UNITED STATES
NUCLEAR REGULATORY COMMISSION
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April 2, 2013

MEMORANDUM TO: Sher Bahadur, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

FROM: Terrence Reis, Director ***/RA: Harold O. Christensen for/***
Division of Reactor Safety

SUBJECT: TASK INTERFACE AGREEMENT – ASSESSMENT OF WATTS BAR NUCLEAR PLANT, UNIT 1, EVALUATIONS THAT ADDRESS THE EFFECT OF AC WAVEFORM HARMONIC DISTORTION ON DEGRADED GRID VOLTAGE RELAY FUNCTION AND THE APPLICABILITY OF 10 CFR 50, APPENDIX B REQUIREMENTS (TIA 2012-14)

INTRODUCTION

This task interface agreement (TIA) documents Region II's position that harmonic distortion of the AC waveform on Class 1E electrical distribution buses could result in the premature reset of the degraded voltage relays at the Watts Bar Nuclear Plant (WBN), Unit 1, during a degraded voltage event. Harmonic-induced reset of the degraded voltage relays (DVRs) and associated timers during the onset of such an event would: (1) prevent the relays from actuating within the time required by technical specifications, (2) represent a condition adverse to the quality of relay operation, and (3) be subject to treatment in accordance with the requirements of 10 CFR 50, Appendix B. Concurrence of this memo by the electrical engineering branch in the Office of Nuclear Reactor Regulation (NRR) indicates their review and approval of Region II's regulatory position.

BACKGROUND

During the Component Design Basis Inspection (CDBI) completed on May 15, 2012, at WBN (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12165A186), the inspection team identified an unresolved item (URI) regarding the effect of electrical system harmonics on DVR function. The item was unresolved pending receipt and review of additional information from the Tennessee Valley Authority (TVA) (licensee) on the specific design and licensing bases of degraded voltage protective features for WBN and additional consultation with NRR.

The WBN degraded voltage protection scheme features three Asea Brown Boveri (ABB) type 27N relays for each 6.9 kilovolt (kV) safety bus, arranged in a two-out-of-three tripping scheme. The ABB instruction bulletin 7.4.1.7-7 contained in vendor manual WBN-VTD-AS04-0080 states that (1) the relay employs a peak voltage detector, and (2) harmonic distortion on the AC waveform can have a noticeable effect on the relay operating point and the measuring instruments used to calibrate the relay. The bulletin also notes that the relay is available with an

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internal harmonic filter for applications where waveform distortion is a factor. The team observed that calculation WBPE2119202001, "6.9kV Shutdown & Logic Boards Undervoltage Relay Requirements/Demonstrated Accuracy Calculation," identified the relay as a model not equipped with a harmonic filter, but did not address the basis for excluding harmonic distortion as a factor which affected relay accuracy. NRC Information Notice (IN) 95-05, "Undervoltage Protection Relay Settings Out of Tolerance due to Test Equipment Harmonics," states, in part: "Although the peak detector circuit is very accurate, it is sensitive to harmonic distortion," and that "the relay operating point is significantly influenced by its peak voltage detection circuitry. Therefore, if the voltage test source power supply is not included in a calibration program, the digital voltmeter (DVM) may not accurately reflect the setpoint of the solid-state relay."

During the inspection, the licensee provided corrective action program documentation related to a 1993 event where maloperation of the electrical distribution system overvoltage relays occurred due to harmonic distortion of the AC waveform at WBN, Unit 1. Specifically, problem evaluation report (PER) 930397 (Enclosure 2) addressed spurious actuations of the ABB type 59H overvoltage relays which are similar in design to the ABB type 27N DVRs. Troubleshooting tests performed to identify the cause of the 59H spurious actuations revealed total harmonic distortions greater than 10 percent on the 6.9 kV system's AC waveform. The transient harmonics documented in PER 930397 were attributed to events that included the trip of the nearby Sequoyah generating station, and to local breaker operations at WBN. The 'causal factor' section of PER 930397 stated that the relays sometimes trip on harmonic distortion although the root mean square (RMS) voltages are at acceptable levels. Corrective actions consisted of replacing the type 59H overvoltage relays with a model equipped with harmonic filters. The 'extent of condition' section of PER 930397 did not identify or address whether the DVR's operating point could also be affected by the same harmonics implicated in the maloperation of the overvoltage relays.

