



Technical information

# COUPLING SURGE ARRESTERS IN MEDIUM VOLTAGE NETWORKS

BBC Cellpack in collaboration with the FKH in Zurich

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This brochure was prepared in cooperation with the High Voltage Testing and Engineering Commission based in Zurich, Switzerland (FKH Zurich) between February and April 2020. It contains general information on surge arresters for the medium-voltage distribution grid and explains general terms as well as the basic selection approach of surge arresters. This brochure was prepared to provide general technical information. It is not a guideline for the selection of a particular surge arrester, since only the respective customer knows the detailed actual grid conditions in each individual case. The respective user in each individual case is therefore solely responsible for selecting a suitable surge arrester, taking into consideration the respective grid conditions.

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# Surge arresters in medium-voltage grids

## 1 | FUNCTION OF SURGE ARRESTERS MEANING OF THE ARRESTER DATA

Surge arresters protect the internal insulation of high-voltage equipment against short term overvoltages. These are caused by lightning strikes (atmospheric overvoltages) or by switching operations (switching overvoltages).

It must be taken into consideration that surge arresters cannot be used to limit temporary overvoltages and in particular not against an unwanted temporary voltage rise due to earth faults in the distribution grid. A surge arrester, with its non-linear characteristics, must be selected so that it does not reach a conductive state in case of temporary overvoltages. It would otherwise be thermally overloaded (see section 2.1). The surge arrester however should reliably limit high dangerous impulse voltages.

The focus is primarily placed on protecting the non-self-healing insulation of the equipment in the medium voltage grid. Overhead medium voltage lines with air-insulated sections are generally not protected by surge arresters. Flashovers on the self-healing outdoor insulation are tolerated for overhead lines. After short disconnection for the arc extinguishing between phase-to-phase or phase-to-earth ground, operation can be continued immediately.

Above all, the distribution transformers and the switchgears, as well as the cables and their accessories are protected against overvoltages. The surge arresters must therefore be installed directly next to the equipment that requires protection. (See section 3)

### 1.1 | TOUCH-PROOF COUPLING PLUG SURGE ARRESTER CTKSA

The CTKSA coupling surge arresters should be installed on the switchgear cable entry and only with the screened separable connectors of BBC Cellpack. Surge arresters are touch-proof and have a screened body according to DIN EN IEC 60099-5 (VDE 0675-5): 2019-02 [2], section 5.2.2.5. Despite their touch-proof features during operation, the switch field must be de-energised and earthed when the surge arresters are disassembled and removed. Disassembly of a surge arrester from the coupling system further requires subsequent voltage-proof termination of the remaining system with insulated screw inserts.

Important applications of CTKSA surge arresters include the following:

- at cable entry points in mixed grids with overhead and cable lines
- on cable outgoing feeder panels for protection against switching overvoltages, especially for longer cable lines
- on transformers with separable connectors with longer cable entry points

Since surge arresters must comply with a specific test standard, application of standards for cable accessories is impossible. It is important to pay attention to the variations in terminology, especially in the voltage terms used.

## 1.2 | DEFINITION OF THE MOST IMPORTANT ELECTRICAL PARAMETERS TO CHARACTERISE A SURGE ARRESTER

- $U_s$  Maximum permissible continuous operating voltage ("system voltage") in the distribution grid (interlinked voltage, RMS value), frequently designated as U in cable accessories sector.
- $U_c$  Maximum permissible continuous operating voltage RMS value of the AC operating frequency) across the arrester terminals for which the thermal stability of the arrester has been verified according to operating duty test.
- $U_{res}$  Measured peak value of the residual voltage of a surge arrester during standard current impulse. Residual voltages measured at individual MO (metal-oxide) resistors can be added to the total residual voltage of an overall arrester.
- $U_{pl}$  Maximum residual voltage of a surge arrester for a lightning discharge current impulse ("lightning impulse protection level")
- $U_{ps}$  Maximum residual voltage of a surge arrester for a switching leakage current surge ("switching surge protection level").
- $U_r$  Rated voltage of a surge arrester, maximum permissible 10s power frequency r.m.s. overvoltage (according to test specifications).
- $U_{ref}$  Reference voltage of an arrester: peak value of the operating frequency voltage divided by  $\sqrt{2}$  across the arrester terminals at which the reference current  $i_{ref}$  flows.  $U_{ref}$  and  $i_{ref}$  are characteristic values which define an operating point which is located in a range of the current voltage characteristic curve where the ohmic leakage current becomes dominant compared to the capacitive current. Voltages higher than  $U_{ref}$  cause a thermal overload of the arrester.
- $Q_{rs}$  Maximum repetitive charge transfer rating during the operation duty test.
- $Q_{th}$  Maximum thermal charge transfer rating. Charge that can be discharged by the arrester within 3 minutes during the thermal recovery test without any thermal runaway during the recovery test.
- $W_{th}$  Maximum thermal energy absorption capacity in kJ/kV of  $U_r$ , which can be introduced into the arrester within 3 minutes without inducing thermal runaway, proven by the so-called thermal stability test.
- $I_n$  Peak value of Leakage lightning impulse currents, for which the residual voltage of the arrester is specified.
- $T_1$  Front time: 1.25 times the time in which a current impulse increases from 10 % to 90 % of its peak value.
- $T_2$  Time to half-value: Time between the start of the surge until it falls to half of its peak value.

## 1.3 | ATMOSPHERIC OVERVOLTAGES

Atmospheric overvoltages in medium-voltage installations may only be expected in grids with overhead lines or outdoor installations. Overvoltages occur not only during lightning strikes direct into the conductors, but also during lightning strikes in the immediate vicinity of medium-voltage overhead lines. The voltages induced by the electromagnetic field, which is generated by the lightning current, may cause flashovers across the insulators. This is why surge arresters, which are used at the ends of medium-voltage overhead lines, are not used to protect the overhead lines themselves, but the equipment connected to them.

