

# Insulation coordination studies

## Selection of insulation strength for system equipment

### At a glance

Insulation coordination encompasses the selection of the dielectric insulation strength of equipment to avoid damage in case of overvoltages related to lightning strikes, switching actions or phenomena related to fundamental-frequency overvoltages (e.g. earth faults).

Siemens Power Technologies International (Siemens PTI):

- advises in all insulation coordination matters affecting development, tendering, bids, project engineering and plant operation,
- calculates possible maximum overvoltage stresses for new and future installations or measures them in existing ones with our specialized measuring equipment,
- develops overvoltage protection concepts (e.g. type and location of surge arresters) taking into account the specific system configuration, but also economical aspects.

### The challenge

The insulation coordination aspects of a power system must be considered in the planning phase of a project and extensive calculations might be needed in certain cases. Performing the studies at a later stage could limit the number of possibilities to tackle over-

voltage problems (e.g. installation of surge arresters physically not possible due to space restrictions).

### Our solution

Insulation coordination includes a variety of typical tasks requiring special attention during the planning process. A few examples:

- surge arrester placing and rating in HV switchyards and provision of a sufficiently high protection level against lightning overvoltages for the equipment
- investigation of overvoltages in case of switching actions, e.g. tripping of a circuit breaker following a fault in the system or energization of a long cable or overhead line
- definition of overvoltage protection for MV switchgear, in particular for special cases such as arc furnace breakers or compensation reactors

### Simulation studies

If detailed simulations are required to investigate overvoltages, appropriate models of the system under study must be developed. Siemens PTI specialists have many years of experience in constructing models for different types of equipment for the frequency range that is considered. This is normally done in PSS<sup>®</sup>NETOMAC and

serves as a basis for the actual overvoltage calculations.

Based on the possible operating scenarios, a number of simulation cases are defined, differing among others in aspects like switching topology (e.g. normal operation or operating with contingencies), operating point (e.g. underexcited versus overexcited generator operation), component characteristics (e.g. remanent flux at transformer energization) and overvoltage excitation (e.g. different lightning strikes types and locations). From these different scenarios, the worst cases overvoltages are determined, both line-to-earth and line-to-line, and used as an input for the insulation coordination procedure.

### Application of insulation coordination procedure

From the worst case overvoltages, resulting from the simulation studies, the required insulation levels for different types of equipment in the system can be determined by applying an insulation coordination procedure. Depending on the standard that is applied (e.g. IEC 60071 or IEEE 1313) this procedure can differ.

The resulting insulation levels are one or more of the following:

- insulation level regarding lightning overvoltages (e.g. Basic Insulation Level (BIL) in IEEE standards, or Lightning Impulse Withstand Voltage (LIWV), in IEC standards)
- insulation level regarding switching overvoltages (e.g. Switching Impulse Level (SIL) in IEEE standards, or Switching Impulse Withstand Voltage (SIWV) in IEC standards)

- insulation level regarding temporary overvoltages (e.g. Short-Duration Power Frequency Withstand Voltage (ACVV) in IEC 60071)

In some cases, the insulation levels of the equipment have been selected prior to the study, e.g. due to long lead time for delivery of equipment. If this is the case, the predefined levels are compared to the minimum required insulation levels that result from the simulation study and the subsequent insulation coordination procedure. In case of discrepancies, mitigation measures are proposed and tested.

Dimensioning and/or verification of protective devices

Protective devices are dimensioned in such a way that the predefined insulation levels are not exceeded or when the insulation levels are defined by the insulation coordination study, that the required dielectric strength is not excessive (for economical reasons). Furthermore, it is ensured that the protective device does not impede normal system operation (e.g. surge arrester overloading in case of earth faults).

#### Application example

A lightning overvoltage study was performed for a GIS (gas-insulated switchgear) substation with two transformer feeders and two cable bays with overhead lines connected about 1.5 km away from the substation – see Figure 1.

Three types of lightning strikes were taken into account:

- direct conductor strike at the last four towers
- direct tower strike to the last four towers, possibly followed by backward flashover of the insulators strings
- distant conductor strike, further away than the last four towers

Based on the maximum overvoltages, the required LWV or BIL of the equipment was calculated according to IEC 60071 and compared to the predefined insulation levels.

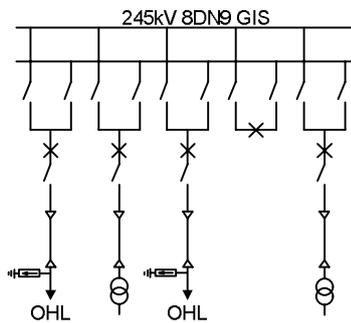


Figure 1: Overview of the case study

The results showed that the predefined insulation levels were not sufficient. As a solution, it was suggested to install additional surge arresters at the HV terminals of the transformers. After dimensioning of these arresters, they were integrated in the simulation model and the simulations were re-

peated. It was shown that the predefined insulation levels were now sufficient to cope with the overvoltages resulting from the different lightning strike scenarios (Figure 2).

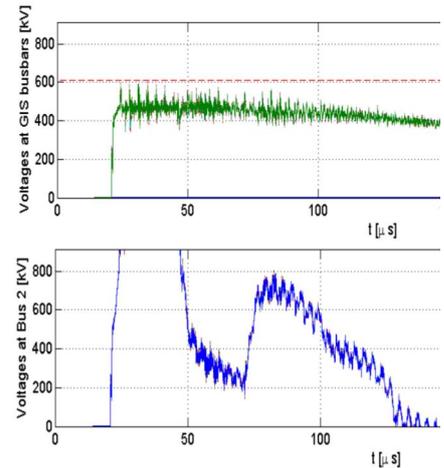


Figure 2: Max. GIS overvoltages without (top) and with (bottom) additional surge arresters

#### Measurements

For measurements of transient overvoltages in medium-voltage networks, Siemens PTI has the special appropriate equipment and many years of experience for measuring voltages and currents up to the MHz-range. Measurements of transient overvoltages can contribute to clarification of reasons for equipment failure and weak points in systems.

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