U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

BRANCH TECHNICAL POSITION (BTP) 8-6

ADEQUACY OF STATION ELECTRIC DISTRIBUTION SYSTEM VOLTAGES

REVIEW RESPONSIBILITIES

Primary - Organization responsible for electrical engineering

Secondary - None

A. BACKGROUND

Events at the Millstone station have shown that adverse effects on the Class 1E loads can be caused by sustained low grid voltage conditions when the Class 1E buses are connected to offsite power. Loss-of-voltage relays, which generally have a low-voltage pickup setting in the range of .7 per unit voltage or less, will not detect these low-voltage conditions. See Reference 2 for further background information regarding these events.

The Millstone events also demonstrated that improper voltage protection logic can itself cause adverse effects on the Class 1E systems and equipment, such as spurious load shedding of Class 1E loads from the standby diesel generators and spurious separation of Class 1E systems from offsite power resulting from normal motor starting transients.

An event at the Arkansas Nuclear One station and the subsequent analysis performed disclosed the possibility of degraded voltage conditions existing on the Class 1E buses, even those with normal grid voltages, as a result of deficiencies in equipment between the grid and the Class 1E buses or by the starting transients experienced during certain accident events not originally considered in the sizing of these circuits. See Reference 3 for further background information regarding this event.

Regulatory Issue Summary (RIS) 2000-24 summarizes the staff's concerns about grid reliability challenges that industry deregulation might impose and potential voltage inadequacies of offsite power sources.

NUREG-1793 discusses the interfaces of the AP1000 passive plant design with the offsite alternating current power system. This report also presents assumptions on the performance of the offsite power system following loss of offsite power (LOOP) required for supporting Chapter 15 analyses.

Information Notice IN 2000-06 informed licensees of possible concerns regarding the voltage adequacy of offsite power sources (i.e., power from the transmission system to nuclear power plants). This notice documents specific examples from plant operating experience.

IEEE Std. 741 provides the principal design criteria, design features, and testing requirements for protection of Class 1E power systems and equipment powered from those systems. This standard includes informative sections on degraded voltage protection and protection concerns associated with auxiliary system automatic bus transfer.

B. BRANCH TECHNICAL POSITION

1. In addition to the undervoltage scheme provided to detect LOOP at the Class 1E buses, a second level of undervoltage protection with time delay should be provided to protect the Class 1E equipment. This second level of undervoltage protection should satisfy the following criteria:

    a. The selection of undervoltage and time delay setpoints should be determined from an analysis of the voltage requirements of the Class 1E loads at all onsite system distribution levels.

    b. Two separate time delays should be selected for the second level of undervoltage protection based on the following conditions:

        i. The first time delay should be long enough to establish the existence of a sustained degraded voltage condition (i.e., something longer than a motor-starting transient). Following this delay, an alarm in the control room should alert the operator to the degraded condition. The subsequent occurrence of a safety injection actuation signal (SIAS) should immediately separate the Class 1E distribution system from the offsite power system. In addition, the degraded voltage relay logic should appropriately function during the occurrence of an SIAS followed by a degraded voltage condition.

        ii. The second time delay should be limited to prevent damage to the permanently connected Class 1E loads. Following this delay, if the operator has failed to restore adequate voltages, the Class 1E distribution system should be automatically separated from the offsite power system. The bases and justification for such an action must be provided in support of the actual delay chosen.

c. The voltage sensors should be designed to satisfy the following applicable requirements derived from IEEE Std. 279 and/or IEEE Std. 603, as endorsed by RG 1.153:

i. Class 1E equipment should be used and should be physically located at and electrically connected to the Class 1E switchgear.

ii. An independent scheme should be provided for each division of the Class 1E power system.

iii. The undervoltage protection should include coincidence logic on a per bus basis to preclude spurious trips of the offsite power source.

iv. The voltage sensors should automatically initiate the disconnection of offsite power sources whenever the voltage setpoint and time delay limits (cited in item 1.b.2 above) have been exceeded.

v. Capability for test and calibration during power operation should be provided.

vi. Annunciation must be provided in the control room for any bypasses incorporated in the design.

d. The technical specifications should include limiting conditions for operations, surveillance requirements, trip setpoints, and maximum and minimum allowable values for the first level of undervoltage protection (LOOP) relays and the second-level (degraded voltage) protection sensors and associated time delay devices.

