Short-Circuit Protection of Lightning Arresters by means of gG Fuses

Lightning currents and line surges may be cause of considerable damage on buildings and electrical installations. Valuable electric and electronic devices may be destroyed, downtime of machinery and production may generate considerable losses and even human lives may be endangered. Where, as a result of a risk analysis, local conditions indicate the necessity for lightning protection, suitable protective measures shall be taken to prevent dangerous lightning currents to enter buildings and equipment. For proper co-ordination of fuses and lightning arresters a basic understanding of current flow during lightning strike is necessary.

How lightning currents enter buildings

When lightning strikes a building, about half of the lightning current only is directly conducted to earth through the external lightning protection system.

Another up to 50 % of the current enters the building through electrically conducting infrastructure, e.g. the main equipotential bonding conductor (IEC 62305). From there, partial currents, evenly distributed according to the number of conductors of the power supply system flow into the supply network (figure 1). Buildings protected by an outside lightning protection system shall therefore always have an inside lightning protection system as well.

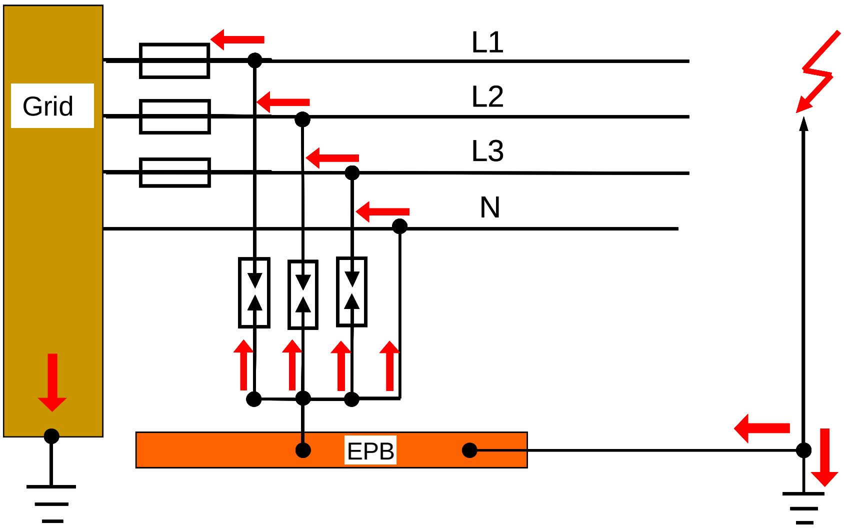

Fig. 1 - Current distribution of a direct lightning strike on a protected building
EPB Equipotential bonding bar

Inside lightning protection

For inside lightning protection systems, the first and most powerful devices are lightning arresters Type 1. They are installed as close as possible to the main supply entrance and provide protection against direct lightning strikes as well as against close-up strikes. (Lightning currents of close-up strikes in neighbouring buildings or overhead lines enter the building through the main supply cable and flow opposite direction to what is shown in Figure 1)

The technical requirements for lightning arresters are similar for direct and close-up strikes: They shall

- provide temporary equipotential between outer conductors, neutral conductor and ground,
- reduce high energy pulses (current and voltage) to a level, that can be absorbed by downstream surge arresters Type 2 without overloading,
- reliably disconnect the mains follow current (short-circuit current) in order to restore insulation,
- not exhibit any significant leakage currents under normal service conditions when installed upstream the meter.

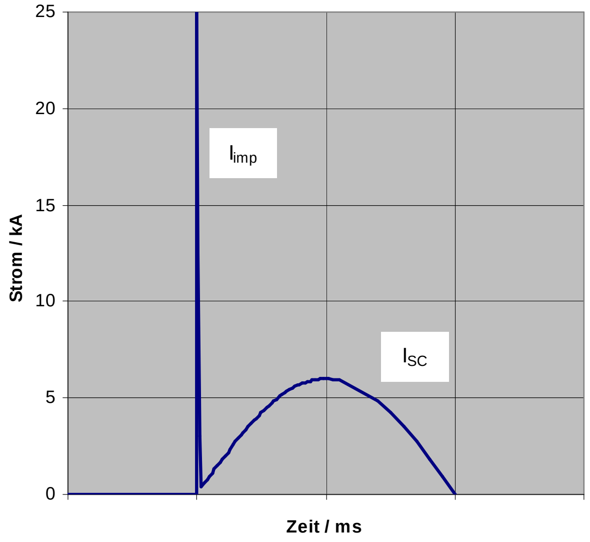

Fig. 2 - Lightning impulse and follow current
I_{imp} Lightning impulse current
I_{SC} Mains follow current

Lightning arresters consisting of spark gaps, having a high discharge capacity and efficient arc quenching systems are widely used for this purpose. Therefore, this type of devices is referred to in the following explanations.

Branch currents

Under normal service conditions, lightning arresters represent high-grade insulation suitable to be installed upstream meters. After sparkover, a low impedance arcing short-circuit will be formed that carries the lightning impulse current of high-amplitude (kA range) but of short duration (10/350 µs). According to the number of active conductors of the supply system, only a fraction of the lightning current passes through each lightning arrester. At sparkover of the lightning arresters, the power supply will be short-circuited as well and the impulse current I_{imp} will be followed by a short-circuit current I_{SC} at power-frequency (mains follow current, see figure 2).