Surge arresters are not essential in pure cable networks. Dangerous surges due to lightning strikes can be ruled out to a large extent.

The protective effect of surge arresters against atmospheric overvoltages is defined by the residual voltages to which the arrester limits the voltage during lightning current impulse.

To characterise the arresters, the residual voltages at standard impulses with different amplitudes and shapes are used (Table

Designation	Front time	Time to half-value	Peak value according to classification			
Lightning impulse	8 $\mu$ s	20 $\mu$ s	2.5 kA,	5 kA	10 kA	20 kA
High current impulse	4 $\mu$ s	10 $\mu$ s	25 kA	65kA	100 kA	
Steep current impulse	0.9 ... 1.1 $\mu$ s	<20 $\mu$ s	2.5 kA	5 kA	10 kA	20 kA
Switching impulse	30 ... 100 $\mu$ s	60 ... 200 $\mu$ s	250 A, 500 A, 1000 A, 2000 A			
Thermal charge transfer rating, medium voltage: $Q_{th}$				0.45 ... 10 C		

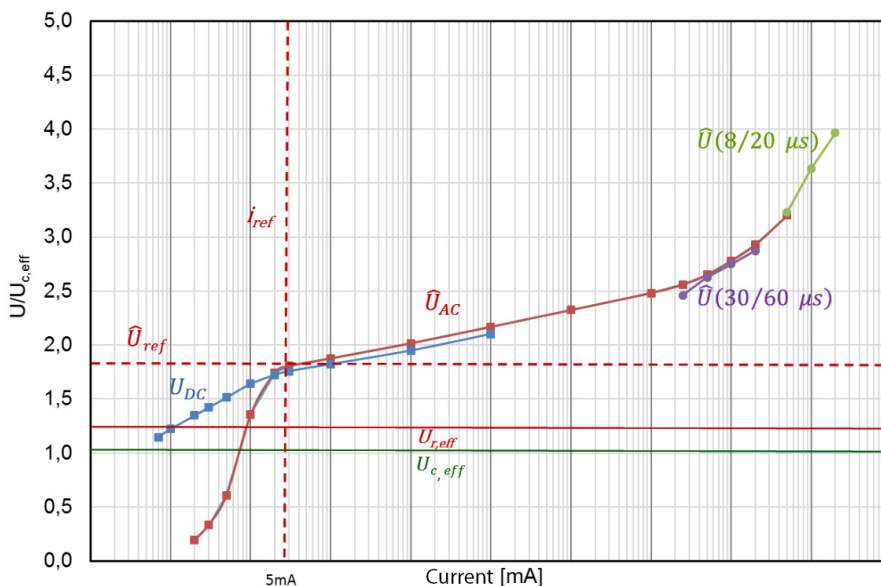
**Table 1** | Test loads of medium-voltage arresters: standardised current impulse shapes to simulate lightning strikes and switching transients as well as value range for the charge transfer rating

## 1.4 | SWITCHING OVERVOLTAGES

In special cases surge arresters are also being used to protect against switching overvoltages. To characterise the residual voltages of surge arresters in this area, there are also standardised longer switching current impulses with a correspondingly lower amplitude (Table 1). An important case of a switching overvoltage is when the voltage doubles on a connected cable or overhead line due to reflection at the open end on the opposite side.

## 1.5 | ELECTRICAL CHARACTERISTICS OF SURGE ARRESTERS DEFINITION OF VOLTAGE LEVELS

The highly non-linear dependence of the arrester current on the applied voltage is represented in Figure 1 over the entire relevant functional range of an arrester. The characteristic curve sections are shown in a qualitative manner and are not considered as specifications. The most important voltage and current characteristics are indicated in the diagram (see also definitions in the section 1.2).



**Figure 1**

Qualitative current-voltage characteristics of a surge arrester for DC voltage, AC voltage, switching and lightning current impulses. The peak value is indicated for alternating voltage. The most important values for the voltage characteristic are presented (see definitions).

## 2 | SELECTING OF THE SURGE ARRESTER

### 2.1 | SELECTION BASED ON THE MAXIMUM PERMISSIBLE CONTINUOUS OPERATING VOLTAGE $U_c$

The maximum permissible continuous operating voltage  $U_c$ , which may be continuously applied across an arrester, is one of the most important dimensioning parameters of an arrester. It must not be exceeded for a considerable period of time during operation to prevent thermal overload of the arrester. The voltage may be exceeded by transient overvoltages and by temporally limited slighter higher voltages lasting a few seconds, which is specified by a characteristic curve (Figure 5). For example, the surge arrester may be loaded with the specified voltage  $U_r$  for 10 seconds.

The correct dimensioning of the permissible continuous operating voltage  $U_c$  takes first priority even before selecting the lowest possible level of protection. If the  $U_c$  is dimensioned too low and does not take into consideration, for example, the highest temporary overvoltages that may occur, the arrester may fail in corresponding operating situations with corresponding consequential damage. The temporary overvoltages (earth fault/earth short circuit) primarily depend on the neutral point treatment.

It should be noted that a large number of special cases are possible for the neutral point treatment. A conclusive description of the respective neutral point treatments and the influence on the selection of surge arresters shall therefore not be given here, especially since the localisation of the surge arrester (application between phase-to-earth or neutral point and earth) play a significant role.

For this reason, only the cases of "ungrounded neutral system" and "solid grounding" are described below in a simplified form for the case of installing the arrester between phase and earth.

#### Simplified representation for low-resistance earthed neutral point

The most important issue is how the distribution network behaves in the event of an earth fault. The neutral point treatment determines the phase voltages which occur in case of an earth fault. The decisive factor is the earth fault factor  $m$ , which, in the event of earth fault, defines the ratio of maximum phase voltages on the unaffected phases to the phase voltage during normal operation.

