Enclosure 1

MFN 14-056

GEH Response to RAI 08.02-1

NRC Request for Additional Information 08.02-1:

On July 27, 2012, the NRC issued Bulletin 2012-01, "Design Vulnerability in Electric Power System," (Agency wide Documents Access and Management System (ADAMS) Accession Number ML 1207 4A 115) to all holders of operating licenses and combined licenses for nuclear power reactors requesting information about the facilities' electric power system designs, in light of the recent operating experience that involved the loss of one of the three phases of the offsite power circuit (single-phase open circuit condition) at Byron Station, Unit 2 to verify compliance with applicable regulations and to determine if further regulatory action is warranted.

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

1. *Describe the protection scheme design for important to safety buses to detect, alarm, and automatically respond to the following open circuit conditions on credited offsite power circuits:*

   (1) Loss of one of the three phases of the offsite power circuit on the high voltage side of a transformer connecting a GDC-17 offsite power circuit to the transmission system under all operating electrical system configurations and loading conditions with a high impedance ground fault condition under all loading and operating configurations.
   (2) Loss of one of the three phases of the offsite power circuit on the high voltage side of a transformer connecting a GDC-17 offsite power circuit to the transmission system under all operating electrical system configurations and loading conditions without a high impedance ground fault condition under all loading and operating configurations.
   (3) Loss of two of the three phases of the offsite power circuit on the high voltage side of a transformer connecting a GDC-17 offsite power circuit to the transmission system under all operating electrical system configurations and loading conditions under all loading and operating configurations.

2. *If the important to safety buses are not powered by offsite power sources during at power condition, explain how surveillance tests (e.g., SR 3.8.1.1) are performed to verify that any of the open circuit conditions described above is detected.*

3. *Describe the plant operating procedures including off-normal operating procedures, specifically call for verification of the voltages on all three phases of the ESF buses.*

GEH Response

Summary

In response to Bulletin 2012-01, GEH is adding detail to DCD section 8.3 on how the safety-related electrical buses will be protected against loss of phase events. Also, GEH will be adding a COL item to Section 8.2 of the DCD to require the COL applicant to address the monitoring and alarms on the high voltage side of the main, unit auxiliary and reserve auxiliary transformers for loss of phase conditions.

Condition Identified in NRC Bulletin 2012-01

The NRC Bulletin 2012-01 identified a condition that degraded one of two offsite AC power supplies at the Byron Unit 2 nuclear plant. The condition was a loss of one phase of the high-voltage AC power system caused by a broken insulator stack of the phase C conductor for the 345-kv power circuit, which resulted in a plant transient. The loss of phase was not detected at the time of occurrence. The Bulletin cites the Bryon event and other instances of plant operating experience that identify a design vulnerability associated with single-phase open circuit conditions that were undetected.

The ABWR is subject to GDC-17 requirements including degraded conditions. Therefore, the ABWR needs to provide design features, as necessary, to detect and alarm in the control room in the event of a single phase open circuit, with or without high impedance ground fault conditions, located on the high-voltage side of a transformer connecting a GDC-17 offsite power circuit to the transmission system for all modes of operation. An NEI-coordinated industry strategy paper, with NRC feedback, indicates that the design features for detection and alarm should be provided in the DCD/FSAR, and that specific ITAAC should be provided to verify the design features (ML13170A236). Plant procedures would specify actions to restore the offsite power source to a functional condition. As explained below, the ABWR Design Control Document (DCD) will be revised to address these elements for the ABWR standard design certification. First is a description of the electrical system design, as described in the ABWR DCD.

DCD Description of Electrical System Design

The ABWR DCD Tier 2 Chapter 8 describes the electrical system design. Protective relaying is described in Section 8.2.1.2, and Sections 8.3.1.0.6 and 8.3.1.1.6.3 which explain that main power transformers and Unit Auxiliary Transformers (UAT) have protective devices for overcurrent, differential current, ground overcurrent, and under voltage.

The ABWR design also requires a Reserve Auxiliary Transformer (RAT) that is outside the scope of the Certified Design. However, the RAT is connected to the alternate preferred offsite power circuit while the UATs are connected to the normal preferred

offsite power circuit. There are additional design commitments that are imposed on the RAT in DCD paragraphs 8.2.5 and 8.3.4.9.

COL Information Items are listed in Section 8.2.4. The ABWR DCD Tier 1 Section 2.13.1 includes ITAAC, and Section 4.2 describes the interface between the onsite portion of the PPS and the site-specific offsite portion of the PPS.