The inspection team was concerned that transient harmonics similar to those observed to occur at WBN could cause the DVRs to spuriously reset during an actual degraded voltage event, thereby delaying the protective function beyond the 10 seconds stipulated in technical specification limiting condition for operation. The DVR's design features an 'instantaneous' reset characteristic that could allow reset of the DVR in less than two cycles in the presence of harmonics, thereby reinitiating the external 10 seconds timer. The reset function of the existing DVRs is identical to the tripping function of the overvoltage relays that actuated due to transient harmonics in 1993. The team noted that similar conditions could exist during load shedding and sequencing in response to an accident scenario when proper performance of the degraded voltage scheme time delay would be critical with respect to satisfying the response time assumptions in the accident analysis.

Additionally, the team noted that during normal bus voltage conditions when voltage is above the DVR reset setpoint, harmonics would shift system peak voltage away from the DVR operating setpoint rather than closer to it, and so the presence of harmful harmonics would not 'self-reveal' by spurious actuations. The type 59H overvoltage relays are now equipped with harmonic filters so they will also not reveal the presence of either transient or persistent harmonics.

THE LICENSEE'S POSITION

The licensee has concluded that harmonic distortion of the AC waveform on class 1E power supplies at WBN is beyond the design and licensing basis of the facility and, therefore, any adverse impact(s) that harmonics may have on the safety function of the DVRs do not require an evaluation of relay operability or other corrective actions. The licensee's position is

described by a position paper provided to the NRC in response to the inspector's concerns (reference Enclosure 3).

NRC STAFF EVALUATION

The NRC staff participated in several discussions with the licensee to ensure understanding of their position and to communicate the NRC position. The NRC staff reviewed the licensee's evaluation of the issue as documented in PER 546072. Additionally, the NRC staff reviewed the licensee's position paper provided to the NRC on September 27, 2012 (Enclosure 3). The following positions from this document have been evaluated by the NRC staff, as follows:

1. Cause as Relay Calibration

The licensee's response stated:

> *"The vendor of the ITE27N undervoltage relays recommended that a Doble test source certified to have less than 0.3% Total Harmonic Distortion (THD) be used to calibrate the relays. For consistency and repeatability, the ITE59H overvoltage relays were calibrated with the same source. The "low harmonic distortion," test source lowered the setpoint of all but one ITE59H relay by 0.7 to 2.68 volts. This was the most likely cause of the 6.9kV shutdown board overvoltage relay actuations which occurred despite the overvoltage relay setpoint not being reached."*

Evaluation:
PER 930397 Tab "A", Paragraph 1 discussed a recent calibration of the ITE59H relays using a low harmonic distortion Doble test set. It stated that the setpoint had been lowered on all but one of the relays by 0.7 to 2.68 volts (V). Lowering the setpoint would make the relays more susceptible to spurious tripping but the PER noted that none of the alarms occurred when system voltage was actually above the relay setpoint. Paragraph 2 noted that voltage spikes that occurred on 12/3/93 to 120.3V to 120.6V did not trigger the 121V alarm, but a later spike to 118.6V did result in an alarm. The PER noted that the earlier non-alarm spikes were accompanied by relatively low system THD (0.2 percent to 0.5 percent) whereas the later spike was accompanied by high THD (10.3 percent to 10.7 percent). The PER concluded that the lower setpoint made the relays more likely to operate during transients that cause harmonic distortion along with voltage levels at the upper end of the load tap changer (LTC) bandwidth. Causal Factor C4 stated that the relays sometimes trip on harmonic distortion although bus RMS voltages are at acceptable levels, and identified the cause as improper component selection, i.e., relays susceptible to harmonic distortion, and not calibration issues or actual overvoltage conditions. The corrective action implemented was to replace the relays with models equipped with harmonic filters. No corrective actions were taken involving adjusting the trip setpoints further away from system operation voltages, but the spurious overvoltage alarms have ceased. Consequently, the suggestion that the overvoltage alarms were caused by lowering the relay setpoints was specifically contradicted by the PER and its supporting data.

