GRID STABILITY AND SAFETY ISSUES ASSOCIATED WITH NUCLEAR POWER PLANTS

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Nuclear Power Plants (NPPs) are used in many countries as an economical and environmentally clean source of base load electrical generation. However, the deployment of NPPs to supply a portion of the electricity on a power grid brings with it a number of requirements on the grid design that are unique to this power source, and which must be considered by power grid planners and system operators. Unlike conventional power sources (thermal power units, or hydroelectric dams), NPPs have long term shutdown cooling requirements which consumes power and with stringent voltage and frequency limitations (imposed to assure the operability of critical emergency cooling systems).

This paper addresses the safety issues associated with the electrical grid to which an NPP is connected and the implications of an unreliable power grid. The technical issues include:

- Magnitude and frequency of load rejections, and loss of load to the NPP
- Grid events involving degraded voltage / frequency
- Complete loss of offsite power to the NPP due to grid disturbances
- NPP unit trip causing a grid disturbance resulting in cascading grid collapse

NPPs are designed to cope with certain magnitudes of load rejections without tripping. For more serious grid disturbances, protection systems are provided to automatically trip the reactor, separate the plant electrical systems from the degraded conditions present on the grid, and rely on DC Batteries and onsite emergency power sources until such time as the grid voltage and frequency are restored to acceptable values. While this type of strategy (focused on protecting the NPP and thus avoiding risk to the public) is used in most countries, it does present problems for countries where an NPP is being deployed in an area with an unstable electrical grid. The sudden automatic shutdown of a large base load nuclear unit during periods where there is a mismatch between generation and load only tends to aggravate the situation.

Nuclear safety regulations and standards dealing with these issues have been developed since the 1960's based on the principles of providing "defense in depth" against a scenario where the NPP is unable to provide long term core decay heat removal. The key defense in depth barriers are: provision of an immediately accessible power source from the offsite electrical grid, provision of an independent connection to the offsite grid, and provision of a redundant and reliable onsite power system based on emergency diesel generators or their equivalent.[1] In the USA, NRC Regulation 10-CFR-50, Appendix A, General Design Criteria 17 defines the requirements for interfacing an NPP to an electrical grid with a clear focus on protecting the reactor from grid disturbances. IAEA Safety Guide No. 50-SG-D7, which is extensively based on the US criteria, provides equivalent international guidance on how to assure proper interfaces of emergency electric power systems with the electric grid. The essential features of both of these safety requirements is the interface of the NPP with the grid via *two physically independent transmission circuits* – to an emergency onsite power system that is *independent, testable, redundant and single failure tolerant.* The requirement for demonstrating the independence of the transmission circuits is primarily accomplished based on application of physical separation criteria. In doing this, however, it must be recognized that in some scenarios involving a weak, poorly interconnected or coordinated electrical grid – the sudden shutdown of a large NPP may result in the collapse the overall power grid despite the use of "physically independent connections" to the grid.

Recommendations:

The operators of national electric grids must recognize the performance characteristics assumed by an NPP they are planning to deploy in their country – and assure that the grid is designed and operated accordingly. This is particularly true when a foreign NPP design, which may be more "attuned" to the electric power grid characteristics in the country of origin, is being installed. The standard way this is done is via performing electric power system simulation studies in which the normal operating environments (nominal system loads and generation in terms of Mwe and MVARs) are assumed, and single faults (sudden losses of key transmission circuits or generating units) are systematically postulated. The simulations identify the time dependent power system response in terms of voltage and frequency, physical limitations to prevent overloading transmission circuits, and the effects of automatic features such as automatic load shedding and emergency disconnects. Such studies can be used in confirming that physically separate transmission circuits are in fact independent and that the desired "defense in depth" is maintained.

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[1] Some emergency onsite power systems utilize hydroelectric dams (Oconee Units 1,2,3), or emergency gas turbine generators (Millstone Unit 1).