



Surge Arresters for Distribution Networks

VARISIL™ Type HE(-S)



Presentation and Technical Guide

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VARISIL™ Type HE(-S) SURGE ARRESTERS

FOREWORD

Whatever the system voltage, power supply networks are stressed by transient overvoltages which often damage the equipment (power transformers, underground cables, ...) because of their high level.

There are two main types of overvoltages :

- overvoltages having an internal origin, i.e. caused by operation or layout of the network (switching surges, resonance phenomena, ...)
- overvoltages having an external origin, i.e. generated by external phenomena among which lightning is the most important.

On power Medium Voltage networks (Distribution networks), overvoltages due to lightning strokes prove to be the most energetic stresses, whether they are caused by direct strokes (overvoltages due to galvanic coupling) or, at a lower rate, indirect strokes (overvoltages due to capacitive and/or inductive coupling).

Their level may reach several hundreds of kilovolts and then far exceed the insulation withstand of the equipment. These overvoltages may then cause the equipment insulation to flashover or/and to puncture if no suitable surge protection device has been previously installed.

In case such a problem actually occurs, operators might regret not to have invested in surge arresters whose cost is far less than that of damaged equipment.

1 SURGE ARRESTERS

1.1 Protective devices

There are two main types of protection devices for Distribution networks : air spark gaps and surge arresters.

These are generally connected between phase and earth so as to create a weak point in the system insulation and thus ensure the overvoltage protection of the equipment against induced or direct surges.

Spark gaps are still widely used to protect air insulated equipment or when a low insulation level is not needed.

However, to improve quality of service, higher performance is required and surge arresters are necessary. Two technologies of surge arresters are available :

- **SiC surge arresters** : their active stack is an assembly of elementary air gaps and non linear silicon carbide resistors which are connected in series
- **MO surge arresters** : their active stack is only made of non linear metal oxide resistors.

The MO technology appeared in the early 70's and provides better performance than SiC. Therefore SiC surge arresters have been progressively replaced by MO surge arresters whose latest polymer housed design is now widely used throughout the world.

1.2 Air spark gaps

The air spark gap is the oldest, the simplest and the cheapest surge protection device.

Design

It is generally made of two electrodes : the first one is connected to the line side of the equipment to be protected and the second one is earthed.

Operating principle

The air gap between these two electrodes is a weak point in the network insulation. The air distance can be set in order to adjust the sparkover voltage to the required value.

Protective level

The protective level of a spark gap is the maximum sparkover voltage under the standard 1.2/50 lightning voltage impulse.

Advantages and drawbacks

Even though spark gaps are very cheap, very strong and can be easily set, they suffer from a lot of disadvantages whose main are :

- once sparkover occurs, the power arc is not able to extinguish spontaneously, so that the circuit breaker has to operate in order to clear the fault current
- sparkover leads to a waveshape with cut tail, which may cause close winding equipment to fail.
- the sparkover voltage depends on climatic conditions (temperature, humidity, ...) and also on the front rise of the overvoltage. In case of steep front of wave, the voltage actually applied to the equipment may be much greater than the sparkover voltage itself (response time), which could also lead to unexpected failure.

1.3 Gapped Silicon Carbide (SiC) Surge Arresters

SiC surge arresters have got rid of some of the drawbacks of the air spark gaps. The principle was to use a non linear resistance in series with the air gap in order to prevent a high power current to flow during operation. Silicon carbide was the first material with a high non linear factor suitable to such an application. Non linear resistors are made of SiC grains, pressed into discs with metallised faces for improved electric contact.

Design

Because silicon carbide has non-linear properties on a limited range of current density values, a gapless device would fail immediately under the normal phase-to-earth voltage. Air gaps are compulsory to isolate the discs under normal conditions.

Therefore, the core of silicon carbide surge arresters is made of SiC resistors in series with several elementary air gaps. This core is enclosed in a porcelain housing filled with dry air or nitrogen. An appropriate sealing system prevents moisture ingress as performance and reliability are very sensitive to humidity.

Operating principle

Under the nominal phase-to-earth voltage, the air gaps isolate the surge arrester. In case of overvoltage exceeding the sparkover voltage of the gaps assembly, a current impulse flows through the SiC resistors whose resistance decreases as the current increases (non linear property), which limits the actual overvoltage level. Once the surge energy has been absorbed, the surge arrester remains conductive till the applied voltage reaches zero at the latest : the resistance of SiC resistors is then high enough to clear the current and to re-isolate the surge arrester.