As a rule, lightning current arresters are able to interrupt high follow currents. However, suitable overcurrent protective devices, usually fuses for general applications (gG fuses), have to be provided to prevent damage in case of thermal overloading due excess or repeated loads (figure 3).

Co-ordination of gG fuses and lightning arresters

Co-ordination of gG fuses and lightning arresters as well as other circuit components is by no means a trivial task, as can be seen from the following general requirements (figure 3):

- **The arrester branch fuse F2 shall safely interrupt the follow current** in case of overloaded or failed arrester, in order to prevent a potentially disastrous arc fault.
- **The arrester branch fuse F2 shall operate selectively to the main fuse F1** in order to avoid breakdown of the main supply system.
- **The arrester branch fuse F2 must by no means operate under the influence of the lightning impulse current**, as this would render overvoltage protection ineffective. In addition, fuses may be destroyed if melting occurs during lightning current flow. Fuses or other overcurrent protective devices are generally not able to interrupt lightning currents because of the extremely high driving voltage.

In order to prevent fuse malfunction caused by lightning currents, the highest rated fuse current possible shall be selected for the arrester branch fuse F2. However, some restrictions apply.

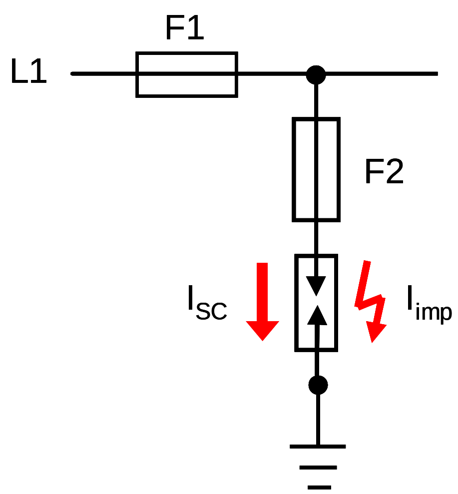

Fig. 3 - Lightning arrester with branch fuse
F1 Main fuse
F2 Arrester branch fuse

Maximum rated current of the arrester branch fuse F2

The rated current I_{NF2} of the fuse F2 associated with the lightning arrester depends on the prospective short-circuit current and the follow current discharge capacity of the lightning arrester. The **maximum fuse rated current I_{Nmax}** is given in the lightning arrester manufacturer's literature and **must not be exceeded: $I_{NF2} \leq I_{Nmax}$.**
No arrester branch fuse is required if the rated current of the main fuse F1 is equal or smaller than the maximum value for F2 as stated by the arrester manufacturer and nor additional requirements exist, e. g. selectivity to the main fuse F1.
In case selectivity of protection is required, the rated current of the arrester branch fuse F2 shall be 1:1,6 times or two steps below the rated current of the main fuse F1: **$1{,}6\ I_{NF2} \leq I_{NF1}$** .
This condition cannot always be met. It depends on the rated current of F1 and on the minimum acceptable rated current of the arrester branch current F2 as given by the arrester manufacturer.
If no minimum but a maximum rated fuse current only is mentioned by the arrester manufacturer, this given rated current shall be selected for the fuse F2!

Minimum rated current of the arrester branch fuse F2

The arrester branch fuse must not operate while carrying a lightning impulse current including a follow current cleared by the lightning arrester, i.e. the minimum pre-arcing I^2t of the fuse must not be exceeded by the arrester current (see figure 2). Unfortunately, the pre-arcing I^2t values obtained from fuse type tests are not fully applicable to the very short impulse durations of lightning currents but may be smaller or higher[1]. Therefore, common fuse data resulting from type tests are of very limited use for the co-ordination of fuses and lightning arresters.

The smallest permissible fuse rated current depends very much on the lightning arrester's ability to limit the follow current (see figure 2). This explains why reliable information on a permissible fuse rating smaller than I_{Nmax} can only be obtained from tests of the fuse in combination with a specific arrester.

By no means, fuses associated with lightning arresters must have smaller rated currents than given by the arrester manufacturer! Smaller fuses prevent to use the arrester's discharge capacity to its full extend and may be cause of significant damage due to malfunction.

Additional selection criteria

As rated currents of arrester branch fuses have to follow strictly the arrester manufacturers' advice, the adjacent conductors have to be selected to be adequately protected by the fuses.

After operation, arrester branch fuses may have to be replaced jointly with an overloaded arrester in order to restore surge protection. Fuse operation shall therefore be clearly visible by indicator and remote signalling shall preferably be possible.

More information and advice on this and other subjects can be obtained from your fuse specialists organized in Pro Fuse International .

fuseXpert
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[1] J. Schönau, F. Noack: Blitzstromverhalten von Niederspannungs-Hochleistungs(NH)-Sicherungen, Jahrbuch Elektrotechnik 2005, VDE Band 24, ISBN 3-8007-2841-9