Monitoring and Alarms for Addressing NRC Bulletin 2012-01

The ABWR detailed design approaches will be specified in one or more technical requirement document(s) for the ABWR electrical systems architecture and design when the detailed design is developed. The detailed ABWR electrical systems architecture and design will address the concerns and issues presented in NRC Bulletin 2012-01. Monitoring for the switchyard will be developed on a site specific basis.

In order to document that loss of one or more phases in the offsite high voltage power to the UATs and RAT does not result in a detrimental condition of the safety-related busses, a description of the monitoring and protection will be part of the ABWR standard plant design in the renewal application. Additional text will be added to Section 8.3.1.1.6.3 to describe how the nonsafety-related and safety-related feeder breakers to the Division I, II, and III buses are protected. These DCD changes will be included in Revision 6 of the DCD.

Since the offsite power is not part of the standard plant design, a COL information item describing the design features for monitoring and alarms for detecting the loss of one or more phases of offsite high voltage power will be added to the ABWR DCD Tier 2 Chapter 8 in a new Section 8.2.4.6, which is included in an attached mark-up of the DCD. These DCD changes will be included in Revision 6 of the DCD.

As with other monitoring and alarms, operator actions will be addressed as part of the development of procedures described in DCD Tier 2 Section 13.5 and no changes to Section 13.5 are necessary. In addition, the Electric Power Distribution System alarms, displays, controls, and status indications in the Main Control Room are addressed by DCD Tier 2 Chapter 18 and Tier 1 Section 3.1 as part of the Human Factors Engineering process.

Description of the Protection Design Features not included in DCD

This section explains the design features of the protective relays that provide for monitoring and alarms for detecting the loss of one or more phases or a ground in the electrical system at the UAT or RAT inputs and on the safety-related medium voltage busses and alarming in the Main Control Room so that operators can take manual action, as appropriate, and initiate corrective actions to address the loss of phase condition.

The ABWR electrical system is protected against faults and abnormal conditions by protective relays. Depending on the protective relay type, these relays are capable of providing most of the standard IEEE C37.2 specified device functions. For example:

- Protective relays for generator protection can provide Type 24 (volts per hertz) and Type 40 (field over/under excitation) protection;
- Protective relays for transformer protection can provide Type 87 (differential current) and Type 50N (instantaneous ground overcurrent) protection; and
- Protective relays for motor protection can provide Type 27 (undervoltage), Type 87 (differential current), and Type 51 (inverse time overcurrent) protection.

Unlike past practice where one physical relay was required for each type of protection, the modern protective relays can be programmed to provide multiple types of protection from the same voltage and current inputs.

These relays are specific to different electrical system monitoring and protection applications of feeder, generator, motor, and transformer protection and can be programmed to provide specific protective device functions. The available protection types overlap. The required functions and setpoints are determined by detailed electrical system analyses by NRC endorsed analysis tools. The relays have several features in common such as;

- The relays measure, compare, and provide trip outputs consistent with the typical 3 – 6 cycle (~50 to 100 mSec) breaker tripping requirements needed to clear faults;
- The relay's input signals come from potential and current transformers which reduce the high- and medium- voltage currents and voltages to within the relay's input capabilities (typically 120 VAC and 5 Amps);
- The relays can input several voltages and currents, for example, the inputs and outputs of a transformer with two secondary windings or the inputs and outputs to a generator or the phases and grounds of a large motor;
- The relays can also obtain their voltage and current data using optical fiber and remote multiplexing and
- The relays can be interfaced to each other to support specific protective functions. For example, all of the relays representing breakers on a specific bus can be connected to share data to provide bus differential current protection or all three relays that support the main generator two-out-of-three trip protection can be connected together to support the voting scheme.

Note that fault protection is similar to previous reactor designs. All hard faults will result in a protective action with specific analyses to indicate that the non-faulted portions of the electrical system remain operational.

The protective relays are used to implement the protective relaying philosophy of the ABWR which can be summarized as follows:

- All faults will be interrupted using a breaker as close as possible to the fault and
- All faults will be provided with redundant protection (primary and backup) such that if the breaker closest to the fault does not operate, another breaker will be opened to clear the fault.

The scope of electrical system protection includes the following plant equipment:

- Unit auxiliary transformers (UAT), reserve auxiliary transformer (RAT), and high side isolation breakers;
- Medium voltage buses, their motor and power center loads, and associated switchgear and
- Low voltage buses, their motor and power center loads, and associated switchgear and
- Emergency diesel generators (EDGs) and combustion turbine generator (CTG).

Only the ABWR plant specific protective relays can directly trip breakers within the scope of the plant's electrical system.

