) on a credited off-site power circuit because there is insufficient current to detect a single-phase open circuit for this configuration. However, if the open phase circuit is solidly grounded, it is expected that the Startup Transformer will be automatically isolated on neutral over current and/or alarm actuates in the control room. When the open phase is solidly grounded, the magnitude of the degraded voltage on the affected phase and the overcurrent on the neutral of the startup transformer high voltage winding are similar for transformer load ranging from 0% to 100%.

When the open phase is not grounded or high impedance grounded, the voltages on the secondary windings (7.2 kV and 4.36 kV) are maintained at all three phases which make it impossible to detect an open phase with undervoltage relays during normal plant operation while the Startup Transformers are on standby. Although the voltage on the lost phase in primary winding is recreated, the voltages on all three phases are not maintained at 100% which create an unbalance voltage at the secondary windings when the Startup Transformers are loaded. The percent of unbalance voltage depends on the percent of loadings on the startup transformer. For example, at 0% load, the voltages on all three phases are balanced and maintained at nominal voltages. However, as load increases on the startup transformer, the secondary winding voltages and currents on the three phases are unbalanced, up to 10%. In general, as load on the startup transformer increases, the voltage imbalance on the secondary windings increases.

1.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.

1. Waterford 3 did not credit in the Current Licensing Basis (CLB) that the Class 1E protection scheme (for the emergency safeguard feature (ESF) buses) was designed to detect and automatically respond to a single-phase open circuit condition or high impedance ground fault condition on the credited off-site power source as described in the UFSAR and Technical Specifications. The offsite power circuits at Waterford 3 consist of two independent circuits between the offsite transmission network and the onsite class 1E distribution system. (ref. Technical Specification 3/4.8.1 A.C. Sources)

2. Since Waterford 3 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 Waterford 3 design or licensing basis, no design basis calculations or design documents exist that previously considered this condition.

3. The Waterford 3 configuration on the Startup Transformers was modeled using PSCAD/EMTDC program to determine the exact voltage and current responses caused by a loss of phase on the primary side. The analysis results concluded that Waterford 3 protection schemes are expected to detect and isolate the offsite power source for an open phase with a ground fault condition. However, Waterford 3 does not have a detection and/or protection scheme for an open phase without a ground fault, especially when the Startup Transformers are unloaded.

4. An open phase circuit with a ground fault will result in automatic actuation of the affected relays (overcurrent and/or undervoltage relays). Loss of offsite power on the affected train occurs and EDG is expected to start and provide power to the safety related buses. Currently (during normal plant operation), for the open phase without a ground, there is no detection device available and visual walkdown inspection of the switchyard connections is the only known acceptable method. Therefore, Waterford 3 implemented an interim compensatory action to perform a daily visual walkdown inspection of switchyard connections to the Startup Transformers to verify all three phases are physically intact. The visual inspection of overhead lines is included in this plant walkdown.

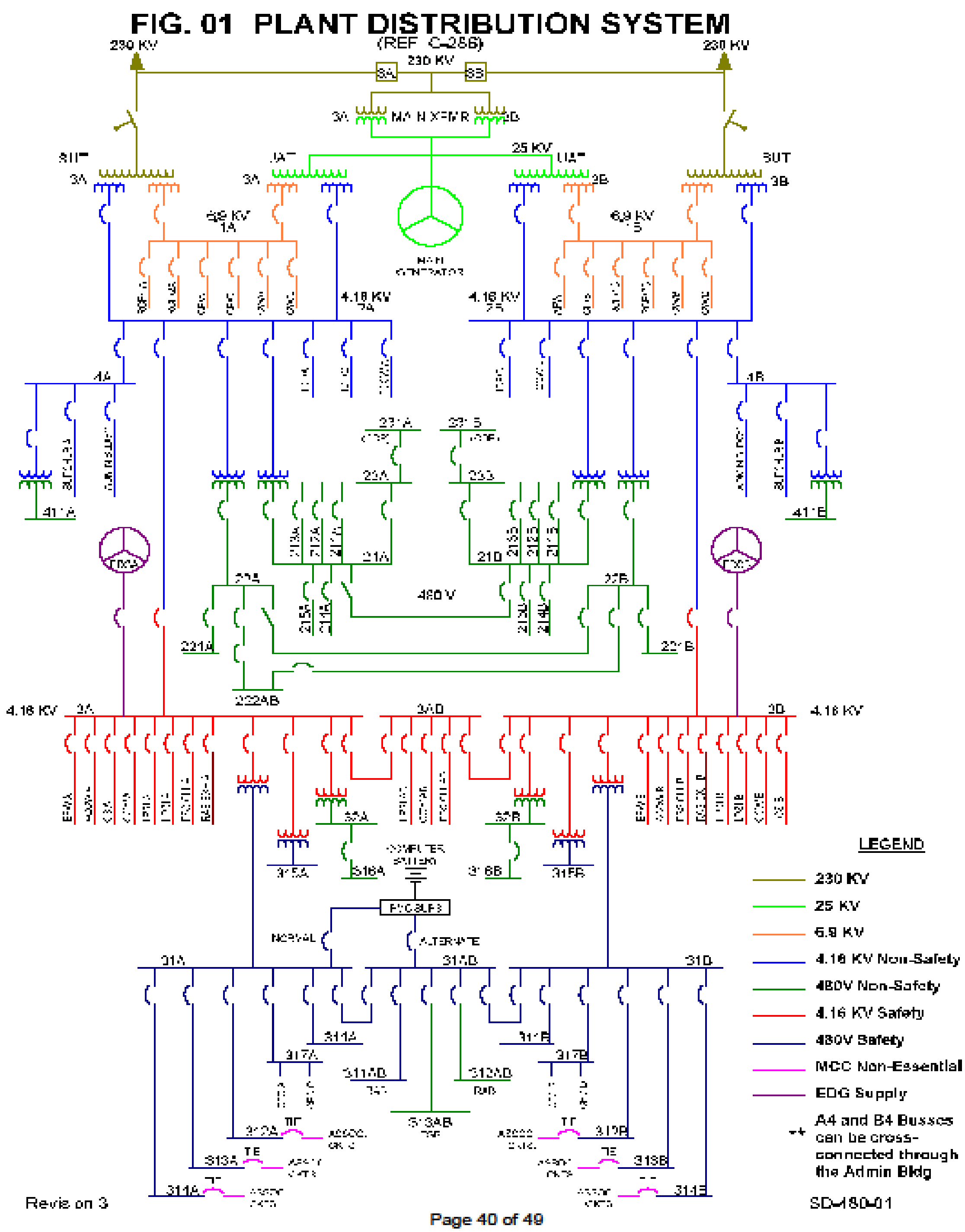
5. For an event on a loss of phase without a ground or with high impedance ground, as load on the startup transformer decreases, the re-generated voltage increases which make it impossible to detect the open phase via voltage and/or current detection schemes without

