UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

June 1, 2005

NRC INFORMATION NOTICE 2005-15: THREE-UNIT TRIP AND LOSS OF OFFSITE POWER AT PALO VERDE NUCLEAR GENERATING STATION

ADDRESSEES

All holders of operating licensees 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 information notice to alert addressees to electrical equipment failures and design deficiencies identified following recent transients at Palo Verde Nuclear Generating Station (PVNGS), Units 1, 2, and 3. As a result, the units lost offsite power, tripped, and experienced other problems, including the loss of an emergency diesel generator (EDG). It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

On June 14, 2004, at 7:41 a.m. Mountain Standard Time (MST), the 500 kV system upset at the PVNGS switchyard originated with a fault across a degraded insulator on a 230 kV transmission line. Protective relaying detected the fault and isolated the line from the remote substation. The protective relaying scheme at the other substation received a transfer trip signal actuating an auxiliary relay (Westinghouse Type AR) in the tripping scheme for two breakers connected to the faulted line. The AR relay had four output contacts, all of which were actuated by a single lever arm. The tripping scheme used two contacts in redundant trip coils for each breaker.

One breaker tripped, demonstrating that the AR relay coil picked up, and at least one of the AR relay contacts closed. The other breaker did not trip. Bench testing of the AR relay

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showed that, even with normal voltage applied to the coil, neither of the tripping contacts for the failed breaker closed. The breaker failure scheme for the failed breaker featured a design where the tripping contacts for the respective redundant trip coils also energized redundant breaker failure relays. Since the tripping contacts for the failed breaker apparently did not close, the breaker failure scheme was not activated, resulting in a persistent uncleared fault on the 230 kV line.

Various transmission system event recorders show that, during approximately the first 12 seconds after fault inception, several transmission lines on the interconnected 69 kV, 230 kV, 345 kV, and 500 kV systems tripped on overcurrent. Also during the first 12 seconds, three cogeneration plants tripped, two with combustion turbines and one with a steam turbine, and the fault alternated between a single-phase-to-ground fault and a two-phase-to-ground fault, apparently as a result of a failed shield wire bouncing on the faulted line. After 12 seconds, the fault became a three-phase-to-ground fault and additional 500 kV lines tripped.

Approximately 17 seconds after fault inception, the three transmission lines between the PVNGS switchyard and the nearby 500 kV substation tripped simultaneously due to the action of their negative sequence relaying, thereby isolating the fault from the several cogeneration plants connected to that substation. Approximately 24 seconds after fault inception, the last two 500 kV lines connected to the PVNGS switchyard tripped, isolating the PVNGS switchyard from the transmission system. At approximately 28 seconds after fault inception, the three PVNGS generators were isolated from the switchyard and, by approximately 38 seconds, all remaining lines feeding the fault had tripped and the fault was isolated.

The trips resulted in a total loss of nearly 5,500 megawatts electric of local electric generation. Because of the loss of offsite power (LOOP), a Notice of Unusual Event was declared for all three Palo Verde units at approximately 7:50 a.m. MST. The Unit 2 train A emergency diesel generator started but failed early in the load sequence process due to a diode which short-circuited. The subject diode had less than 70 hours of run time in the exciter rectifier circuit. As a result, the train A engineered safeguards features busses deenergized, limiting the availability of certain safety equipment for operators. Because of this failure, the emergency declaration for Unit 2 was elevated to an Alert at 7:54 a.m. MST. All three units were safely shut down and stabilized under hot shutdown conditions. Units 1, 2, and 3 were without offsite power for approximately 4 hours and 9 minutes, 1 hour and 46 minutes, and 2 hours 15 minutes, respectively.

DISCUSSION

External fouling on a 230 kV insulator resulted in the deenergizing of a 500 kV switchyard, removing all sources of power to three nuclear units. The single-failure susceptibility of a transmission line protective system was the primary cause of the cascading blackout.

The insulator degradation was caused by external fouling and did not, by itself, represent a concern about the reliability of the insulators on the 230 kV transmission system. Nevertheless, the failed AR relay and the lack of a robust tripping scheme raised concerns about the maintenance, testing, and design of 230 kV system protective relaying. The 230 kV substation where the relay failure occurred was subject to annual maintenance and testing. Following the event, the failed AR relay was visually inspected. No apparent signs of contamination or deterioration were found.

As noted earlier, the tripping scheme lacked redundancy that could have prevented the failure of the protective scheme to clear the fault. The review of the design of the substations connected to the PVNGS switchyard indicated that two transmission lines at the subject substation featured a tripping scheme with only one AR relay. The newer lines had two AR relays. However, the review found that the bus-sectioning breakers at the subject substation contained only one trip coil instead of two trip coils.

To improve reliability, the tripping schemes for the two identified lines were modified to have two AR relays energizing separate trip coils for each breaker. The utility is considering installation of two trip coils in all single-trip-coil breakers. The tielines that connected 500 kV and 230 kV switchyards did not have overcurrent or ground fault protection. The installation of overcurrent protection for these tielines were completed in a later modification.

The apparent failure of the Unit 2 train A EDG was a failed diode in phase B of the voltage regulator exciter circuit. The diode failure resulted in a reduced excitation current and the current was unable to maintain the voltage output with the applied loads. The failed EDG did not have a significant impact on plant stabilization and recovery, but it did result in limited availability of certain safety equipment during a design basis event.

Refer to Attachment 1 for additional discussion.

CONTACTS

This information notice requires no specific action or written response. Please direct any questions about this matter to the technical contact(s) listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Note: NRC generic communications may be found on the NRC public Web site, http://www.nrc.gov, under Electronic Reading Room/Document Collections.

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ATTACHMENT (NON-PUBLIC) ML051520164

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