The ABWR protective relays are assigned a safety-related classification commensurate with their safety function. Safety-related protective relays are qualified appropriately for the electrical bus function(s) they are supporting.

The protective relays serve as electrical system "sensors" in that they can provide their measurements to the Instrumentation and Control systems through appropriate interfaces.

The ABWR certified standard plant design electrical system boundaries for electrical protection and coordination are well defined, both internally (e.g.; voltage levels and zones) and externally (e.g.; interface to equipment in switchyard and through it to offsite electric power). It is important to note that one of the ABWR plant electrical system external boundaries is located on the high voltage side of the UATs and RATs. This boundary is instrumented with appropriate current and potential transformers for control, monitoring, and alarming functions using protective relays.

ABWR electrical system protective relays will provide trip or closing commands to the switchyard breakers used to isolate a high voltage cable fault or when synchronizing with the transmission grid.

Switchyard electrical system protective relays will provide trip commands to the UAT protective relays used to isolate the plant electrical system from switchyard or high-voltage cable faults.

These interfaces are already provided for in the COLA through DCD COL Information Items COL 8.2.4-1 and 2 and will be considered in further development of detailed design.

Note that the protection of the three Class 1E buses design also influences the electrical system protection philosophy. The protective relaying is designed to preserve the Class 1E electrical system, including the emergency diesel generators, and protect them from damage. Where there is a conflict, the system is designed to disconnect the power provided from either normal or alternate preferred power from offsite. Continuity of safety-related electricity for the ABWR is ensured by the three emergency diesel generators which will automatically start and connect to the divisional bus on the loss of voltage.

Description of the Monitoring Design Features

The ABWR safety related and nonsafety-related Instrumentation and Control continuously monitor and alarm various parts of the plant electric system. The instruments produce an analog output for both monitoring and alarming purposes. Each of the nonsafety-related electrical buses and safety-related buses listed below is monitored for abnormal voltages and each of the three phases are monitored by a separate instrument, sensor, or transducer.

- A1, B1, and C1 6.9 kV nonsafety-related buses
- A2, B2, and C2 6.9 kV nonsafety-related buses
- A3, B3, and C3 6.9 kV nonsafety-related buses
- A4, B4, and C4 6.9 kV nonsafety-related buses
- Division I (E), Division II (F), and Division III (G) 6.9 kV safety-related buses
- 480 VAC FMCRD power center buses
- 480 VAC nonsafety-related power center buses
- 480 VAC safety-related power center buses

The four Class 1E divisional 120 VAC safety-related electrical buses are monitored for abnormal voltage and frequency. The plant safety and nonsafety-related batteries are monitored and alarmed for current and voltage.

The plant or site specific electrical design may also include switchyard buses, transmission lines, or feeder lines but any monitoring and alarming of these systems is independent of monitoring the normal and alternate preferred power feeds to the plant. Recall that the ABWR standard plant design monitoring is included in the protective relay monitoring of the high-voltage power feeds to the UATs and RATs for transformer protection purposes. Note that the plant electrical system monitoring is done by the protective relaying and sent to the safety-related and nonsafety-related I&C. For example, the protective relays used for UAT and RAT transformer protection will require both voltage and current measurement on the primary side (i.e.; high voltage) and secondary side of the transformers. The protective relays can also provide additional information, such as real and apparent power, VARs, power factor, energization time, and relay self-diagnostics.

Description of the Specific Monitoring Concerns

The ABWR protective relaying schemes result in the appropriate circuit breaker trip actions, fast or slow bus transfer actions, or generator and turbine trip actions. The same relays provide continuous monitoring outputs, specifically including three phases of bus voltage, to the Instrumentation and Control systems such that they can be continuously monitored and alarmed, so no specific surveillance is required.

Most of the monitoring is straightforward. However, two specific kinds of measurements provide ABWR operators with appropriate information about the status and control of the electrical system. The first measurements are the undervoltage monitoring of the three phases of the Division I (E), Division II (F), and Division III (G) safety-related 6.9 kV buses that, after appropriate time delays, will command the start of the emergency diesel generator(s). Specifically, the undervoltage monitoring will be responsive to all three phases. The monitoring will be effective for both load shedding and emergency diesel start and protection of the safety-related bus loads for grounds and loss of one or more phases. Additionally, the nonsafety-related busses A4, B4, C4, and the new H bus are monitored by their own protective relays and will trip power to the safety-related buses on detection of abnormal voltages and frequency, including loss of one or more phases and ground conditions.

