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Good afternoon, Ladies and Gentlemen, FERC and NERC staff and fellow panelists. My name is Singh Matharu. I am a Senior Electrical Engineer in the Electrical Branch at US Nuclear Regulatory Commission. Prior to joining the NRC, I worked as an Engineering Supervisor in design, operation and maintenance activities associated with commercial nuclear plants for more than 30 years. I have also worked on transmission system analyses associated with power supplies to industrial complexes. I am a Chartered Engineer (British PE) and currently participating in working groups responsible for development of IEEE Standards associated with nuclear plants. I am also participating in development of International Atomic Energy Agency (IAEA) Guides for electric power requirements for International nuclear plants.

**THE DISCUSSION BELOW PROVIDES THE VIEWS OF THE NRC STAFF, AND DO NOT NECESSARILY REPRESENT THE VIEWS OF THE NRC AS AN AGENCY.**

**NRC ROLE**

The NRC's overall responsibility is to license and regulate the nation's civilian use of nuclear materials in order to ensure the adequate protection of public health and safety. Its main regulatory functions are to:

- establish standards and regulations;
- issue licenses for nuclear facilities and users of nuclear materials; and
- ensure compliance with requirements via independent observation and/or review.

These regulatory functions relate to both nuclear power plants and other civilian uses of nuclear materials.

Commercial nuclear power plants rely on the electric power transmission network to export power and to safely shutdown the plant when required. For this reason, the NRC regulations assume high reliability of the transmission system in the vicinity of the plants to ensure long term safe shutdown capability of the plants and the continued cooling of stored fuel in onsite spent fuel pools. Onsite power systems (back-up, emergency and station blackout) such as batteries and emergency diesel generators are available in the event of loss of power from the transmission system, and have a capability to provide power for up to seven days, depending upon the circumstances. The NRC does not have direct regulatory authority over electric transmission systems; however, the Staff at NRC does collaborate closely with the Federal Energy Regulatory Commission and the North American Electric Reliability Corporation on electric grid reliability, cyber security issues, Electromagnetic Pulse (EMP) and Geomagnetic (space weather) effects, and research into these and related areas.

**Current Regulations**

The regulatory requirements for design and operation of nuclear plants are delineated in Title10, Part 50, of the Code of Federal Regulations (10CFR50). Appendix A titled 'General Design

Criteria For Nuclear Power Plants' provides specific guidelines that US plants are required to comply with.

*General Design Criterion (GDC) 17, "Electric Power Systems,"* requires, in part, that nuclear power plants have onsite and offsite electric power systems to permit the functioning of structures, systems, and components that are important safety.

The onsite system is required to have sufficient independence, redundancy, and testability to perform its safety function, assuming a single failure. The offsite power system is required to be supplied by two physically independent circuits that are designed and located so as to minimize, to the extent practical, the likelihood of their simultaneous failure under operating and postulated accident and environmental conditions. In addition, this criterion requires provisions to minimize the probability of losing electric power from the remaining electric power supplies as a result of loss of power from the unit, the offsite transmission network, or the onsite power supplies.

*GDC 2—'Design bases for protection against natural phenomena'*. Requires that structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed.

10CFR50.63 "Loss of All Alternating Current Power," requires that each light-water-cooled nuclear power plant be able to withstand and recover from a station blackout (i.e., loss of the offsite electric power system concurrent with reactor trip and unavailability of the onsite emergency ac electric power system) of a specified duration. Section 50.63 requires that, for the station blackout duration, the plant be capable of maintaining core cooling and appropriate containment integrity. It also identifies the factors that must be considered in specifying the station blackout duration.

### **NRC Activities**

The existing nuclear plants were designed prior to an in depth understanding of geomagnetic storms and their impact on electrical equipment. Hence, GDC 2 applicability for potential GMD or EMP related degradation was not in the scope of the design basis of most nuclear plants.

The NRC is aware of the potential significance of EMP to the nation's critical infrastructure and has reviewed the "Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack," issued in 2004. Beginning in the late 1970s, the NRC undertook a research program to study the effects of a high-altitude EMP on nuclear power plant safe-shutdown systems. From a series of reports, the last of which was completed in 2010, we concluded that reactors can achieve safe shutdown following a manmade EMP event or a solar or geomagnetically-induced current event.

