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FOLLOW CURRENT LIMITING LIGHTNING CURRENT ARRESTER FOR APPLICATION IN MAIN DISTRIBUTION SYSTEMS

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The “Technical Supply Conditions (TAB) for connections to low-voltage installations” of 1997 allow, for the first time, the use of lightning current arresters in main distribuiton systems upstream the meter mounting board kept under seal by the power supply company. The electrician can now offer a modern solution to the customer. However, this is only possible when lightning current arresters are available meeting the high requirements stipulated to them with regard to the discharge capability and the mains follow current quenching capability. A newly developed technology fulfilling these requirements is described in the following.

By publication of DIN VDE 0100 part 534/A1 (draft) [1] regarding the application of lightning current arresters and surge arresters in l.v. consumer installations in agreement with the protection against indirect contact, a discussion has started about the use of lightning current arresters (Class-B-arresters according to E DIN VDE 0675 part 6 [2] and part 6/A1 [3]) in the sealed part of consumer systems. Reason for the discussion was that, on the one side a VDE-draft representing the state of engineering shows the application of lightning current arresters in the main distribution system of a consumer installation, on the other side, however, the majority of the power supply companies do not allow their application (with reference to the existing technical conditions for connection to l.v. distribution systems). This problem was solved by the publication of the technical conditions in the version of 1997 [4]. Now, it is possible for the electrician to offer a technical solution which does not only meet the general technical regulations, but also the present state of engineering. At the same time, the electrical industry is now requested to produce arresters which meet the specific requirements for application in main distribution systems.

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1. Requirements by the “Technical Supply Conditions”

Main distribution systems - from the delivery point of the power supply company through the final overcurrent protective device or main branch circuit terminal before the electricity meter - must have a short-circuit withstand capability of 25 kA peak short-circuit current according to section 7.2 of the “Technical Supply Conditions for the Connection to Low-Voltage Distribution Systems” [6].

Concerning the use of lightning current arresters in main distribution systems, only arresters on spark gap basis are allowed according to the “Instructions for the Application of Class-B-Arresters in Main Distribution Systems” [5]. Lightning current arresters of usual construction can meet the required short-circuit withstand capability of 25 kA at this location only in combination with a back-up fuse.

According to section 7.3 (2) of the technical supply conditions, the nominal current of the last overcurrent protective device upstream the measuring equipment must not exceed 100 A. Fuses upstream the measuring equipment with nominal currents lower than 63 A in combination with circuit breakers in consumer systems, however, will no longer guarantee a satisfying selectivity. That is why, the arrangement of overcurrent protective devices according to **Figure 1 and Figure 2** has proven in practice [6].

The back-up fuse of the arrester will be triggered if its follow current quenching capability is exceeded. Especially in case of low nominal current back-up fuses, it will always interrupt the mains follow current, because the pre-arcing I²t value of the fuse will already be exceeded by the flowing short-circuit current during the first current half-wave. This also happens when the arrester would still be able to quench the mains follow current automatically at the next zero crossing of the current wave (i.e. within 10 ms at least). For the application at main distribution systems, a lightning current arrester on spark gap technology in required which is able

1. to meet the requirements of the “Instructions for the Application of Class-B-Arresters in Main Distribution Systems” [5] with regard to the required discharge capability, and
2. to limit the arising mains follow current in a such way that the service fuses will not trip, in order to fulfil the demand of the “Technical Supply Conditions” (section 7.3 (1)) that selectivity must be guaran-