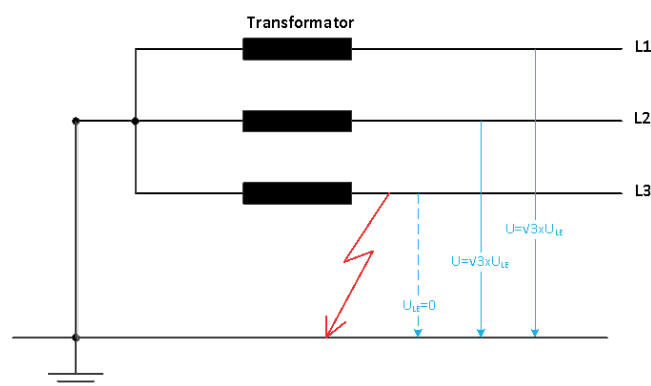


Figure 2 | Faulty low-resistance earthed neutral point

The earth fault factor is  $m = 1$  for a grid with directly earthed transformer neutral points (an exception in medium-voltage networks). This means that the phase voltages of the unaffected phases generally remain unchanged in case of an earth fault, because a rapid disconnection usually occurs in less than one second (a so-called earth short circuit with corresponding tripping current for an overcurrent protection device).

In this case, the arrester must be required to have a maximum continuous voltage  $U_c$  that is greater than the system voltage during operation.

$$U_c > U_s / \sqrt{3}$$



A safety factor of 5% is usually chosen:

$$U_c = 1.05 \cdot U_s / \sqrt{3}$$

#### Simplified representation for isolated neutral point or earth fault compensation

In network with "isolated transformer neutral points" or in the "inductive compensated networks" the phase-to-earth voltage on the unaffected phases rises continuously to the value of interlinked voltage (system voltage). This voltage rise can occur over several hours or days (the so-called "earth fault"). The following therefore applies to the earth fault factor:  $m = \sqrt{3}$ .

The following then applies to  $U_c$ :

$$U_c > U_s$$

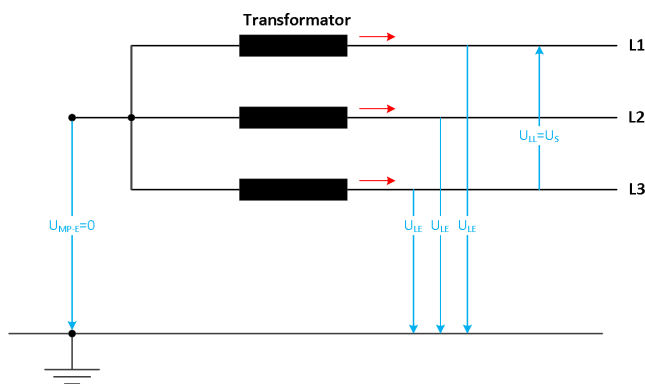


Abbildung 3 | Isolated neutral point without fault

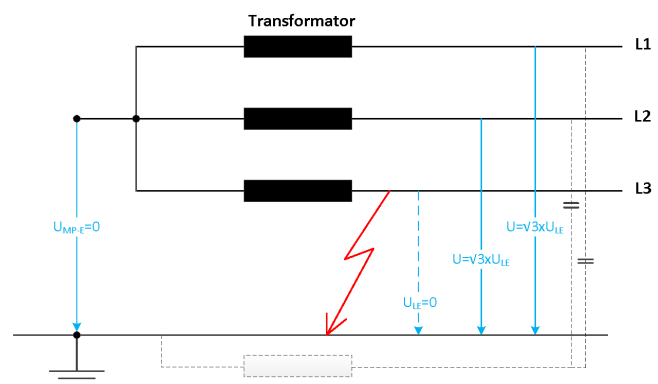


Abbildung 4 | Isolated neutral point with a fault

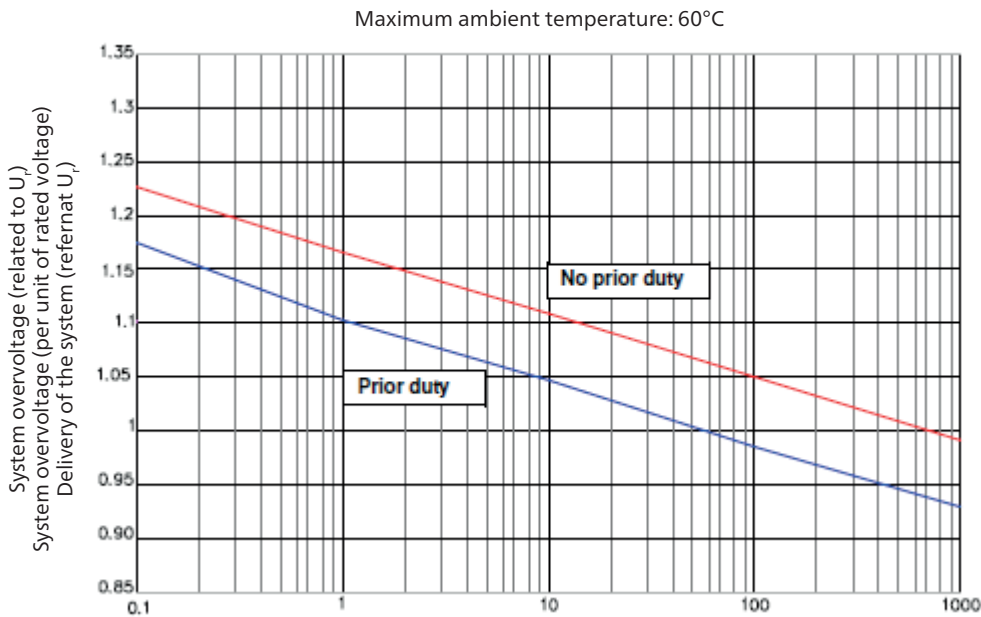
It must be taken into consideration that voltages higher than  $U_c$ , so-called temporary overvoltages, can overload the arrester. This would be the case, for example, if the terminal voltage would ultimately be above the selected voltage  $U_c$  after the voltage was increased by a factor of  $\sqrt{3}$ .