2. Effect of Voltage Fluctuations

The licensee's response stated:

> *"A degraded grid event will likely produce voltage fluctuations which are caused by automatic protection in the transmission system (e.g. line switching, load shedding,*

generator tripping, etc.). These voltage fluctuations may be indicative of a recovering grid or they may be short-lived and only last a few seconds or less. The voltage spike scenario proposed during the 2012 CDBI at WBN would have the same effect as RMS voltage fluctuations due to a degraded voltage event; namely, to reset the DVRs."

Evaluation:
Voltage fluctuations may be present during an event. By "RMS" fluctuations, WBN is referring to variations in the magnitude of the fundamental 60Hz voltage. Perturbations in the electrical system will result in momentary variations of the fundamental 60Hz voltage and could potentially reset a degraded voltage relay that was actuated due to a real degraded condition. However, the experience at WBN, Unit 1, indicates that the spurious operation (detecting momentary over voltage condition) of the ABB 59H relays was related to harmonic distortion generated by switching surges. Filtering the sub-harmonic component of the perturbation reduced or eliminated the spurious actuation of the 59H relays. Similarly, switching surges or other system perturbations that result in generation of sub-harmonics in the electrical system can result in false resetting the undervoltage relays that are similar in design and use similar sensing circuits as the 59H relays. Thus, the ITE27N degraded voltage relays are susceptible to spurious reset during sustained under voltage conditions with harmonic distortion. The false reset of the 27N relay may have adverse impact on any operating safety related equipment required to mitigate the consequences of an event and also preclude transfer of the safety busses to the onsite power system.

3. Reset Time Delay

The licensee's response noted in several instances that typical industry design and NRC guidance does not call for a purposeful reset time delay:

Evaluation:
The URI noted that the DVRs had an instantaneous reset feature. This was not described in the URI as a design deficiency. The failure to evaluate the susceptibility of the degraded voltage relay to system harmonics was considered the deficiency

4. Licensing Basis

The licensee's response stated that the scenario discussed in the URI, concurrent LOCA with a degraded voltage condition, is not consistent with the WBN licensing basis. It states that the design basis scenario described in Branch Technical Position (BTP) PSB-1 is a degraded voltage event followed by a subsequent LOCA.

Evaluation:
The BTP PSB-1 describes how the degraded voltage scheme should react to a degraded voltage followed by a LOCA but does not define this as the limiting design basis scenario. Regulatory Issue Summary (RIS) 2011-12, "Adequacy of Station Electric Distribution System Voltages," notes that the basis for degraded voltage protection requirements is 10 CFR Part 50, Appendix A, Criterion 17 (GDC-17) which requires transfer to the onsite power system if the offsite system is not available, e.g., if it is degraded. The RIS discusses various findings at other plants where degraded voltage protection was not available during an accident. In particular, the RIS states:

"The DVR design should protect (ensure voltage requirements are met) Class 1E

safety-related buses and components from sustained degraded voltage conditions on the offsite power system coincident with an accident as well as during non-accident conditions."

The scenario described in the URI is consistent with GDC-17, as clarified in RIS 2011-12.

The licensee has stated in their response, as documented in Enclosure 3:

"The WBN DVR scheme is purposely designed to reset immediately anytime voltage recovers above the reset setpoint in order to favor offsite power, which is the preferred power supply in accordance with Chapter 8 of the WBN UFSAR, as discussed above.

This is a typical industry design that does not introduce any purposeful time delay into the reset function. Neither industry standard IEEE: 741-2007 or NRC BTP PSB-1 call for any reset time delay. The DVR scheme at most nuclear stations would reset in this manner in order to prevent an unnecessary LOOP, which is a major contributor to core melt risk."

While the NRC staff agrees that the design reset of the DVRs in response to a momentary degraded voltage event allows the electrical distribution system to favor the preferred offsite power supply, the staff is concerned that the response still fails to address the unresolved item where an unintended reset of DVR timer due to harmonic distortion during a sustained (i.e., longer than momentary) degraded voltage condition would prevent safety related equipment from receiving adequate power to perform safety functions necessary to mitigate a design basis event (from either the preferred or emergency sources of power). Additionally, an engineered safety feature actuation system (ESFAS) actuation of safety related equipment under degraded voltage conditions could result in damage to the equipment and significantly complicate event mitigation and recovery. The NRC staff also notes that the 10 second time delay associated with actuation of the DVR is 'purposeful' in that it is required by plant technical specifications and, in part, establishes operability requirements for the DVRs.