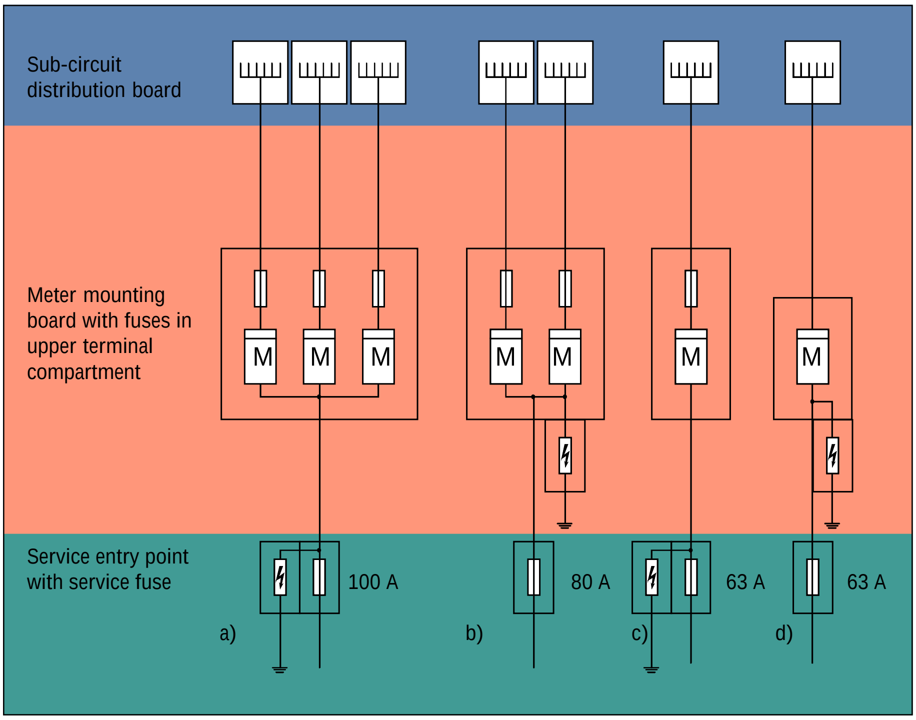

Figure 1: Suggested application of lightning current arresters in main distribution systems without line-side meter fuses

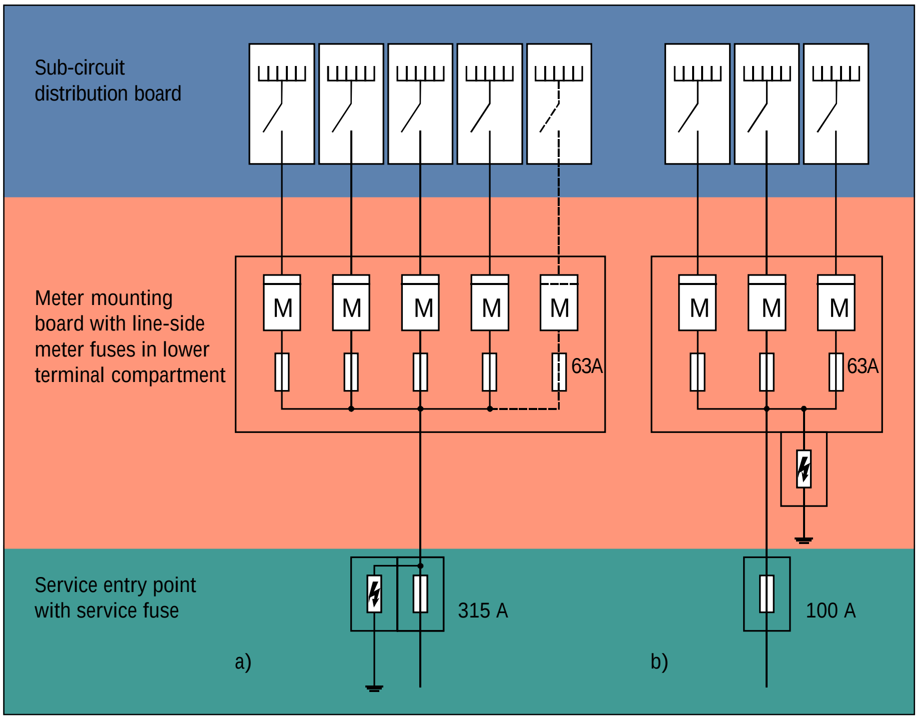

Figure 2: Suggested application of lightning current arresters in main distribution systems with line-side meter fuses

teed for the overcurrent protective devices which is kept under seal by the power supply company.