For the design of  $U_c$  in addition to the above conditions, a small reserve must be provided which takes into consideration the highest possible operating voltage, the presence of harmonics as well as voltage transients in case of repetitive earth faults. This is why the manufacturer specifies a voltage-time curve which indicates the maximum duration for exceeding the continuous operating voltage  $U_c$ . This curve is still permissible without overloading the arrester (Figure 5).

Two different curves are specified for the overload time curve:

1. in case the arrester has been pre-loaded by a preceding transient overvoltage and a corresponding preheating process was carried out (lower blue line)
2. for the non-preloaded case (upper red straight line).

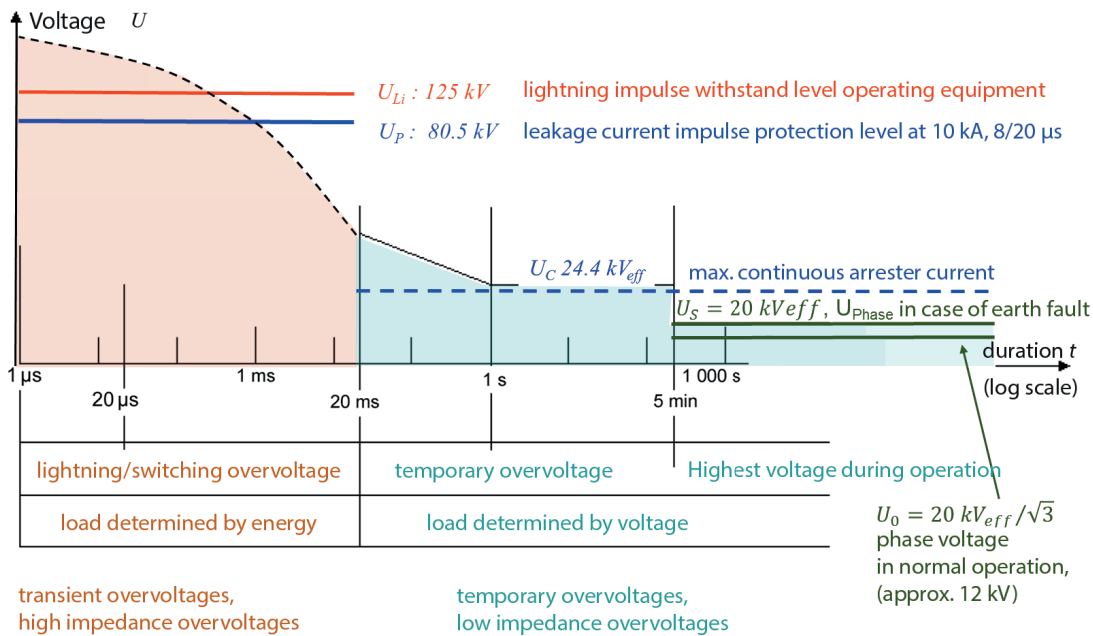
The lower straight line applies to standardised preloading, which corresponds to the nominal thermal charge transfer rating  $Q_{th}$  and is specified for each type of arrester. To verify the specified load capacity with temporary overvoltages, the arrester is subjected to two lightning current impulses within 1 minute, the net charge of which must correspond to  $Q_{th}$ . The arrester must then withstand any overvoltage with the corresponding duration according to the red curve without sustaining any damage. This is selectively checked with an alternating voltage load directly following the impulses with  $U_r$  for 10 seconds and then with  $U_c$  for 30 minutes (see also section 2.4).


**Figure 5**

Voltage-time diagram for the permissible temporary overvoltages (Temporary Overvoltage TOV) according to (IEC 60099-4 [1] section 6.10) at 60°C ambient temperature. Top red: no prior duty, bottom blue: prior duty with the maximum thermal charge transfer rating  $Q_{th}$

After determining the minimum permissible continuous voltage at the arrester  $U_c$ , the next higher stage value is usually selected from the manufacturers table.

The considerations regarding insulation co-ordination and the selection of the characteristics of the surge arrester are summarised in Figure 6 (see also Figure7).


**Figure 6**

Voltage levels according to IEC 60071-1 [3] for planning the insulation co-ordination in a medium-voltage grid using an example of an arrester with  $U_c$ : 24.4 kV ( $U_i$ : 30 kV) with  $U_{residual}$  8/20μs/10kA = 80.5kV:  
red: Equipment insulation level  
blue: Voltage level of the surge arrester  
dark green: operational voltage values

## 2.2 | CHECK OF THE PROTECTION LEVEL

For each type of arrester, the protection levels for the impulse voltage forms, which are tabulated in the brochure, are obtained by selecting  $U_c$ , Table 2. If the highest network voltage during operation is 20.8 kV (fault operation), the type CTKSA 24 kV would have to be selected.

Figure7 provides an example of the voltage curve on one phase during the limitation of a lightning impulse voltage by a surge arrester to the corresponding residual voltage at a lightning impulse of 8/20μs 10 kA.