The second type of measurement includes monitoring and alarming for the availability of the normal and preferred ABWR offsite power sources. As previously stated, the UATs (i.e.; normal preferred offsite power) and RAT (i.e.; alternate preferred offsite power) are protected by protective relays using voltage and current measurements on both the primary (i.e.; high voltage) side and secondary (e.g.; 6.9 kV) sides of the transformers. The same high voltage measurements support detection in all three phases of abnormal operating voltages as well as both zero and negative sequence currents. In a perfectly balanced three-phase system, only positive sequence currents exist. As the phases become more unbalanced, up to and including the loss of a single phase, greater amounts of negative sequence current are generated. A hard fault on one phase will also generate negative sequence current. Negative sequence current detection is therefore a useful and sensitive way of detecting open phases or phase imbalance with or without an accompanying fault to ground. For example, if the entire load is connected between two of the three phases with no load on the third phase (e.g.; as would occur if a phase was opened), the negative sequence current would be the maximum load current divided by the square root of three instead of zero.

Because both the positive and negative sequence transformer current decreases as the transformer load decreases there is a lower limit to the detection of an open single phase as the currents approach the resolution of the current transformers. If the transformer is normally loaded (e.g.; UAT) a phase imbalance will be detected almost immediately and the signal can be used to initiate a fast electrical bus transfer from the UAT to RAT circuits. Detection of a single phase loss cannot be guaranteed for an unloaded or lightly loaded transformer (e.g.; RAT); therefore, the protective relays will only generate an alarm for that case. Hard single phase faults, which are the most

common type, will always be detected. Note that even if a loss of phase is undetected on the RAT, an automatic transfer of power from the UAT to the RAT will load the latter enough to trip; in no case will the safety-related busses be adversely affected.

In all cases for nonsafety-related equipment, there is no analyzed potential for individual load equipment (e.g.; motor or power center) damage because their individual protective relaying will trip them if they try to operate on only two phases, whatever the electrical system feed source. In the worst case of a bus transfer from the UATs to the RAT with a single lost phase, the transformers will be tripped immediately with load pickup. Therefore, the plant motors will remain unharmed as a result of actions by their individual protection devices such that they will be available as soon as the lost phase is repaired or the plant emergency diesel generators are started and connected.

Since the ABWR does not require offsite supplied electric power for safety, the problem identification and repair has no significant time constraints. Additionally, the Combustion Turbine Generator can also provide the ABWR with an onsite alternate AC power to the Divisional buses. Furthermore, the AC-Independent Reactor Core Isolation Cooling (RCIC) System also can be utilized to ensure the core is adequately cooled for at least 8 hours with no AC power available.

ABWR DCD Tier 2 COL Item 8.3.4.9 also requires that at least one of the three divisional buses of Figure 8.3-1 be fed by the alternate power source (RAT) during normal operation, in order to prevent simultaneous de-energization of all divisional buses on the loss or degradation of only one of the offsite power supplies. The size of the RAT is sufficient to power all three of the Divisional buses in the event that the normal preferred power source is lost.

The protective relays used to monitor normal and alternate offsite power will typically include IEEE device Types 46 and 27 to continuously monitor for a specific fraction (normally close to zero) of negative to positive sequence current (phase imbalance) or individual phase abnormal voltage and are programmed to alarm through the Instrumentation and Control alarm management system (detected hard faults will result in alarms and trips). No special surveillance is necessary.

As with all faults and electrical system alarms, the operator is expected to determine the cause of the event, appropriately align the electrical system, ensure plant safety, and arrange to have the problem corrected. Most single phase electrical system faults and alarms will not adversely affect plant operation, allowing for reasonable times to repair and correct a condition. If the plant remains on-line, there should be no reason for the operator to operate the plant differently while awaiting repairs. Design features of the ABWR ensure that no internal or external plant high-voltage, medium-voltage, or low-voltage faults or alarms should adversely affect the ABWR safety-related buses or challenge the ability of the plant operator to bring the plant to a safe shutdown condition. As with other monitoring and alarms, operator actions will be addressed as part of the development of procedures described in DCD Tier 2 Section 13.5.

Summary of Monitoring and Alarms Design Features

The ABWR design complies with GDC-17 for two physically independent circuits of offsite power. Whether offsite or within the plant electrical system, a fault in the normal preferred high or medium voltage power circuits would result in an automatic transfer to the alternate preferred power circuit. Using protective relays, the UAT and RAT transformers are monitored and alarmed. These signals are communicated to the Main Control Room in the event of a loss of phase condition on either side of the transformers, allowing detection of a loss of phase in the high-voltage electrical system as is the expectation of NRC Bulletin 2012-01.

Because the ABWR offsite and onsite high and medium voltage circuits will be monitored and alarmed in the Main Control Room, operators can take manual action, as necessary, and initiate corrective actions to address a loss of phase condition.