(For instance )

A 1983 Sandia Laboratories report\* commissioned by the U.S. Nuclear Regulatory Commission analyzed the "worst case" scenario and concluded that EMP poses no substantial threat to

nuclear power plant's safe shutdown functions based upon both analysis and simulated EMP tests.

\*(D. M. Erickson et al., Interaction of Electromagnetic Pulse with Commercial Nuclear Power Systems, Sandia Report, SAND82-2738/2, 1983.)

Following the March 13, 1989 geomagnetic storm that caused major damage to electrical power equipment in Canada, Scandinavia, and the United States, the NRC issued Information Notice (IN) 90-42 'Failure of Electrical Power Equipment Due to Solar Magnetic Disturbances'. The intent of the IN was to alert the nuclear plant owners about possible failure modes of electrical power equipment in nuclear power plants and the connected transmission systems due to solar magnetic disturbances. The events described in the Information Notice were considered as precursors to station blackout or partial loss of offsite power.

The Information Notice cited specific events that occurred at the Three Mile Island Unit 1, Hope Creek Unit 1, and Salem Unit 1 nuclear power plants. The observations included:

1. At Three Mile Island 1, tripping of capacitor banks in the 500-kilovolt substation.
2. At Hope Creek 1, swings in reactive electrical power and six operations of the main generator negative sequence alarm, indicating electrical faults or power imbalances that could damage equipment.
3. At Salem swings in reactive electrical power and, in a subsequent inspection of the generator step-up transformer, signs of overheating.
4. The September 19, 1989, event at the Salem Unit 2 nuclear power plant, when a second solar storm damaged the generator step-up transformer

In 2009\*\*, the EMP study was redone by Sandia to consider differences in technology in use at nuclear plants since the 1980s. The conclusion was again reached that the ability of a nuclear power plant to safely shutdown should not be impacted by an EMP event. In addition, a letter report was done by Sandia in December 2010\*\*\* based on a very brief comparative analysis of EMP and geomagnetic storms. Based on this preliminary analysis, the same conclusion was reached that the safe shutdown function of a nuclear power plant would not be impacted by GMD activity.

\*\* (F. J. Wyant et al., Assessing Vulnerabilities of Present Day Digital Systems to Electromagnetic (EM) Threats at Nuclear Power Plants, Sandia Report, 2009.)

\*\*\* (M. J. Walker, A Comparison of HEMP MHD and Geomagnetic Induced Currents and a Preliminary Assessment of Digital System Vulnerability at Nuclear Power Plants, Sandia Letter Report, 2010.)

### **Geomagnetic Disturbance Task Force**

The NRC staff has been participating with other federal agencies in evaluating the effects of GMDs. Any recommendations from the NERC led Task Force will be considered for applicability to transmission system elements pertinent to nuclear plants.

### **Potential Impact of a Severe Geomagnetic Disturbance on nuclear plant electric power system**

#### **Offsite Power Source Vulnerability**

Typically, the offsite power system associated with Nuclear Power Plant (NPP) emanates from a switching station or switchyard close to the plant which may also have large high voltage transformers associated with the network. GIC related relay malfunctions can result in breaker operations and also damage capacitors and transformers near the switchyards. Thus, the offsite power systems are vulnerable to grid perturbations resulting from GMDs. The scope of protecting transmission networks is beyond the jurisdiction of NRC. The NRC can recommend protective/precautionary measures that grid and plant operators can implement when the magnitude of predicted solar storms is estimated to be potentially damaging to systems in the vicinity of NPPs.

### NPP Transformers

A typical NPP single unit configuration consists of one fully rated or two 50% rated main step up transformers (MTs), two unit auxiliary transformers (UATs) and two start up or standby transformers (SATs).

During normal plant operation, the MTs are fully loaded and connected to the high voltage (HV) transmission network. These MTs are vulnerable to GIC and sub harmonics generated in the transmission network, as they are fully loaded when the nuclear plant is at power, typically have a grounded neutral which provides a path for GIC and are therefore susceptible to core saturation and thermal damage. The protective schemes associated with these transformers are also susceptible to GIC related malfunctions.