Technical data	CTKSA 8kV	CTKSA 12kV	CTKSA 17kV	CTKSA 19,5kV	CTKSA 22kV	CTKSA 24kV	CTKSA 34kV
Rated voltage ( $U_r$ )	10 kV	15 kV	21 kV	24 kV	27 kV	30 kV	42 kV
Maximum continuous operating voltage ( $U_c$ )	8.0 kV	12.7 kV	17.0 kV	19.5 kV	22.0 kV	24.4 kV	34.0 kV
Residual voltage (IEC 60099-4) with:							
Steep current impulse (1/T, $T < 20 \mu s$ )	28.3 kV	42.5 kV	59.5 kV	68.0 kV	76.5 kV	85.0 kV	119.0 kV
Lightning current impulse 8/20 $\mu s$ :							
5 kA	24.8 kV	37.2 kV	52.1 kV	59.6 kV	67.0 kV	74.4 kV	104.0 kV
10 kA	26.9 kV	40.3 kV	56.4 kV	64.4 kV	72.5 kV	80.5 kV	112.8 kV
20 kA	29.3 kV	44.0 kV	61.6 kV	70.4 kV	79.2 kV	88.0 kV	123.2 kV

Table 2 | Manufacturer specification of the arrester data

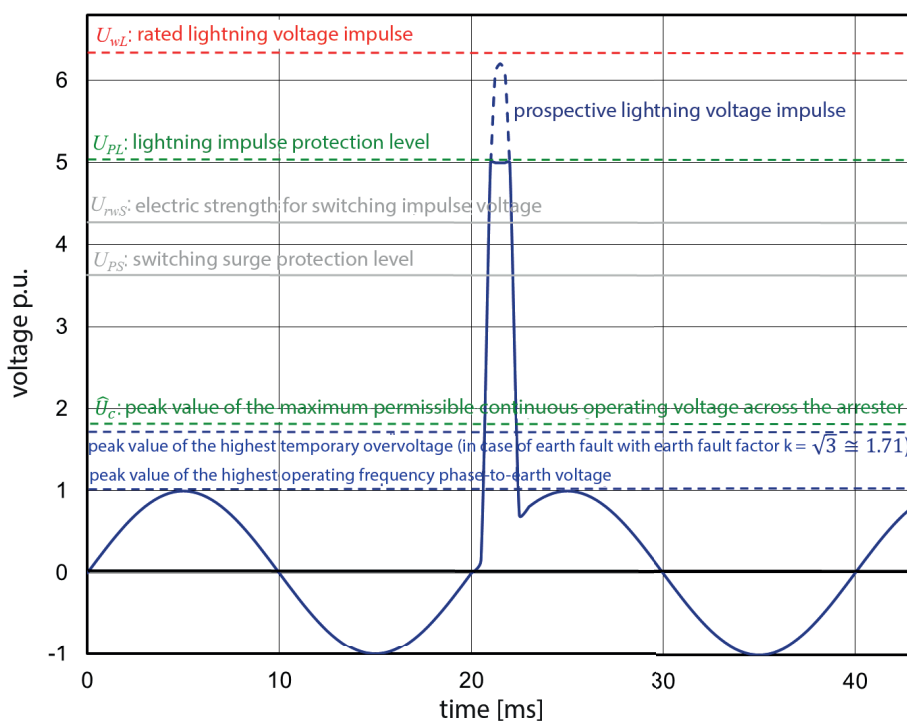


Abbildung 7

Example of a voltage curve of a network phase when a lightning overvoltage occurs, which is limited ("cut off") by a surge arrester. Comments: Note that, unlike in Figure 1, the unit of voltage (1 p.u.) is not the RMS value but the peak value. For the withstand voltage at switching impulse voltage, the factor from [4] item 5.2 was used  $U_{rw}$  ("required withstand voltage").

### 2.3 | SELECTING THE NOMINAL DISCHARGE CURRENT $I_n$

The nominal discharge current should correspond to the current impulse at the maximum expected lightning overvoltage at the input of a switching station. The arrester is designed to meet the requirements arising from a distant lightning strike into the overhead line. Usually dimensioning for a rare lightning strike with a high lightning impulse  $> 100$  kA directly at the connection point of a transformer station is not cost-effective.

In the event of a strike into an overhead line, the maximum current amplitude  $I_{max}$ , which the arrester must conduct to earth,

is calculated from the flashover voltage  $U_{fo}$  of the overhead line insulators, the lightning protection level  $U_{pl}$  of the arresters and the characteristic impedance  $Z$  of the overhead line.

$$I_{\max} = \frac{2 \cdot U_{fo} - U_{pl}}{Z_s} \quad (1)$$

$U_{fo}$  Flashover voltage of the overhead line insulation  
 $U_{pl}$  Protection level during a lightning impulse  
 $Z$  Wave impedance of the line

The following numerical values can be calculated for a network with  $U_s = 20$  kV (12/20 (24) kV):

$$Z=300 \, \Omega, \quad U_{fo}=320 \, \text{kV}, \quad U_{pl}=80.5 \, \text{kV}, \quad \Rightarrow I_{\max}=1.865 \, \text{kA}$$

In this case, an arrester for 10 kA nominal discharge current with a reserve could be sufficient. However, for strikes close to the station, the leakage current increases up to the value of the lightning impulse, depending on the distance of the strike, and may exceed the determined value.

## 2.4 | CRITERIA FOR SELECTING THE ARRESTER CLASS (PERFORMANCE CHARACTERISTICS OF THE CLASSES)

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In contrast to the voltage parameters of the surge arresters, the values regarding the energy absorption capacity is less clear, and the effect on network availability is also complex. As a result, the class selection must be based either on extensive studies or on experience-based rules of the network operator.

The design of the arrester class depends on the maximum expected energy with which the surge arrester can be loaded during operation.

Even arresters of lower classes can generally withstand the load caused by atmospheric overvoltages or their lightning impulse currents at the end of overhead lines without any damage. Technical parameters with respect to atmospheric loads is always a matter of statistics and always refers to the characteristics of the discharge capacity for a specific percentile of the lightning charges, which only put full load on the arrester in the event of close lightning strikes into the line. Usually it must be assumed that in the event of rare nearby lightning strikes with a high current amplitude, surge arresters may be overloaded, fail and trigger an earth fault (for statistics on lightning parameters, see lightning protection standard IEC 62305-1 [8]).