concern of spurious actuations. While the startup transformer is on standby, the PSCAD/EMTDC analysis shows that voltages and currents are normal during a loss of one existing phase (without a ground fault). There may not be a relaying scheme existing that can adequately detect and protect an open phase on a transformer, especially when the transformer is unloaded. Future technology, such as Carrier Frequencies, may be employed as a long term corrective action to detect the open phase (without ground) condition. This is a generic concern throughout the industry. Waterford 3 continues to work with NEI and the industry to address the condition as described in the NRC Bulletin.

2.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.

Not applicable since Waterford 3 does not use a common or single offsite circuit to supply redundant ESF busses.

Figure 1: Simplified One-Line Diagram



Tables

Table 1 - ESF Buses Continuously Powered From Offsite Power Source(s)

Description of ESF Bus Power Source	ESF Bus Name (normal operating condition).	Original licensing basis configuration (Y/N)
N/A	N/A	N/A

Table 2 - ESF Buses Not Continuously Powered From Offsite Power Source(s)

Description of ESF Bus Power Source	ESF Bus Name (normal operating condition).	Original licensing basis configuration (Y/N)
N/A	N/A	N/A

Table 3 - ESF Buses Normally Energized Major Loads

ESF Bus	Load	Voltage Level	Rating (HP)
N/A	N/A	N/A	N/A

Table 4 - Offsite Power Transformers

Transformer	Winding Configuration	MVA Size (OA/FOA/FOA)	Voltage Rating (Primary/Secondary)	Grounding Configuration
Start-up Transformer 3A	Wye-Delta-Delta	H Winding: 33.6/44.8/56 X Winding: 21.6/28.8/36 Y Winding: 12/16/20	230kv/6.9kv/4.16kv	Neutral Solid Grounded
Start-up Transformer 3B	Wye-Delta-Delta	H Winding: 33.6/44.8/56 X Winding: 21.6/28.8/36 Y Winding: 12/16/20	230kv/6.9kv/4.16kv	Neutral Solid Grounded

Table 5 - Protective Devices

Protection Zone	Protective Device	UV Logic	Setpoint (Nominal)	Basis for Setpoint
4 KV ESF Bus	Loss of Voltage Relay	3 of 3	3675V (88.3% of 4160V)	To actuate upon complete loss of 4kV ESF Bus voltage condition. To preclude equipment damage upon undervoltage or loss of voltage.
4 KV ESF Bus	Degraded Voltage Relay	3 of 3	3875V (93.1% of 4160V)	To actuate upon degraded 4kV ESF Bus voltage condition. To preclude equipment damage upon sustained degraded voltage.
4 kV ESF Bus	Ground Protection	1 of 1	* See Note 1	System has high impedance ground. Alarm actuates at Control Room when phase to ground occurs.
4 kV ESF Bus	Blown Fuse Alarm	1 of 3	3675V (88.3% of 4160V) or 3875V (93.1% of 4160V)	The relay contacts are combined in a one out of three logic to generate an alarm on loss of instrument potential transformer fuse.
480V ESF Bus	Loss of Voltage Relay	3 of 3	372V (77.5% of 480V)	To actuate upon complete loss of 480V ESF Bus voltage condition. To preclude equipment damage upon under-voltage or loss of voltage.
480V ESF Bus	Blown Fuse Alarm	1 of 3	372V (77.5% of 480V)	The relay contacts are combined in a one out of three logic to generate an alarm on loss of instrument potential transformer fuse.

Note 1 - High resistance grounding is used on the 4.16 kV and 480 V ESF systems so that ground fault currents will be too small (about 10 A) to require tripping of the affected breaker. Ground faults are detected and alarmed by a sensitive relay connected to a current transformer.