The Salem nuclear plant transformers that are identified in Oak Ridge report as an example of damage due to GICs were main step up transformers. From nuclear safety perspective, MTs can be used to supply offsite power to plant auxiliaries (via a backfeed scheme), but are generally not the preferred source of power for plant shutdown.

NPP operators in areas most vulnerable to GIC-related transformer damage have procedures to reduce plant power (hence the load on MTs) when solar storm warnings are issued by National Oceanographic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC).

During normal plant operation, the UATs supply power to the plant auxiliary system and are connected to the output of the main generator. These transformers, though fully loaded are not directly connected to the grid, operate at lower voltages and are 'shielded' from GICs by the MTs which are the interface point between the NPP and the grid. Hence these transformers are not expected to be vulnerable to GICs and will be available for plant shutdown as long as the transmission network in the vicinity of the plant is stable.

The GDC 17 required source of offsite power for plant shutdown is normally through the SATs. During normal operation, these transformers are energized and lightly loaded. The minimum rating of SATs exceeds the total power requirements of safety significant loads. Though these transformers have grounded neutrals and are connected to the HV transmission network, they are not expected to be vulnerable to GIC damage as the heating effects will be minimal due to light load on the transformers during normal operation. There are few plants that use the SATs for supplying station auxiliaries during normal operation. These cases require specific evaluation. To date, no SAT failures have been attributed to GIC related damage.

The above discussion is a quantitative evaluation of transformers to appreciate the scale of vulnerability. Plant designs that are unique may require specific considerations depending on susceptibility to GIC damage.

The onsite power system EDGs are normally in standby state and are not expected to be affected by solar storms. In the remote event that EDGs are operating in test mode during a solar event, the grounded neutrals of station transformers (UATs or SATs) are expected to drain GICs into the ground thus shielding the EDGs. The EDGs are designed for extended operation and have the capability of mitigating the consequences of an accident and support spent fuel pool loads. In the event of loss of offsite power, the EDGs auto start and power safe shutdown busses of the plant. The design basis of most U.S. plants requires onsite storage of EDG fuel oil capability for seven days of operation without replenishment. The NRC is now reviewing a petition for rulemaking that questions the adequacy of the current onsite storage requirements for EDG fuel in the event of a long term grid outage caused by a geomagnetic storm. Options for maintaining fuel oil delivery capability for longer duration are currently being considered.

### **Current Practices**

1. The NERC mandated requirements provide assurance that transmission system operators have reliable offsite power sources for nuclear plants.
2. In the event of loss of power in the vicinity of a nuclear plant, existing agreements between nuclear plant operators and grid operators require high priority for restoration of power to the nuclear plant.
3. Some plants have procedures to reduce power output in the event of a solar storm warning

### **Conclusion**

The GDC 17 mandated transformers, required for offsite power for nuclear power plants, are normally in a standby state or have built in design margin and are unlikely to be degraded by GICs. The safe shutdown capability of NPPs is not an immediate concern as the onsite EDGs can provide adequate power in the event of the loss of transmission system. The NRC staff is monitoring NERC's activities for protecting critical infrastructure from EMPs. The staff is monitoring congressional activities on this issue, such as House Resolution 668 (the Secure High-Voltage Infrastructure for Electricity from Lethal Damage Act or SHIELD Act) to amend the Federal Power Act to protect the bulk-power system and electric infrastructure critical to the defense of the United States against natural and manmade EMP threats and vulnerabilities.

The near term actions now being taken to respond to the Fukushima Daiichi event of March 11, 2011, are expected to include deployment of resources from remote locations to cope with loss of offsite and onsite power for an extended duration. The NRC has also published an Advance Notice of Proposed Rulemaking on possible changes to the NRC's station blackout rule. If adopted, the revised rule is also expected to increase the capability of nuclear power plants to cope with loss of offsite power for extended periods. Finally, resolution of a petition for rulemaking, PRM-50-96, could provide further assurances of onsite power availability in the event of loss of offsite power for an extended duration. The NRC is considering all information available to date about the threats from a great geomagnetic storm and from a manmade EMP that could have potential adverse effects on the safe operation of nuclear power plants.

**Thankyou**