The arresters, however, should be able to repeatedly discharge overvoltages due to the relatively frequent switching operations in the network without any damage.

A typical overvoltage that must be dissipated is, for example, a voltage that doubles when an unloaded cable is switched on.

The thermal switching energy of the arrester depends on the following parameters:

- Overvoltage level and waveform
- Network configuration and line impedance
- Protective properties of the arrester
- Frequency of switching operations within a short period of time.

The energy absorption capacity of the selected surge arrester must finally be greater than the energy accumulated during the most unfavourable switching operation. Determination of the required energy absorption capacity is made more difficult by the complicated shapes of the switching transients and by the non-linear characteristics of the surge arrester.

Before the edition of IEC 60099-4 (2009) [1] was published, energy absorption capacity was defined in the form of line discharge classes 1 to 5. Class 1 was intended for arresters in the distribution network and classes 2 to 5 for station arresters and applications with repetitive loads.

Since the 2014 edition, the station arresters have been designated S (station) and the arresters in the distribution network D (distribution). For both application types there are three application classes (H: high, M: medium, L: low).

The thermal load capacity of surge arresters is specified by the three parameters described below. Tests must be carried out to verify compliance with these parameters. The tests are designed to ensure the quality and reliability of the arresters according to their class. The definitions of these parameters according to IEC 60099-4 [1] are indicated in Table 3 for the standard surge arrester classes (see also definitions in section 1.2).

### $Q_{rs}$

The repeated nominal charge transfer rating is demonstrated with twenty impulses in groups of two. The arrester is allowed to cool down to ambient temperature between the groups of two. The test simulates unfavourable multiple operational loads. The value is about four times lower than the thermal charge transfer rating.

### $Q_{th}$ und $W_{th}$

The two parameters thermal charge transfer rating and specific thermal energy absorption capacity quantify the unique ability to absorb an energy input without sustaining any damage. This can be expressed in the form of a warming rate that is still tolerable. The aforementioned parameters are equivalent to each other and both feature the charge unit "Coulomb". The thermal energy absorption capacity  $W_{th}$  is specified in relation to the voltage  $U_r$  ([kJ/kV]  $\triangleq$  [C]). The verification in the type test is provided after preheating to 60°C by applying  $Q_{th}$  or  $W_{th}$ . The arrester must withstand a subsequent alternating voltage load with  $U_r$  for 10 seconds and then with  $U_c$  for 30 minutes.

During all these tests, the arrester must not become thermally unstable. In addition, it must not exhibit any mechanical damage or a significant change in its electrical characteristics.

Arrester class	Station			Distribution		
Designation	SH	SM	SL	DH	DM	DL
Nominal discharge current [kA]	20	10	10	10	5	2.5
Switching impulse discharge current [kA]	2	1	0.5	-	-	-
$Q_{rs}$ [C]	$\geq 2.4$	$\geq 1.6$	$\geq 1.0$	$\geq 0.4$	$\geq 0.2$	$\geq 0.1$
$W_{th}$ [kJ/kV]	$\geq 10$	$\geq 7$	$\geq 4$	-	-	-
$Q_{th}$ [C]	-	-	-	$\geq 1.1$	$\geq 0.7$	$\geq 0.45$
Corresponding previous line discharge class according to IEC 60099-4: (2009)	4/5	3	2	1	-	-

**Table 3** Classification of surge arresters according to their energy and charge absorption capacity in accordance with IEC 60099-5.  
Comment: The last line with the previously used line discharge classes is derived from table L.3 in IEC 60099-5:2018 [2].

Within this context, DIN EN IEC 60099-5 (VDE 0675-5):2019-02 [2] stipulates the following:

"Arresters with the designation SL, SM or SH are generally used for surge arresters which protect equipment in high-voltage switchgear. Arresters with the designation DL, DM or DH are primarily used in medium-voltage grids."

Arresters of the Distribution High classification (high energy absorption capacity) are primarily used in medium-voltage distribution networks to protect transformers, medium-voltage switchgears and circuit breakers. Other applications include the protection of generators, motors, smelting furnaces, dry transformers as well as airfield lighting and converters for electrical drives. Applications involving one-sided earthing also include protecting cable sheaths (induction phenomena due to over-voltages occurring in the conductor).

Computer simulations of the switching operations may provide information for precise determination of the energy or charge load of the arrester.

If no such studies are available for the switching conductors, equation (2) offers an approximate conservative estimation of the necessary energy absorption capacity  $W$  (see also the definition of the conductor discharge class equation in IEC 60099-4 [1], table 5).

The simplified energy equation (2) is based on the assumption that the entire line is charged to a prospective switching impulse voltage and discharged by the arrester to the value of the protection level within twice the wave travel time of the line.

$$W = U_{ps} \cdot Q_s = U_{ps} \cdot \frac{U_{rp} - U_{ps}}{Z} \cdot \frac{2 \cdot L}{v} \quad (2)$$

$L$  Length of the line

$v$  Propagation speed of the travelling wave

$Q_s$  Charge discharged by the surge arrester

$Z$  Wave impedance of the line

$U_{ps}$  Residual voltage at the lower point of the specified switching impulse amplitude

$U_{rp}$  Highest switching overvoltage to be expected.