This means that there is a demand for a spark gap technology that is considerably different from the presently known.

2. State of the Arrester Technology

Presently available lightning current arresters (Class-B-Arresters according to E DIN VDE 0675 part 6/A1) are mostly designed in spark gap technology. This technology is chosen in order to safely control the high electrical and mechanical stress arising in the phase when lightning currents are discharged. By using the typical behaviour of spark gaps, the transient lightning currents of a waveshape 10/350 µs to be discharged are, at the same time, reduced to surges of compatible levels for downstream surge arresters (waveshape < 8/20 µs).

A further advantage of spark gap type arresters is that they can only have two defined operating states. This behaviour is comparable to that of a circuit breaker.

The two operating states are defined as follows:

- **Arrester has not operated (high-resistance state)**

In this operating state, the insulation resistance values of the spark gap are in the range of some 10 Megaohms. This value is by far higher than that required for the insulation resistance of 230/400 V low-voltage consumer systems. Thus, a spark gap type lightning current arrester at its usual operating state has an insulation capacity which is comparable to that of cables and conductors in low-voltage consumer systems. In this way, it is possible to use lightning current arresters before the meter which should be preferred with regard to the protection effects, avoiding that higher lightning currents or lightning partial currents are conducted through the meter. This also voids the concerns of the power supply companies regarding the "loss" of power due to leakage currents of the arresters.

- **Arrester has operated (low-resistance state)**

On exceeding a certain voltage value (sparkover voltage) at the terminals of the spark gap type arresters, the spark gap "switches" from the already described high-resistance state to a low-resistance state characterized by a resistance of a few Milli-ohms. Thereupon an arc is generated, where the energy of the arising surge voltage will be discharged to ground, so that the downstream installed systems and equipment are protected against the effects of surge voltages. However, this represents a short circuit in low-voltage consumer systems. On the now conductive spark gap of the lightning current arrester, a mains follow current is generated which can be as high as the maximum expected short-circuit current at the place of installation. Conventional types of lightning current arresters on spark gap basis are able to quench mains follow currents up to 4 kA_{RMS} (50 Hz). If the short-circuit current is due to exceed the mains follow current quenching capacity of the arrester, the mains follow current must be disconnected by a suitable overcurrent protective device. Hence follows that the application of lightning current arresters must be considered in correlation with the corresponding back-up fuse. This back-up fuse can either be the next upstream system fuse or it can be installed separately in the arrester branch. In order to avoid problems of selectivity, this, however, should only be done when the next upstream system fuse is rated higher than the maximum permissible back-up fuse indicated by the producer of the arrester [7]. That means that the operation of conventional spark gap type lightning current arresters, the power system will not only be stressed by transient lightning currents but also by short-circuit currents.

In order to keep these effects as low as possible, spark gaps have been developed not necessarily generating a mains follow current (short-circuit current). In order to achieve this, the arrester, for example, integrates two spark gaps connected in series. On operation of such a device, there will be two partial lightning arcs which, by their total voltage drop, act against the generation of a mains follow current already in the formation of the arc [7]. With regard to the availability and safety of operation of low-voltage consumer systems, the overcurrent protective device related to the arresters are weak points. They can be tripped due to the stressing by lightning currents and/or by mains follow currents, although there is no defective lightning current arrester. It would be advantageous for the user to have a lightning current arrester which

1. does not need any back-up fuse to safeguard the short-circuit withstand capability, and
2. limits mains follow currents to such low amplitudes that overcurrent protective devices in the low-voltage system will not be tripped.