For ease of reading the GEH RAI responses has been broken into Parts 1-3.

NRC Request for Additional Information 08.02-1, Part 1:

Describe the protection scheme design for important to safety buses to detect, alarm, and automatically respond to the following open circuit conditions on credited offsite power circuits:

> *(1) Loss of one of the three phases of the offsite power circuit on the high voltage side of a transformer connecting a GDC-17 offsite power circuit to the transmission system under all operating electrical system configurations and loading conditions with a high impedance ground fault condition under all loading and operating configurations.*
>
> *(2) Loss of one of the three phases of the offsite power circuit on the high voltage side of a transformer connecting a GDC-17 offsite power circuit to the transmission system under all operating electrical system configurations and loading conditions without a high impedance ground fault condition under all loading and operating configurations.*
>
> *(3) Loss of two of the three phases of the offsite power circuit on the high voltage side of a transformer connecting a GDC-17 offsite power circuit to the transmission system under all operating electrical system configurations and loading conditions under all loading and operating configurations.*

GEH Response to RAI 08.02-1, Part 1:

The important to safety buses for the ABWR are the three 6.9 kV divisional buses; Division I (E), Division II (F), and Division III (G) 6.9 kV safety-related buses. Text will be added to DCD Tier 2 Section 8.3.1.1.6.3 to indicate that nonsafety-related supply

breakers from buses A4, B4, and C4 supplying power from the UATs (normal preferred offsite power) to the three 6.9 kV divisions provide for protection against loss of phase events as well as other protective functions.

Additionally, DCD Tier 2 Figure 8.3-1 and Section 8.3.1.1.6.3 will be revised to indicate a new stub bus (H) with three nonsafety-related breakers supplying power from the RAT (alternate preferred offsite power) to the three 6.9 kV divisional buses; Division I (E), Division II (F), and Division III (G) 6.9 kV safety-related buses. The new H1, H2 and H3 nonsafety-related breakers providing power to the three divisional buses will protect against loss of phase events, as well as abnormal voltage and frequency and, after appropriate time delays, the protective relays will command them to trip open disconnecting the 6.9 kV supply from the RAT.

NRC Request for Additional Information 08.02-1, Part 2:

2. *If the important to safety buses are not powered by offsite power sources during at power condition, explain how surveillance tests (e.g., SR 3.8.1.1) are performed to verify that any of the open circuit conditions described above is detected.*

GEH Response to RAI 08.02-1, Part 2:

The three divisional buses (safety-related) are normally powered from either the normal or alternate preferred (offsite) power source. Therefore, a response to this question is not required.

NRC Request for Additional Information 08.02-1, Part 3:

3. *Describe the plant operating procedures including off-normal operating procedures, specifically call for verification of the voltages on all three phases of the ESF buses.*

GEH Response to RAI 08.02-1, Part 3:

Plant operating procedures will be developed prior to plant startup and operation according to provisions of DCD Tier 2 Section 13.5 and Chapter 18 and will include how the operators respond to a loss of phase event.

Impact on DCD:

As described above, changes are proposed for the ABWR DCD, Revision 6, and are described below. Actual markups are in Enclosure 2.

1) Reference to IE Bulletin 2012-01 will be added to Tier 2, Table 1.8-22 (IE Bulletins)

2) Tier 2, Section 8.2.4.6, "Monitoring and Protection Against Design Vulnerabilities," will be added to state:

   The COL applicant shall describe the monitoring and protection scheme for the high voltage side of the UATs and RAT to protect against the concerns raised by NRC Bulletin 2012-01, Design Vulnerability In Electric Power System (Reference 8.2-3).

3) NRC Bulletin 2012-01 will be added to Tier 2, Section 8.2.6, References

4) Tier 2, Section 8.3.1.1.6.3, Bus Protection, Item (1) will be modified to state:

   (1) 6.9 kV bus incoming circuits have inverse time over-current, ground fault, bus differential and under-voltage protection. The undervoltage monitoring is responsive to all three phases. The monitoring is effective for both load shedding and emergency diesel start and protection of the safety-related bus loads for grounds and loss of one or more phases.

5) Tier 2, Section 8.3.1.1.6.3 Item (6) will be added

   (6) Nonsafety-related busses A4, B4, C4 and the new H bus are monitored by their own protective relays and will trip power to the safety-related buses on detection of abnormal voltages and frequency, including loss of one or more phases and ground conditions.

6) Tier 2, Figure 8.3-1 will be modified to show the addition of Bus H with H1, H2, and H3 breakers from the second winding of the RAT to the Division I, II, and III buses.