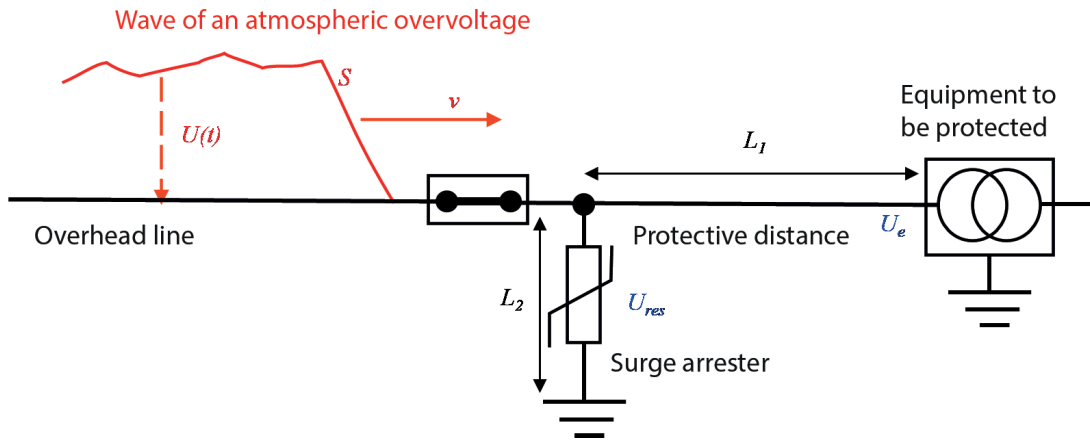
If a surge arrester is still overloaded, e.g. by a high current from a nearby lightning strike with a high amplitude, it will fail and cause an earth fault. When destroyed, it must not explode or result in consequential damage. The earth fault must be rectified by replacing the arrester.

### 3 | INSTALLATION PLACE CONSIDERATIONS CONCERNING THE PROTECTIVE AREA OF AN ARRESTER

When installing an arrester, the distance to the operating equipment requiring protection must be observed. A rough estimation of the protection area can be derived from the following considerations (see Figure 8):

After a lightning strike into an overhead line with flashover to earth, a travelling wave  $U(t)$ , which is limited to the earth flashover voltage, runs at a speed  $v$  towards the end of the line with the equipment to be protected. If it is a distribution station equipped with a transformer, it must be considered as high-impedance due to the winding inductance for fast processes. The same applies to an open switch. The voltage of the travelling wave is doubled to  $2 U(t)$  at this "open end" due to reflection. Upon closer examination, the voltage rise does not occur in stages, but with the voltage slope  $S$  of the incoming wave.

In any case, twice the running time on the section  $L$  must be shorter than the time period for the voltage rise of the travelling wave. The voltage rise is interrupted when the travelling wave, which is reflected at the transformer, has returned to the surge arrester. Equation (3) provides an approximate estimation for the voltage  $U_e$  that is still applied to the equipment. On the other hand, the protective distance  $L$  for the arrester can be derived from equation (4) from the rated lightning impulse voltage of the LIWV equipment. For this purpose, the length of the arrester with its connection to the earthing system must also be taken into consideration ( $L=L_1+L_2$ ). The distance  $L$  between the installation location of the arrester and the equipment to be protected is therefore of crucial importance.



**Figure 8**  
Schematic diagram for the approximate determination of the protective distance for an arrester at a distance

$$\frac{LIWV}{K_s} \geq U_e = U_{res} + \frac{2 \cdot S \cdot L}{v} \quad (3)$$

$$L \geq \frac{v}{2 \cdot S} \cdot \left( \frac{LIWV}{K_s} - U_{res} \right) \quad (4)$$

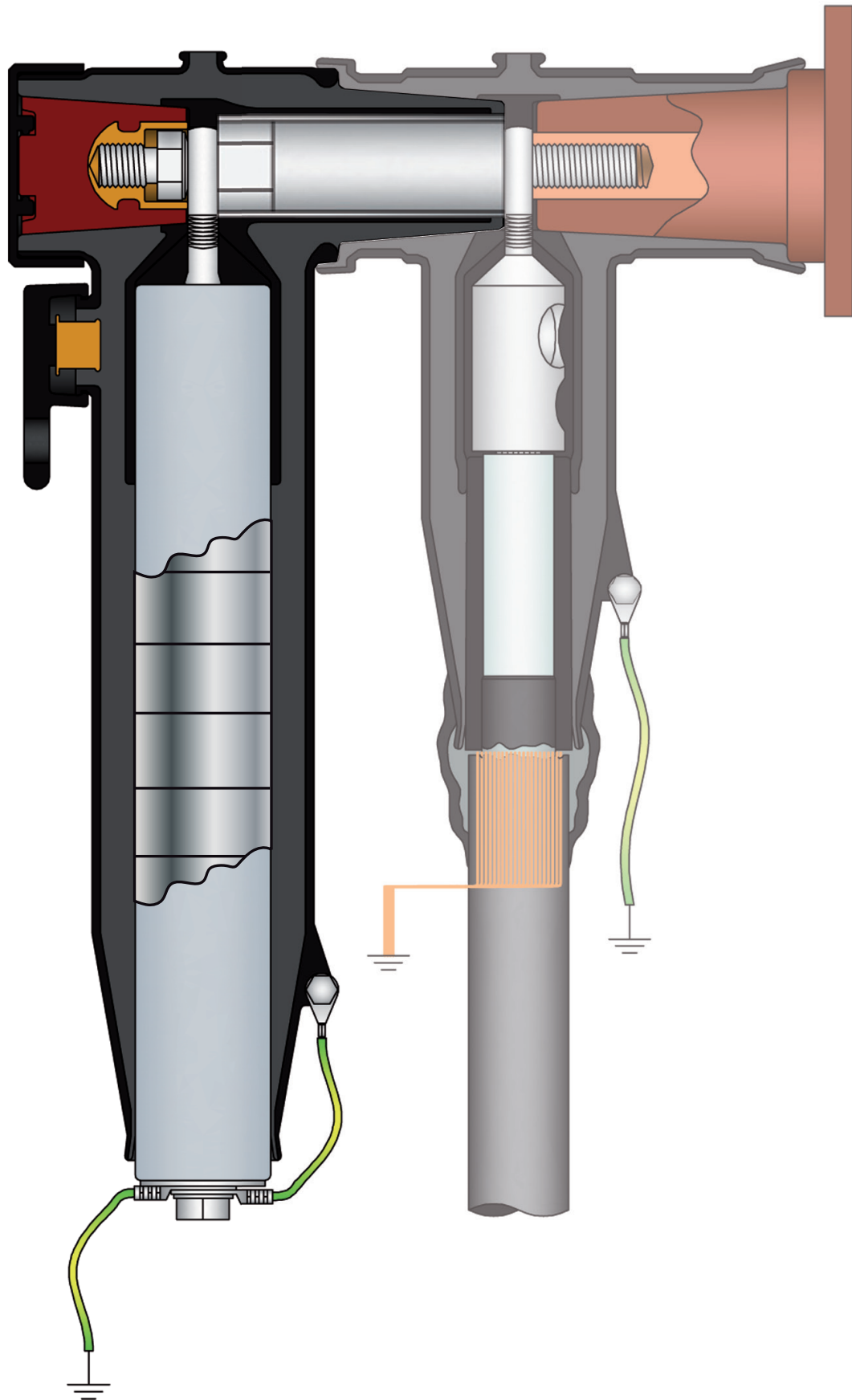
LIWV	LIWV "lightning impulse withstand value" also BIL "Basic Impulse Level"; at $U_m$ 24 kV, LIWV is: 125 kV)
$K_s$	Safety factor, reduction of the lightning impulse withstand level, based on experience , $K_s = 1.2$ should be selected [4]
$U_e$	Voltage occurring at the equipment insulation
$U_{res}$	Residual voltage = Protection level of the surge arrester
$S$	Front slope of the incoming lightning surge wave
$v$	Propagation speed of the overvoltage, approx. 300 m/ms
$L=L_1+L_2$	Protective distance of the arrester

