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Risk Management

Pilot Study on Loss of Offsite Power Frequency and Duration, LOOP Events and PSA Modeling

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By Per Hellström, Relcon Scandpower AB

Co-authors: Erik Sparre - Risk Pilot, Stockholm, Sweden
Gunnar Johanson, Linnéa Casselbrant, Helen Bigun - ES-Konsult, Stockholm, Sweden
Anders Persson, - RelconScandpower, Stockholm, Sweden

The pilot study Background

- **The treatment of loss of off-site power (LOOP) in the Nordic PSA studies has been discussed many years and ideas on establishing a basis for harmonization in this area have been proposed.**
- **Several proposals on work to be performed were presented to the Nordic PSA group (NPSAG), some inspired by the Forsmark event in July 2006.**
- **The different proposals were combined into the pilot study, financed by NPSAG.**

Objectives

- **Overall objective is to increase knowledge about the grid behavior among PSA practitioners and exchange ideas among the stake holders in order to improve and harmonize modeling.**
- **It is also expected to contribute to improved safety with regard to electrical events and to support development of best practices in the field.**
- **The pilot study specific objectives:**
- **Create a platform for further work concerning development of:**
  - the event reporting task and experience feed-back
  - LOOP event characterization
  - PSA modeling principles.

The Nordic grid

The Nordic Grid

- **Nordic nuclear power plant grid connections**
  - 400 kV grid.
  - 130 kV grid (110 kV in Finland)
  - 70 kV grid.
- **Disturbances in the grid may lead to a need to disconnect the plant and switch over to house turbine operation (if possible) or shut down the plant.**
- **The stability of the 400 kV grid in terms of expected number of LOOP events, their consequences for the plant and the safety related electrical equipment and their duration is important for plant safety.**

The grid operators – responsibility

- **The 400 kV grid is operated by the Transmission System Operators (TSO's),**
  - Svenska kraftnät (SvK) in Sweden
  - Fingrid in Finland
- **The TSOs monitor the national grids and ensures**
  - **that there is always a state of balance between the consumption and production of electricity.**
  - **that the grid is operationally reliable and efficient**
- **Svk and Fingrid thus play an important role both for users of electricity and for Nuclear safety.**

TSO requirements

- Production units (including NPPs) shall meet certain requirements
  - **Resilience to disturbances**
  - **Voltage regulation**
  - **Power regulation**
  - **Shutdown and start after loss of the grid**
  - **Communication and control**
  - **Verification and documentation**
  - **Deviations are allowed for certain circumstances related to e.g. nuclear power plants**

Swedish TSO activities

- **All disturbances (about 250 each year) affecting the grid are documented and analyzed.**
- **In general, disturbances constitute less than a fraction of 10E-6 of the total delivered energy.**
- **Disturbances that are analyzed include both major failures resulting in loss of the grid and events that are taken care of by switching to redundant systems without affecting producing units or consumers.**
- **The type of analysis being the main interest from a nuclear power safety point of view is not performed by the TSO, i.e. calculations of frequency and duration of disturbances of the grid from a NPP perspective.**

Nordel

- Nordel is the collaboration organization of the TSOs of Denmark, Finland, Iceland, Norway and Sweden.
- The objective is to promote the establishment of a seamless Nordic electricity market, as an integrated part of the North-West European electricity market and to maintain a high level of security in the Nordic power system.
- Nordel collects statistics for the entire Nordic market and maintains a database and statistics of identified cases of disturbances and sources of failures, as well as categorization of failures.

The grid - Findings

- **The TSO information on disturbances and durations and the distribution of events to e.g. substations and grid can provide a better understanding of grid disturbances for the PSA community.**
- **Several NPPS are currently performing power uprate projects. This situation is affecting the grid in two ways;**
  1. The largest unit will be bigger and thus require larger reserves for being able to cope withy a loss of the large unit,
  2. Requirements on power grid transfer capacity from the sites with increased power output.
- **Both aspects are of interest regarding the risk for LOOP event frequencies and duration.**
- **Grid unavailability may be very short from TSO perspective, but long for the NPP**

Events – Databases and reports

- Search includes all NPP sites in the countries participating in the framework of the IAEA and the OECD/NEA.
- Number of reported incidents related to high voltage and low voltage failure were documented.
- Third edition of the IRS Blue book (data for 2002-2005)
  - electrical grid stability and availability of power plant safety systems
  - Voluntary
  - ~0.5 events per plant and year
- Stagbas, an SKI database with all LERs from Swedish NPPs.
- Swedish TSO database AnnaKlara
- NUREG/CR-6890 Reevaluation of Station Blackout Risk at Nuclear Power Plants vol. 1 and 2.

Events - Findings

- **Inconsistency in reporting criteria and the extent of reporting.**
  - all events of safety significance for the international community should be reported to IRS, but since it is voluntary not all events are reported.
  - Authorities in different countries have different reporting criteria.
  - A new event similar to previous event may seem less important to report.
  - Operator dependent
  - different meaning of codes in different databases

Modelling – Questionnaire

- **The following main areas were covered :**
  - IE definition
  - Modelling of
    - House turbine operation
    - Return of offsite power
    - Switch-over to alternate grid and diesel generators
    - Modeling of diesel generators
    - Modeling of gas turbines
    - Modeling of electrical busbars
  - Failure data and statistical treatment

Modelling – Findings (1)

- **Return of offsite power**
  - In some PSAs, separate IEs are created for LOOP, taking account for the duration of the event.
  - Other do not consider the length of the LOOP in the IE. The return of power is instead handled separately in the fault trees.
  - Others use a simulation model for calculating the frequency and duration of the LOOP, resulting in a division into different categories for the duration.

Modelling Findings (2)

- **One plant has included voltage transients, caused by switchyard failures, as a possible effect in case of LOOP.**
- **House turbine operation.**
  - Some plants do not take house turbine operation into account, other plants do.
  - The level of detail, with regard to breaker maneuvers and electrical dependencies varies however.
- **Modeling of switch-over (to alternate grid, gas turbines or diesel generates).**
  - Some plants have a very detailed modeling where the dependencies for the breakers (relays including electrical dependencies) are included in the fault trees.
- **Different failure data sources and data handling**

Modelling Findings (3)

- **The dependencies and modeling of the electrical bus bars have to be adjusted for in case of LOOP, e.g. in order to avoid circular logic and to take batteries into account in a correct way.**
  - The modeling differs significantly between the PSAs, since different approaches in the modeling of the electrical systems are used.
- **In general, a lot of effort have been put in the modeling of electrical dependencies, although different approaches have been used.**
- **Especially when it comes to defining frequencies and duration of LOOPs, the strategies and level of detail varies.**

Conclusions

- **Inclusion of the Transmission System Operators experience and data has the potential to improve data on the frequency and duration of LOOP events.**
- **International experience can easier be compared to Swedish knowledge by using for example information from the IRS database.**
- **TSOs can contribute with information that has not been evaluated in this kind of work before.**
- **Modeling of LOOP**
  - A high level of detail, although the focus differs between the NPPs.
  - A large effort has been made at some NPPs in defining frequency and duration of LOOP.
  - The modeling of electrical dependencies is in general well developed, although different strategies are used.

Further work

- **A proposal for further work is currently being worked out for the Nordic PSA group (NPSAG). Focus is on the following areas:**
  - The Grid stability
  - Good practice in modeling and data
  - Experience feedback

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