3. New Spark Gap Principle

The spark gap in the lightning current arrester must build up a "counter voltage" in the range of the operating voltage of the supplying mains in order to reach such a follow current limiting behaviour. Quite a number of basic technical solutions are known from the l.v.- switchgear engineering for generating such a high "counter voltage" ("arc voltage"). In a number of switchgear equipment, the arc-voltage is increased by the arc prolongation using hornlike contact pieces. Sometimes, this effect is combined with a deion plate package which splits the total arc into partial arcs again improving the quenching capacity. These decade-long proven construction methods of switchgear engineering can only be used in spark gaps fulfilling certain conditions:

This method requires a considerable volume so that the application in compact arresters is almost impossible. Further constructive marginal conditions must be considered, especially due to the lightning current stressing of arresters. Therefore, a completely new function principle had to be developed for the required follow current limiting spark

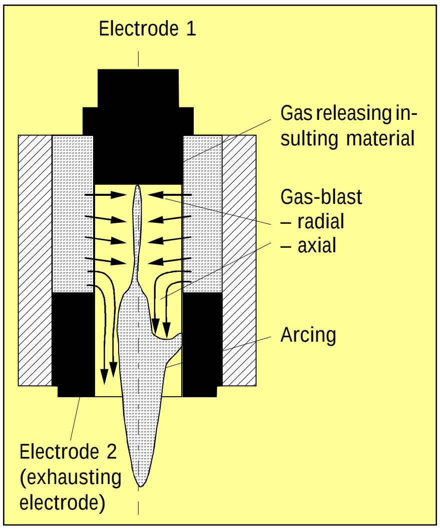

Figure 3: Function diagram of an arc blast radially and axially (RADAXflow technology)

gap:
It is based on an optimized cooling of the arc by radial and axial blowing. The hereto necessary cooling gas is generated under the influence of the arc by the surrounding plastic material. The forced exhaustion achieved by this causes the desired influence on the arc voltage [8].
Figure 3 is the function diagram of a **rad**ially and **ax**ially blast arc (RADAXflow-technology): The cooling gas released under the influence of arc streams radially (from all sides) towards the arc and "presses" it. The reduction of the cross section of the arc pillar causes an increase of the arc resistance and thus an increase of the arc voltage. The gas heated by the influence of arc is finally exhausted by anaxial gas flow through an expulsion nozzle.

