

Investigation of transient voltage loads and insulation coordination

Overview

The purpose of the investigation of transient voltage loads and insulation coordination is to protect operating equipment from excessive voltage loads and to select the electrical insulation resistance. Overvoltage (surges) can be caused by lightning strikes, switching operations or temporary overvoltage (e.g. ground faults). Siemens Power Technologies International (Siemens PTI) supports you with:

- Consulting in topics of insulation coordination, arrester design, arrester positioning, protection against transient surges, and selection of insulation levels.
- Simulation of transient surges in planned, existing or extended facilities.
- Studies of transients in breaker loads (e.g. TRV (Transient Recovery Voltage) and "skipped current zero crossings") or for analysis of electromagnetic transient compensation processes as a result of switching operations.
- Development of overvoltage protection concepts (e.g. type and installation location of arresters) with consideration of the system configuration, as well as economic aspects.

The Challenge:

A typical medium or high-voltage grid consists of a large number of re-

sources, such as cables, transformers and switchgear. The acquisition costs for these resources are significant and often exceed the costs of a transient simulation study by several orders of magnitude. The lack of a study can have significant effects, as excessive transient voltage loads can damage equipment. In addition to the repair costs, there may also be additional economic losses, such as penalty payments (e.g. missed deliveries).

Transient voltage loads and insulation coordination for a plant should therefore be included in the planning phase and also simulated in detail if this is reasonable. A reduced number of solution possibilities may result at later times in a project (e.g. because the installation of arresters is not possible due to a lack of space).

Our solution

There are several typical tasks regarding transient voltage loads that must be given special attention in the planning phase. These include:

- Positioning and dimensioning of the surge arresters in high-voltage switchgear, as well as sufficient protection levels in the equipment to protect against lightning surges.
- Investigation of unaffected switching surges after switching operations caused by faults or by the switching of long cables, or over-

head lines and transformers, for example.

- Determination of overvoltage protection for Siemens medium-voltage switchgear in special applications, such as vacuum breakers for arc furnaces or compensation chokes.
- Determination of the electrical loads on breakers (e.g. TRV, arcing time) in order to enable the selection of a suitable switching device for a defined task.

Consulting based on experience

Although overvoltages are mostly caused by complex physical processes, comprehensive studies are not always necessary, as some typical scenarios can be defined. In this case, Siemens PTI offers support in basic questions about overvoltage protection and insulation coordination, saving time and money.

Comprehensive studies

If comprehensive studies are necessary, appropriate simulation models are prepared according to the frequency range to be investigated. This is usually done with the PSS®NETOMAC simulation program.

A specific number of simulation cases are specified depending on the grid topology. Depending on the type of study, these may include strike scenarios for lightning strikes in overhead lines (strike location, lightning currents), switching states of switchgear, elements to be switched (cables, transformers, etc.), fault locations, etc.

The maximum voltages resulting for the simulations are taken as the basis for insulation coordination, for example.

Insulation coordination

Insulation coordination procedures are used to determine the necessary insulation level of the equipment according to the applied standard (IEC 60071). This yields the corresponding insulation levels:

- Design lightning impulse withstand voltage LIWV per IEC standards.
- Design switching impulse withstand voltage SIWV per IEC Standards.

Because of long lead times, the insulation level of the equipment is often already specified. In this case, the specified insulation levels are compared with the insulation levels to be fulfilled, which are calculated from the representative overvoltages from the simulations and additional factors. If the specified insulation levels are lower than the levels to be fulfilled, measures such as the installation of arresters or their low-inductive connection are recommended.

Dimensioning and/or verification of surge arresters

Surge arresters are designed to prevent the anticipated violation of predefined insulation levels. If the insulation levels are specified by the study, the electrical insulation resistance should not be too high due to economic requirements. Furthermore, the arrester should not be compromised under normal conditions (e.g. overloading of the arrester in the event of a ground fault).

Implementation example I: Lightning overvoltage study

The results of a lightning overvoltage study are explained below. Figure 1 shows a GIS supplied by two transformers and two cables connected to overhead lines after 1.5 km.

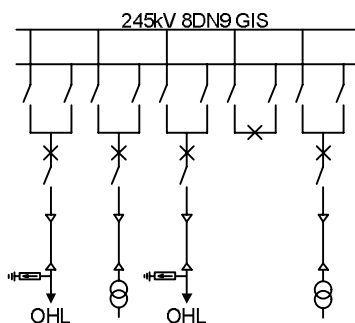


Figure 1: Overview of example

Three different types of lightning strikes are taken into account:

- Direct strike on conductor in the area of the last masts.
- Direct strike in the last masts, possibility followed by rearward insulator arcing.
- Conductor strike far away.

The necessary LIWV for the equipment was calculated in accordance with IEC 60071 based on the maximum voltages and was compared with the predefined insulation levels. The results show that the predefined insulation levels are insufficient in the event of a mast strike with rearward insulator arcing. The installation of surge arresters on the high-voltage side of the transformers was therefore recommended. Once these were dimensioned, this was accounted for in the simulations and the simulations repeated. This proved that the equipment was now sufficiently protected against lightning surges with the specified insulation levels (see Figure 2).

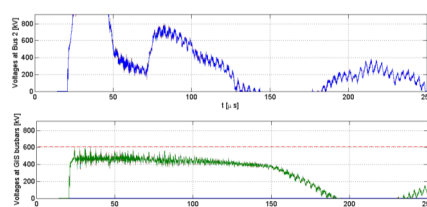


Figure 2: Maximum voltages without (upper plot) and with (lower plot) additional surge arresters

Implementation example II: TRV study

The recurring voltage across the terminals of a circuit breaker after the deactivation of a short-circuit current is called the "transient recovery voltage" (TRV). To ensure safe deactivation, the gradient and maximum value of the TRV are not permitted to exceed defined test values specified in international standards.

The TRV is calculated as an example for the SF6 circuit breaker in the GIS switchgear from implementation example I (Figure 1). A 3-pole fault in the overhead line for bay No. 1 (far left) is considered. Figure 3 shows the simulated TRV across the "first-pole-to-clear" of the breaker if all of the bays in the switchgear are in operation. Both, the gradient, as well as the maximum value of the TRV are clearly within the envelopes. If the fault is fed only from one transformer bay supplied (1 overhead line bay and 1 transformer bay out of operation), this yields the results in Figure 4. In the investigated

switching configuration, only the capacitance of the short cable between the GIS and the transformer is effective on the source side of the breaker for the TRV. This significantly increases the gradient of the TRV compared with that in Figure 3, and the maximum permissible gradient is barely complied with. If a busbar connection is implemented instead of the short cable, the calculated TRV values are outside of the permissible range. In this case, corrective measures would have to be investigated and planned in the context of the Engineering of the facility in order to comply with the normative requirements.

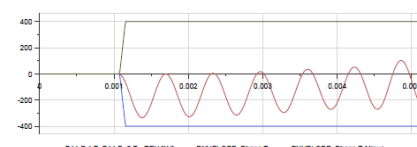


Figure 3: Simulated TRV – normal condition

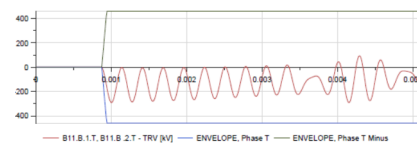


Figure 4: Simulated TRV – transformer feeds fault

The permissible maximum TRV is defined as the envelope. If the voltage across the breaker poles is within the envelope over time, the normative TRV requirements are complied with. The envelopes are dependent on the amplitude of the short-circuit current to be interrupted. The lower the short-circuit current, the higher and steeper are the permissible envelopes.

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