Enclosure 1

MFN 13-040

GEH Response to RAI 8.1-22

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Question Summary:

The staff's question is in regard to the ESBWR design basis and ITAAC information in view of the design vulnerability identified in NRC Bulletin 2012-01, "Design Vulnerability in Electric Power System."

Full Text:

General Electric-Hitachi (GEH) Nuclear Energy on Economic Simplified Boiling-Water Reactor Design Control Document (DCD) Section 8.1.5, "Design Basis," Revision 9, Chapter 8, Electrical Power states:

> *The offsite power system is designed to provide a continuous source of power to the onsite power system throughout plant startup, normal operation (including shutdown), and abnormal operations.*
>
> *AC safety-related loads are powered by four physically separate and electrically independent divisions. Any two out of four divisions can safely shut down the unit and maintain it in a safe shutdown condition.*

DCD 2.13.1, "Electric Power Distribution System," Revision 9 states:

> *The Plant Investment Protection buses also supply power to the four (4) safety-related, 480VAC, Isolation Power Center buses and the two (2) ancillary diesel buses. The nonsafety-related PIP buses and ancillary diesel buses have a function to supply power to RTNSS credited loads.*

DCD 4.2, "Interface Requirements," of "Offsite Power," states:

> *A combined license applicant referencing the ESBWR certified design shall develop an ITAAC to verify that the as-built offsite portion of the PPS [Preferred Power Supply] from the transmission network to the interface with the onsite portions of the PPS satisfy the applicable provisions of GDC 17.*

GEH stated the following in a public meeting dated June 6, 2013, regarding the design basis of offsite power circuits to provide adequate capacity and capability for important to safety systems in view of the design vulnerability identified in NRC Bulletin 2012-01," Design Vulnerability in Electric Power System."

> *Because the ESBWR offsite and onsite high and medium voltage circuits will be monitored and alarmed in the Main Control Room, operator manual action can address an issue and take actions to maintain power to nonsafety-related plant loads in the unlikely event that the automatic logic did not maintain power continuity (safety-related plant loads are continuous without operator action).*
>
> *ESBWR detailed design already includes plans and requirements documents for detection and alarms of three phases of AC power.*

No further action is necessary for ESBWR design capabilities to address NRC Bulletin 2012-01.

GEH is requested to provide the design basis (Chapter 8, Tier 2) and ITAAC information (Chapter 2, Sections 2.13 and 4.2, Tier 1) in accordance with § 52.47, "Contents of applications; technical information," for the Electrical Engineering Branch staff to determine whether it meets the 10 CFR 50 Appendix A, GDC 17, "Electric power systems," requirements regarding the offsite power circuits and onsite electrical power distribution system to provide adequate capacity and capability in view of the design vulnerability identified in NRC Bulletin 2012-01," Design Vulnerability in Electric Power System." The design bases and ITAAC information for interface requirement submitted should include, as a minimum, design details to automatically detect and alarm in the main control room for a single-phase open phase condition (with or without a ground), on the high voltage side of a transformer connecting a GDC-17 offsite power circuit to the transmission system. The information should have sufficient details for the combined operating license applicants to complete the detailed design (e.g., location of relays) and analyses (e.g., setpoints) in final safety analysis report in accordance with § 52.79, "Contents of applications; technical information." In addition, GEH is requested to provide the delineation of scope between the DCD and COL applicants in regards to the bulletin. GEH is also requested to provide information regarding the adequacy of electric power system design as stated above (GEH DCD Section 8.1.5 and DCD Sections 2.13.1 and 4.2) in view of the single-phase open phase issue.

GEH Response

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.

In an NRC presentation in a public meeting held on June 27, 2013, the NRC indicated that passive designs remain subject to GDC-17 requirements in the event of a degraded condition (ML13169A330). Therefore, passive plants need 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). For passive designs, plant procedures would specify actions to restore the offsite power source to a functional condition. As explained below, the ESBWR Design Control Document (DCD) will be revised to address these elements for the passive ESBWR standard design certification. First is a description of the electrical system design, as described in the ESBWR DCD.