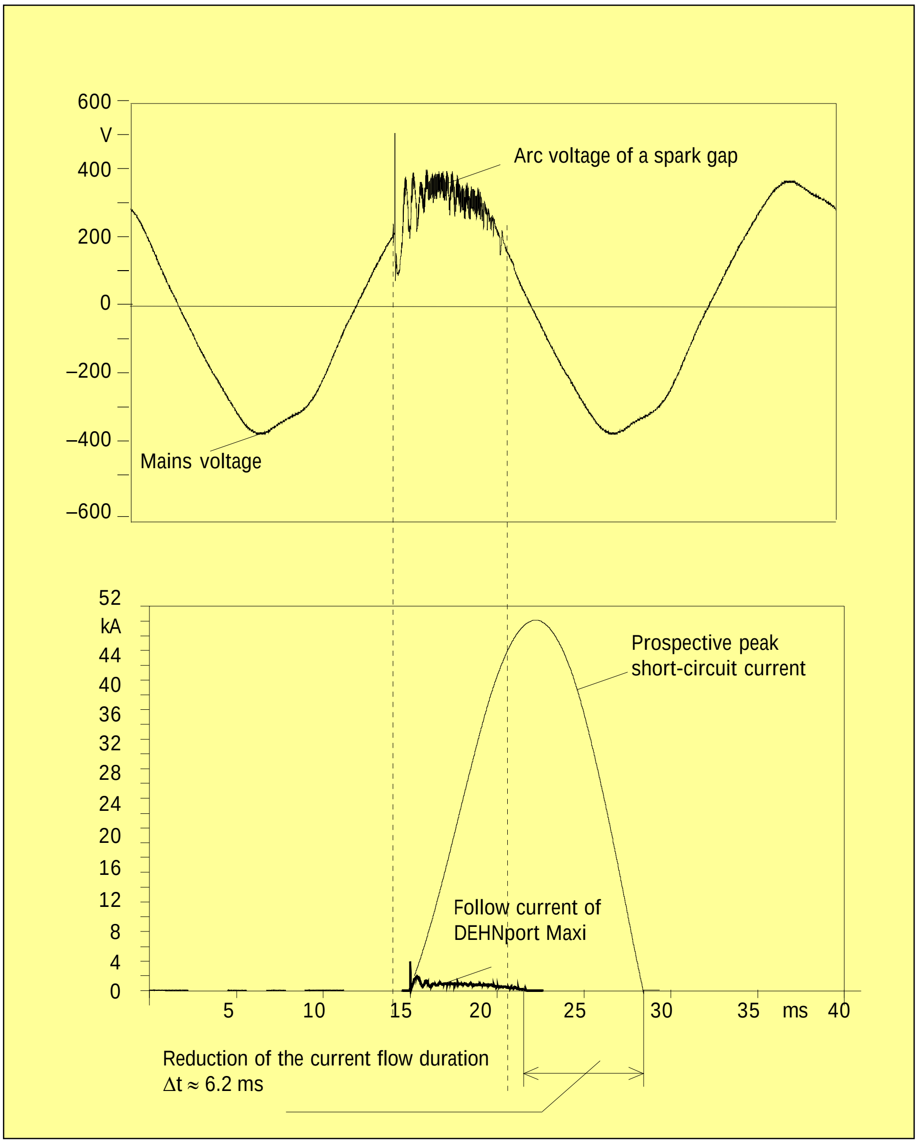

Figure 4: Interruption of the short-circuit current using the RADAXflow technology (DEHNport® Maxi)

4. Mains Follow Current Behaviour of Arresters in RADAXflow Technology

After the discharge of the lightning surge current there may be a follow current through the spark gap arrester under the influence of the mains voltage (as described). In case of usual spark gap arresters an amplitude of the follow current appears that is almost equal to that of the prospective peak short-circuit current of the mains. In case of the RADAXflow-spark gap technology, the follow current (let-through current) which is actually flowing through the arrester will be limited to a very low value, independent from the possible mains short-circuit current. **Figure 4** shows the typical tripping characteristic (prospective peak current: 37 kA_{RMS}, cosφ = 0.23) of an arrester in RADAXflow-technology. The arc voltage shown in the upper part of the figure hardly differs in its amplitude from the mains voltage (the „dip" of the mains voltage which is typical for conventional spark gaps, does not appear). In this way, electronic devices sensitively reacting on voltage dips or fluctuations are not interfered. The effective limitation of the mains follow current is apparent in the lower part of the oscillogram: It represents the prospective (i.e. the theoretically possible) as well as the actually flowing short-circuit current through the arrester. As one can see, only a very little share of the theoretically possible current stresses the arrester and thus the whole l.v. system.
Another effect of the high arc resistance is the reduction of the current flow duration. As the oscillogram **(Figure 4)** demonstrates, the let-through current of the arrester DEHNport Maxi in RADAXflow-technology is only about 1.7 kA even at a short-circuit current up to 37 kA_{RMS}.
Figure 5 shows this value transferred to a scheme as usual for the selectivity consideration of overcurrent protective devices (fuses, circuit breakers): It shows the let-through integral (I^2t) of the RADAXflow-arrester DEHNport Maxi at different short-circuit currents. The pre-arcing values of NH-fuses of different nominal currents are also indicated for better classification. Arresters in RADAXflow-technology can, as **Figure 5** shows, effectively limit short-circuit currents of 50 kA_{RMS}. The integral of the let-through current remains lower than the fusing integral of a 63A-fuse so that it cannot trip it. This let-through current limiting characteristic brings about the selectivity between the overcurrent protective devices in low-voltage consumer systems and lightning current arresters.
When installing a Class-B-Arrester (lightning current arrester) in RADAXflow-technology in the main distribution system, a tripping of the service fuses or line-side meter fuses by mains follow currents is avoided.
Thus, the user practically does not notice an operation of the lightning current arrester.