2. The Class 1E bus load shedding scheme should automatically prevent shedding during sequencing of the emergency loads to the bus. The load shedding feature should, however, be reinstated upon completion of the load sequencing action. The technical specifications must include a test requirement to demonstrate the operability of the automatic load shedding features at least once every refueling outage/cycle.

An adequate basis must be provided if the load shedding feature is retained during the above load sequencing of the emergency loads to the bus.

3. The voltage levels at the safety-related buses should be optimized for the maximum and minimum load conditions that are expected throughout the anticipated range of voltage variations of the offsite power sources by appropriate adjustment of the voltage tap settings of the intervening transformers. The tap settings selected should be based on an analysis of the voltage at the terminals of the Class 1E loads. The analyses performed to determine minimum operating voltages should typically consider maximum unit steady-state and transient loads for events, such as a unit trip, loss-of-coolant accident, startup or shutdown, with the offsite power supply (grid) at minimum anticipated voltage and only the offsite source being considered available. Maximum voltages should be analyzed with the offsite power supply (grid) at maximum expected voltage concurrent with minimum unit loads (e.g., cold

shutdown, refueling). A separate set of the above analyses should be performed for each available connection to the offsite power supply.

4. The analytical techniques and assumptions used in the voltage analyses cited in item 3 above must be verified by actual measurement. The verification and test should be performed before initial full-power reactor operation on all sources of offsite power by taking the following actions:

   a. Loading the station distribution buses, including all Class 1E buses down to the 120/208-volt level, to at least 30 percent

   b. Recording the existing grid and Class 1E bus voltages and bus loading down to the 120/208-volt level at steady-state conditions and during the start of both a large Class 1E and non-Class 1E motor (not concurrently)

      Note: To minimize the number of instrumented locations (recorders) during the motor-starting transient tests, the bus voltages and loading need only be recorded on that string of buses that previously showed the lowest analyzed voltages from item 3 above.

   c. Using the analytical techniques and assumptions of the previous voltage analyses cited in item 3 above, and the measured existing grid voltage and bus loading conditions recorded during conduct of the test, calculate a new set of voltages for all the Class 1E buses down to the 120/208-volt level

   d. Compare the analytically derived voltage values against the test results

   With good correlation between the analytical results and the test results, the test verification requirement will be met. That is, the validity of the mathematical model used to perform the analyses of item 3 will have been established, thereby establishing the validity of the results. In general the test results should not be more than 3 percent lower than the analytical results; however, the difference between the two, when subtracted from the voltage levels determined in the original analyses, should never be less than the Class 1E equipment-rated voltages.

C. REFERENCES

1. Regulatory Guide 1.153, "Criteria for Power, Instrumentation, and Control Portions of Safety Systems."

2. Millstone Unit No. 2, Safety Evaluation Supporting Amendment No. 16 to License No. DPR-65.

3. NRC Summary of Meeting for Arkansas Nuclear One Incident of September 16, 1978, February 9, 1979.

4. IEEE Std. 279-1971, "Criteria for Protection Systems for Nuclear Power Stations."

5. IEEE Std. 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations."

6. NRC Information Notice 2000-06, “Offsite Power Voltage Inadequacies,” March 27, 2000.

7. NRC Regulatory Issue Summary 2000-24, “Concerns About Offsite Power Voltage Inadequacies and Grid Reliability Challenges due to Industry Deregulation,” December 21, 2000.

8. NUREG-1793, “Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design,” September 2004.

9. IEEE Std. 741-1997, “IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations.”