DCD Description of Electrical System Design

The ESBWR DCD, Tier 2, Chapter 8, describes the electrical system design. Protective relaying in the switchyard is described in Section 8.2.1.2.1, and Section 8.3.1.1 explains that main power transformers, UATs, and RATs have protective devices for overcurrent, differential current, ground overcurrent, and sudden overpressure. COL Information Items are listed in Section 8.2.4. The ESBWR 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

As GEH explained during the public meeting June 6, 2013, the ESBWR detailed design approaches are already in the planning stages and will be specified in one or more technical requirement document(s) for the ESBWR electrical systems architecture and design. Also, as GEH explained, the ESBWR electrical systems architecture and design has anticipated and addresses the concerns and issues presented in NRC Bulletin 2012-01. Monitoring for the switchyard is discussed in the ESBWR DCD, Tier 2, Section 7.1.5.2.5, although this section does not describe the extent or parameters monitored.

In order to document that loss of a single phase offsite high voltage power condition monitoring will be part of the ESBWR certified design or standard plant design, information describing the design features for monitoring and alarms for detecting one or more loss of phase offsite high voltage power condition will be added to the ESBWR DCD, Tier 2, Chapter 8, in a new Section 8.2.1.2.2, which is included in an attached mark-up of the DCD. In addition, ITAAC that verify the monitoring and alarms are implemented and function will be added to the ESBWR DCD, Tier 1, Section 2.13.1. These DCD changes will be included in Revision 10 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 3.3, as part of the Human Factors Engineering process.

Because these changes will become part of the ESBWR certified design or standard plant design, verified through Tier 1 ITAAC, no additional COL Information Items or interface items are necessary.

Description of the Protection Design Features not included in DCD

This section explains the design features of relays that provide for monitoring and alarms for detecting the loss of a single phase in the electrical system 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 ESBWR electrical system is protected against faults and abnormal conditions by Digital Protective Relays (DPR). Depending on the DPR type, these relays are capable of providing most of the standard IEEE C37.2 specified device functions. For example:

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

Unlike past practice where one physical relay was required for each type of protection, the DPR 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 approved 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.
- The relays can be networked using data links 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 buss 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 in that 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 DPRs are used to implement the protective relaying philosophy of the ESBWR which can be summarized as follows:

- All faults will be interrupted using a breaker as close as possible to the fault.
- 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 electrical system and protective relaying will be configured such that a single failure or fault will not cause a plant trip.
- The scope of electrical system protection includes the following plant equipment:
    - main generator, main generator transformer, and generator breaker
    - unit auxiliary transformer (UAT), reserve auxiliary transformer (RAT), and high side isolation breakers
    - medium voltage buses and associated switchgear
    - low voltage buses and associated switchgear
    - standby diesel generator (SDG) and ancillary diesel generator (ADG)
- Only the ESBWR plant specific protective relays can directly trip breakers within the scope of the plant’s electrical system.

The ESBWR DPRs are assigned a safety-related classification commensurate with the safety function. Safety-related DPRs, which include both digital hardware and software, are qualified appropriately for the electrical bus function(s) they are supporting. There are three safety-related classifications and associated quality assurance levels for combined digital hardware and software equipment which are:

- Class “Q” for safety-related digital hardware and software.
- Class “S” and “N3” for RTNSS or active cold safe shutdown digital hardware and software, respectively.
- Class “N” and N2” for nonsafety-related digital hardware and software, respectively.

Two representative examples of these safety-related classifications and associated quality assurance levels are the following:

- PIP/RTNSS electrical bus circuit breakers and DPRs are assigned Class “S” and “N3” levels.
- Nonsafety-related power generation breakers and digital protective relays are assigned Class “N” and N2” levels.

The ESBWR DPRs are redundantly powered by both plant batteries and uninterruptible power systems because the relays support both monitoring and alarming functions in addition to their protection function. The relays serve as electrical system “sensors” in that they can provide their measurements to the N-DCIS over digital data communication networks or data links.

The ESBWR 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 ESBWR 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 digital protective relays. There will be instances whereby the following conditions exist:

- Internal plant DPRs must provide trip and control information to external circuit breaker trip units or protective relays.
- External relays must provide trip information to internal plant relays.

Examples of these conditions are the following:

- Internal plant DPRs providing control information to external equipment will provide ESBWR trip or closing commands to the switchyard breakers used to isolate a high-voltage cable fault or when synchronizing with the transmission grid.
- External trip commands to the UAT breakers used to isolate the plant from switchyard or high-voltage cable faults.

The trip and control information needed to protect the external and internal plant electrical systems is provided by discrete (i.e.; open or close) signals using hard wiring or data communications using optical fiber. The external protective relaying does not have data link access to the ESBWR plant internal digital protective relaying networks for cyber security reasons. Additionally, the external protective relaying has no direct access to the ESBWR plant internal electrical system circuit breaker trip units. Such system interfaces are only through and supervised by the ESBWR plant digital protective relaying.

