UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-0001

August 10, 2007

NRC INFORMATION NOTICE 2006-18, SUPPLEMENT 1: SIGNIFICANT LOSS OF SAFETY-RELATED ELECTRICAL POWER AT FORSMARK UNIT 1 IN SWEDEN

ADDRESSEES

All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this supplement to Information Notice (IN) 2006-18, "Significant Loss of Safety-Related Electrical Power at Forsmark Unit 1 in Sweden," to provide additional information regarding the incident that occurred at the Forsmark Nuclear Power Station, Unit 1 (Forsmark-1), involving the loss of several safety-related electrical busses. It is expected that addressees will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

On July 25, 2006, while the plant was operating at full power, a significant event occurred at Forsmark-1, a 1020 Megawatt electric boiling-water reactor designed by ASEA-Atom. The event began in the offsite 400 kilovolts (kV) switchyard, which consisted of two main buses and one transfer bus, during a bus transfer operation being conducted to support maintenance work. However, due to inadequate administrative procedures, the transfer and connection activities were not properly implemented. A disconnect switch that was carrying load was opened which resulted in arcing and a two-phase short circuit at the disconnect switch. The fault was isolated after approximately 400 milliseconds by the remote circuit breakers on two of the outgoing transmission lines. The high-voltage fast-acting bus protection was ineffective during the bus transfer operation.

When the short circuit occurred in the switchyard, the generator bus voltage dipped to approximately 50 percent of nominal voltage for approximately 300 milliseconds. The breakers on the high-voltage side of the main transformers tripped on low voltage. This resulted in a loss of load, and a generator bus voltage surge to approximately 120 percent of nominal voltage for approximately one second. The loss of offsite electrical load caused an automatic partial scram of the reactor, a transition to steam dumping, and house load operation by the turbine generators.

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After disconnection from the 400 kV grid, the plant electrical system continued to be connected to the generator buses (house load operation). The voltage surge at the generator buses caused tripping of the inverters of the battery-backed uninterruptible power supply (UPS) Subs A and B in the plant auxiliary electrical system. [Subs are similar to the trains/divisions in U.S. nuclear plants]. As a consequence, the rectifier and inverter of Subs A and B were bypassed, as designed, by the fast-acting electronic/static switch. The voltage transient at UPS buses due to the electronic switch transfer resulted in tripping of the recirculation pumps of Sub B. Reactor water level remained within acceptable limits.

The UPS Subs C and D were not impacted by the generator bus voltage surge due to the slightly lower voltage surge seen by the related rectifiers and inverters because of slight difference in the impedance path from the generators to the rectifiers. Subsequent tests of the UPS showed that the rectifier in the UPS could not reliably block steep voltage transients larger than 25 percent within the 80-130 percent range of nominal voltage. During such a voltage transient, the inverter voltage surge protection could trip before the rectifier protection if the rectifier and inverter direct current voltage protection settings are very close to each other. As result of this lesson learned, Forsmark revised the rectifier and the inverter voltage protection settings.

One turbine tripped due to low oil pressure caused by 50 percent voltage drop in the switchyard, the other turbine tripped due to high pressure in condensers; this lead to low frequency operation by the generators. However, the low frequency protection for the generators did not actuate due to an incorrect phase connection of frequency relays. With the turbines tripped, the generators continued to supply house loads, and the voltage and frequency continued to drop. When the voltage at the UPS Subs A and B decreased to 90 percent, the UPS Buses A and B automatically transferred to the alternate parallel path through the isolating transformer. During this transfer, UPS Subs A and B lost power for approximately 2 seconds (as per design), which caused the reactor to trip on two-out-of-four connection logic.

When the frequency at the 6 kV buses dropped below 47 hertz for 3 seconds, the feeders from the 6 kV buses to the 500 volt diesel buses tripped due to the underfrequency protection provided at the 6 kV buses. Also, the UPS buses of Subs A and B (fed through isolating transformers) lost power. However, the UPS buses of Subs C and D continued to be powered by battery-backed inverters.

Due to the loss of two trains of UPS, some instrumentation and control equipment was impacted. The major impacts were:

- The network between the automatic processors and the operator stations, and the process computer, was lost.

- The “control rod in” indication in the control room’s core map for all control rods belonging to Subs A and B was lost.

- The average power range monitor and wide range neutron monitor indications that were powered from Subs A and B were not available.

The 500 volt safety buses lost power due to the tripping of feeder breakers between 6 kV buses and 500 volt safety buses. Each emergency diesel generator (EDG) of Subs A, B, C, and D received its startup signal due to low voltage. EDGs C and D successfully connected to the safety buses. However, EDGs A and B tripped due to a "long startup time" since the EDG speed measurement signal, powered from its respective UPS bus, was not available.

The delayed tripping of main generator breakers occurred (approximately 38-45 seconds) when the power supplied by each generator became less than 5 Megawatts in conjunction with the previous turbine trip signal. Due to this, the 6 kV buses lost power and the automatic switchover (dead bus transfer with 2 second delay) to the 70 kV alternate offsite occurred per design. After approximately 22 minutes, voltage was restored to 500 volt diesel buses A and B by manually closing the 6 kV ties between the 6 kV buses and the 500 volt diesel buses.

DISCUSSION

The lessons learned from the Forsmark-1 event that can be applicable to U.S. plants are as follows:

(1) The voltage transient (due to the delayed fault clearing in the switchyard) can impact the plant electrical system up to the UPS buses.

(2) The protection relays, if dependent on proper phase connections, can malfunction if not properly connected.

(3) The failure of UPS can impact important equipment/systems such as the reactor recirculation pump control system and important control room indications.

CONTACT

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation project manager.

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