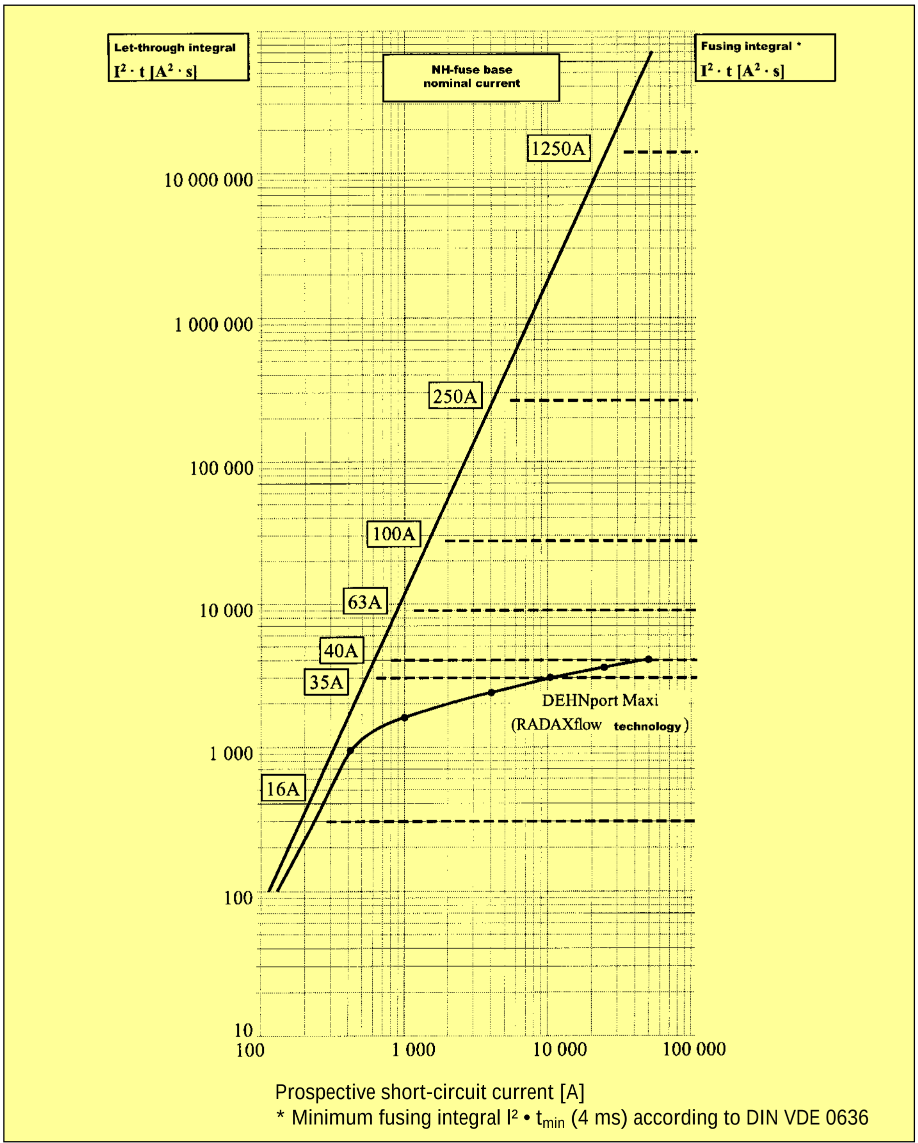

Figure 5: Selectivity peak current with several back-up fuses and DEHNport® Maxi

Figure 6: Lightning current arrester DEHNport® Maxi in RADAXflow technology for series installation

5. Summary

By converting the RADAXflow-technology into a series bay of usual dimensions **(Figure 6)**, the user has got a completely new generation of lightning current arresters combining lightning current discharge capacity with the breaking behaviour of a circuit breaker. The problem of false tripping of fuses due to mains follow currents is solved.
Because of these excellent operating characteristics, lightning current arresters in RADAXflow-technology (for example DEHNport® Maxi) are especially suitable for use at that part of the consumer system which is sealed by the power supply company (main distribution system).

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