Information Notice No. 90-42: Failure of Electrical Power Equipment Due to Solar Magnetic Disturbances

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

June 19, 1990

Information Notice No. 90-42: FAILURE OF ELECTRICAL POWER EQUIPMENT DUE TO SOLAR MAGNETIC DISTURBANCES

Addressees:

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose:

This information notice is intended to alert addressees to possible failure modes of electrical power equipment in nuclear power plants and the connected transmission systems due to solar magnetic disturbances. The events described herein may be precursors to station blackout or partial loss of offsite power sequences. 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 do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

On March 13, 1989, an exceptionally strong geomagnetic storm caused major damage to electrical power equipment in Canada, Scandinavia, and the United States. The greatest damage occurred in Canada, where the Hydro-Quebec extra high voltage (EHV) transmission system experienced seven static compensator trips, causing system instability and tripping of lines carrying power to Montreal from hydroelectric generating facilities at James Bay. Automatic load-shedding was not able to offset the loss, and within a few seconds, frequency and voltage excursions occurred throughout the rest of the system resulting in total blackout of the Hydro-Quebec system.

In the United States, a voltage fluctuation of up to 4 percent was recorded on the EHV systems in Pennsylvania, New Jersey, and Maryland. In the Allegheny Power System, this storm caused 10 of the 24 transmission class capacitor installations to trip and eight EHV autotransformers to heat.

Specific events occurred at the Three Mile Island Unit 1, Hope Creek Unit 1, and Salem Unit 1 nuclear power plants. At Three Mile Island 1, the licensee observed tripping of capacitor banks in the 500-kilovolt substation. At Hope Creek 1, the licensee observed swings in reactive electrical power and six operations of the main generator negative sequence alarm, indicating

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electrical faults or power imbalances that could damage equipment. At Salem 1, the licensee observed swings in reactive electrical power and, in a subsequent inspection of the generator step-up transformer, the licensee observed severe overheating, melted low-voltage service connections in phases A and C, and insulation discoloration in phase B.

On September 19, 1989, at the Salem Unit 2 nuclear power plant, a second solar storm damaged the generator step-up transformer.

Discussion:

Solar flares and other solar phenomena radiate waves of ions, electrons, and protons called the solar wind. The solar wind interacts with the earth's ionosphere and magnetic field in a complex manner to produce auroral currents near the earth. The auroral currents induce an earth-surface potential (ESP) that establishes geomagnetically induced currents (GICs) in electrical power distribution systems through the neutral grounding points of wye-connected transformers at the ends of high-voltage transmission lines.

The GICs are quasi-direct currents, compared to the usual alternating current frequency of 60 hertz. Measured values of GICs in transformer neutral grounding points have exceeded 100 amperes. Such currents can distort current transformer responses and undesirably trip protective relays. Further, GIC can cause magnetic saturation of transformer cores. Depending on the extent of saturation, these GICs may initiate excessive reactive, eddy, and harmonic currents. Excessive reactive current can overheat transformers and produce excessive voltage drops in a transmission system. Core saturation with harmonic currents can cause localized heating in transformer steel members, winding conductors, and leads. Excessive harmonic currents in transmission lines can cause system voltage distortions, which can overload capacitors in the transmission system and trip their protective devices, causing further voltage degradations.

In general, solar magnetic disturbances follow an 11-year cycle. In the present cycle, these disturbances exhibited minimum activity in September 1986 and are expected to peak in 1990-91 and in 1993-94. Some researchers in the field of solar activity expect this present cycle to be the strongest yet recorded. If these predictions are accurate, these peaks may produce equipment damage, loss of electrical power, and problems with voltage control in transmission systems connected to nuclear power plants.

Several organizations are actively studying the effects of solar magnetic disturbances and ways to mitigate these effects. In particular, the Institute of Electrical and Electronics Engineers (IEEE) has established a working group that convened a group of experts to discuss these phenomena in July 1989 ("Effects of Solar-Geomagnetic Disturbances on Power Systems," Special Panel Session Report, IEEE/PES Summer Meeting, July 12, 1989, Long Beach, California). A copy of this report is available in the NRC Public Document Room, 2120 L Street, N.W., Washington, DC.

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This information notice requires no specific action or written response. If you have any questions about the information in this notice, please call one of the technical contacts listed below or the appropriate NRR project manager.

Charles E. Rossi, Director
Division of Operational Events Assessment
Office of Nuclear Reactor Regulation

Technical Contacts: Vern Hodge, NRR
(301) 492-1861

Subinoy Mazumdar, AEOD
(301) 492-4308

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