These interfaces are already provided for in the COLA through DCD COL Information Item COL 8.2.4-8-A and will be considered in further development of detailed design.

Note that the ESBWR passive design also influences the electrical system protection philosophy. The protective relaying is designed to preserve the electrical system, including the diesel generators, and protect them from damage. Where there is a conflict, the system is not designed to provide continuity of electricity because the ESBWR does not require offsite preferred power or onsite generated AC power for assuring safety-related equipment functionality. Additionally, the digital protective relaying is not relied upon to provide power to or protect the four divisional safety-related low voltage electrical buses. Those low voltage electrical buses are protected by the design of the safety-related inverters and battery chargers, which will separate from onsite or offsite AC power, whenever abnormal conditions are detected, to allow the safety-related 72-hour batteries to supply the safety buses. Specifically due to the ESBWR passive design, no plant safety-related function is adversely affected by the status of onsite or offsite nonsafety-related electric power including the loss of a single phase with or without an accompanying fault to ground.

Description of the Monitoring Design Features

The ESBWR Q-DCIS and N-DCIS 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 isolation power center 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.

- Each of the normal and alternate high voltage power feeds to the UATs and RATs
- A1, B1, A2, B2 13.8 kV buses
- A3 and B3 6.9 kV buses
- A4, B4, C4 6.9 kV buses
- 480 VAC FMCRD power center buses
- 480 VAC isolation power center buses
- 480 VAC nonsafety-related inverter output buses

The eight (i.e.; one per inverter) 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 ESBWR certified design or standard plant design monitoring is included in the digital protective relay monitoring of the high-voltage power feeds to the UATs and RATs for transformer protection purposes. Note that most of the plant electrical system monitoring is done by the DPR and sent to the N-DCIS through digital data communications or data links. For example, the DPR 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 (e.g.; 13.8 kV and 6.9 kV) of the transformers. This information is also available through the data links for monitoring and alarming purposes. The data links will also provide additional information, such as real and apparent power, VARs, power factor, energization time, and relay self-diagnostics.

Where DPRs are not used, generally for the safety-related buses, individual instruments, sensors, or transducers are used.

<u>Description of the Specific Monitoring Concerns</u>

The ESBWR 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 N-DCIS such that they can be continuously monitored and alarmed, so no specific surveillance is required. The ESBWR electrical system and protective relaying configuration is such that no single failure will cause a plant trip.

Most of the monitoring is straightforward. However, two specific kinds of measurements provide ESBWR 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 PIP/RTNSS 6.9 kV or ancillary diesel generator 480 VAC electrical buses that, after appropriate time delays, will command the start of the diesel generator(s). Similarly, the isolation power centers driven by the PIP/RTNSS electrical buses are protected against abnormal voltage and frequency and, after appropriate time delays, the digital protective relays will command them to separate from the 6.9 kV electrical buses. This protection is independent of the ability of the safety-related inverters and battery chargers to protect the four divisional safety-related electrical buses by separating themselves from their isolation power centers.

The second type of measurement includes monitoring and alarming for the availability of the normal and preferred ESBWR offsite power sources. As previously stated, the UATs (i.e.; normal preferred offsite power) and RATs (i.e.; alternate preferred offsite power) are protected by digital protective relays using voltage and current measurements on both the primary (i.e.; high voltage) side and secondary (e.g.; 13.8 kV and 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 transformer (e.g.; RAT); therefore, the digital protective relays will only generate an alarm for that case. Hard single phase faults, which are the most common type, will always be detected. In all cases, there is nearly no potential for individual load equipment (e.g.; motor) damage because their individual digital 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 RATs 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 diesel generators are started and connected. Since the ESBWR does not require either offsite or diesel generator supplied electric power for safety, the problem identification and repair has no significant time constraints.

The DPRs 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 N-DCIS 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 and, thus, allow 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. In any case, due to the passive design features of the ESBWR, no internal or external plant high-, medium-, or low-voltage faults or alarms should adversely affect the ESBWR safety-related buses or challenge the 72-hour post-accident period when no operator or no onsite or offsite generated electricity is assumed, if a design-basis accident were to occur while corrective actions are still ongoing. 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 ESBWR 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 digital 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 ESBWR 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.

Impact on DCD

As described above, changes are proposed for the ESBWR DCD, Revision 10, which will be as shown on the attached mark-ups.