## 4 | HANDLING OF THIS DOCUMENT - DISCLAIMER

This document is an information brochure which is intended to illustrate how to handle and to deal with surge arresters. In order to have this document simple, it is not possible to cover and describe all applications that may occur. The brochure intentionally does not serve and should not be seen as a specific selection guide, since BBC Cellpack, as a supplier, does not have the information regarding particular grid parameters and other conditions (in addition to rated voltage and operating voltage, as well as parameters, such as switch-off times, overvoltage levels, installation locations and equipment to be protected, etc.). **The selection of the surge arresters will remain the responsibility of the distribution system operator.** Only the operator can assess the potential loads that may occur and is able to prepare internal specifications for corresponding products. For this reason, no specific selection tables can be provided and therefore BBC Cellpack will not accept any liability for a wrong selection and the resulting consequences.

As is the case with all electrotechnical products, in addition to correct selection and calculation, only specially trained personnel with the relevant specialist expertise is allowed to be used for installation.

## 5 | SCHEMATIC IMAGE OF A COUPLING CONSTRUCTION CTS+CTKSA 630A TYPE C



## 6 | TERMS AND ABBREVIATIONS

### Lightning current impulse

Current impulse 8/20  $\mu$ s, for which the equipment must be designed to produce a front time between 7  $\mu$ s and 9  $\mu$ s and a time to half-value between 18  $\mu$ s and 22  $\mu$ s.

### Earth fault factor

Ratio of the highest RMS value of the phase-to-earth voltage during an earth fault on an unaffected phase to the RMS value of the phase-to-earth voltage during normal operation without an earth fault.

### IEC

International Electrotechnical Commission, based in Geneva.

### LIWV

Lightning impulse withstand value, also BIL "Basic Impulse Level"; at  $U_m$  24 kV, LIWV is: 125 kV).

### Residual voltage

$U_{res}$  Peak value of the voltage at the terminals of an arrester when a current impulse flows.

### Switching current impulse

Peak value of the current impulse with a front time between 30  $\mu$ s and 100  $\mu$ s and a time to half-value of approximately twice the front time.

### Protective area, protective distance

Area or distance from the surge arrester within which a high-voltage equipment must be located so that it is protected from atmospheric overvoltages through the surge arrester's voltage-limiting effect. The protection is valid up to a maximum lightning impulse amplitude and lightning impulse rise slope.

### TOV

Temporary overvoltage

## 7 | REFERENCE DOCUMENTS

### 7.1 | STANDARDS

- [1] IEC 60099-4: Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems
- [2] IEC 60099-5 Ed. 2.0: Surge arresters – Part 5: Selection and application recommendations
- [3] IEC/EN 60071-1, Insulation co-ordination Part 1: Definitions, principles and rules
- [4] IEC 60071-2 Ed. 3.0: Insulation co-ordination – Part 2: Application guide
- [5] IEEE Std C62.11-2012, IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV)
- [6] IEEE Std C62.22-2009, IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems Amendment 1: Supplement to Consider Energy Handling Capabilities
- [7] IEEE Std C62.22a-2013, IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems Amendment 1: Supplement to Consider Energy Handling Capabilities
- [8] IEC 62305-1 Protection against lightning. Part 1: General principles

### 7.2 | TECHNICAL LITERATURE

- [9] Hinrichsen, Volker: Metalloxid-Ableiter in Hochspannungsnetzen Grundlagen Siemens AG, [www.siemens.com/energy/arrester](http://www.siemens.com/energy/arrester)
- [10] Cigré report No 60 "Metal oxide arresters in AC systems" Working Group 06 of Study Committee 33, Cigré 1991, rue d'Artois 21, FR-75 008 Paris
- [11] Cigré report No 544 "MO Surge Arresters, Stresses and Test Procedures", Working Group A3.17, Cigré 2013, rue d'Artois 21, FR-75 008 Paris
- [12] ABB-Anwendungsrichtlinie Überspannungsableiter in Mittelspannungsnetzen [Application guideline for surge arresters in medium voltage networks], ABB, 5. Auflage 2011,
- [12] ABB-Anwendungsrichtlinie Überspannungsableiter in Mittelspannungsnetzen, ABB, 5. Auflage 2011,



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