Additionally, the licensee stated in their response, as documented in Enclosure 3:

"The design basis scenario described in BTP PSB-1 is a degraded voltage event followed by a subsequent LOCA. In this scenario, the LOCA occurs after the DVR time delay, and power to the 6.9kV shutdown boards is immediately transferred from offsite power to the onsite EDGs. It should be noted that even though the WBN DVR scheme is designed in accordance with BTP PSB-1, which allows a time delay of limited duration for operators to restore adequate voltage, it will transfer power to the 6.9kV shutdown boards immediately (after the nominal 10-second time delay) even without a LOCA occurring. This design conservatively favors transfer to the EDGs for sustained degraded grid voltage events. If a LOCA occurs during the 10-second time delay period, the WBN design would also transfer the source of power to the 6.9kV shutdown boards immediately after the 10-second time delay."

The NRC staff does not agree with the licensee's interpretation of BTP PSB-1 that the design basis scenario is narrowly defined by a degraded voltage event followed by a subsequent LOCA. The NRC staff is concerned that such an interpretation would not be consistent with the design requirements contained in GDC-17. The NRC staff does not find any evidence to support that BTP PSB-1 communicated a more narrow or altered interpretation of the design basis scenario in the context of degraded voltage design.

CONCLUSION

Based on the above, the NRC staff concludes that harmonic distortion of the AC waveform on Class 1E electrical distribution buses (similar in nature to those that were actually observed to occur at WBN in 1993) could result in the premature reset of the DVRs during a degraded voltage event. Harmonic-induced reset of the DVRs (and associated timers) during the onset of such an event would: (1) prevent the relays from actuating within the time required by technical specifications, (2) represent a condition adverse to the quality of relay operation, and (3) be subject to treatment in accordance with the requirements of 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." Furthermore, the NRC staff concludes from the information contained in PERs 930397 and 546072 that WBN has not taken adequate action to (1) identify and evaluate harmonic distortion of the AC waveform as a condition adverse to DVR quality and (2) evaluate the impact of harmonics on DVR operability. Additionally, the NRC staff concludes that the licensee has not provided sufficient objective evidence to support the conclusion that harmonics are "beyond the design bases" of WBN. Therefore, the licensee should take actions to address the adverse condition consistent with the requirements of 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," and evaluate the operability of the DVRs in a manner consistent with the guidance provided by NRC Inspection Manual Part 9900 Technical Guidance, "Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety." In addition, the NRC is evaluating the issue generically. If it is determined that additional licensees are affected, the staff will pursue notification via generic communication.

REFERENCES

1. NRC Inspection Manual Part 9900 Technical Guidance, "Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety," (ADAMS Accession No. ML081360529).
2. Watts Bar Nuclear Plant, Unit 1, NRC Component Design Basis Inspection Report 05000390/2012008, (ADAMS Accession No. ML12165A186).
3. Information Notice 95-05, "Undervoltage Protection Relay Settings Out of Tolerance Due to Test Equipment Harmonics," (ADAMS Accession No. ML031060397).

Docket No.: 50-390
License No.: NPF-90

Enclosures:

1. Watts Bar Nuclear Experience Review (NER), NER 950161, "IE Notice 95-005, Under Voltage Protection Relay Settings Out of Tolerance Due to Test Equipment Harmonics 2", dated April 27, 1995. (ADAMS Accession No. ML13092A334)
2. Watts Bar Problem Evaluation Report (PER), PER 930397, "Overvoltage condition on 6.9 kV Shutdown Boards," dated October 8, 1995. (ADAMS Accession No. ML13092A343)
3. Watts Bar Position Paper, "Watts Bar Nuclear Plant 2012008-004 Degraded Voltage Relay Issue Response", dated September 27, 2012. (ADAMS Accession No. ML13092A347)

Memo to Sher Bahadur from Terrence Reis dated April 2, 2013.

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