Thanks to the non linear resistance of their SiC resistors, silicon carbide surge arresters are able to limit overvoltages while respecting the continuity of supply requirements.

Protective level

The protective level of a silicon carbide surge arrester is defined as the maximum value among :

- 1,2/50 lightning impulse maximum sparkover voltage
- front-of-wave maximum sparkover voltage divided by 1.15
- maximum residual voltage at the nominal discharge current.

Remaining disadvantages

Even though they allow to avoid most of the drawbacks of single spark gaps, SiC surge arresters still have some :

- once the overvoltage has been limited, a power frequency current still flows (called "follow current", which can reach a hundred amps or more) till the applied voltage reaches zero, that is during half a cycle in the worst case.
- although the series air gaps are enclosed in a tight housing, the sparkover voltage is sensitive to external voltage distribution along the porcelain housing which is modified by environment stresses (rain, salt fog, ...).

1.4 Gapless Metal Oxide Surge Arresters (MOSAs)

In the 60's, non linear resistors made of metal oxides were designed for the protection of electronic equipment. Ten years later, MO surge arresters intended for Medium Voltage applications were introduced.

These were characterized by two main advantages :

- a very high non linear factor on an extended range of current density values
- a far higher energy absorption capability than SiC surge arresters

Design

The high non-linearity on an extended range of current allows to remove the air gaps. The MO resistors are enclosed into a tight housing which used to be of porcelain type. The porcelain housing must be equipped with a pressure relief system to avoid shattering in case of internal failure (subsequent to a very high lightning stress for instance).

More recently, manufacturers have replaced this traditional porcelain housing by a polymeric housing with appropriate properties so as to withstand climatic stresses and ensure tracking resistance. To get the required mechanical strength for the surge arrester (which was formerly obtained by the porcelain housing itself), the metal oxide resistors are now wrapped in a fiberglass reinforced resin.

The manufacturing process of the MO resistors (also called "MOV blocks") requires a strong experience to get the expected performance and reliability. A particular care is necessary during the manufacture processes. A block is made of zinc oxide (90 %) mixed with others metal oxides (Bismuth, Cobalt, Manganese, ...). The formula (chemical composition) and the processes (especially the sintering cycle) are carefully checked in order to guarantee high quality and reliability levels.

Operating principle

The main advantage of a MO resistor is the highly non linear current vs voltage characteristic curve (see curve on page 13).

Under the nominal phase-to-earth voltage, the impedance of a MO surge arrester is very high so that the leakage current is very low (typically less than 0.1 mA).

When an overvoltage appears, the ohmic resistance decreases very quickly in order that the surge current flows to the earth and the overvoltage level is limited. The non-linear factor is so high that between 0.1 mA and 10 kA the voltage is only doubled.

Protective level

The protective level of a metal oxide surge arrester is defined as the maximum residual voltage at the nominal discharge current.

Ratings

Selection of an appropriate surge arrester (i.e. define the suitable rated voltage) is based on considerations having opposite trends :

- optimize the protection provided, but the lower the protective level the lower the rated voltage
- ensure the withstand to applied voltages, but the higher the voltage withstand the higher the rated voltage

The complete procedure for selection is exposed in section 4.

In any case, the surge arrester changes electrical energy into thermal energy. When electrically stressed, the internal temperature of MO resistors may increase very quickly. If the absorbed energy is higher than the heat dissipation capability, failure may occur by a thermal runaway phenomenon.

Line discharge class

The energy of switching surges depends on the system voltage. The higher the system voltage, the higher the stored energy due to capacitive behaviour of the network. In high voltage networks, the energy of some switching surges often exceeds that of lightning strokes.

Therefore, former IEC 60099-4 : 2009 standard had defined line discharge classes (from 1 to 5) corresponding to increased energy absorption capability under switching surges. For Distribution networks, Class 1 is usually used. Classes 2 and 3 are more commonly specified for system voltages ranging from 60 to 245 kV and Classes 4 and 5 above.

Notes :

1. Line discharge class is only applicable to surge arresters having a nominal discharge current of 10 kA (Classes 1 to 3) and 20 kA (Classes 4 and 5).
2. Line discharge class 2 or 3 surge arresters may be required in Medium Voltage sub-stations in case of high reactive power (e.g. presence of capacitor banks for compensation purpose).

Main characteristics of a MO surge arrester

- The rated voltage (U_r) is the maximum permissible rms value of power frequency voltage which can be applied to the surge arrester during 10 s (i.e. temporarily) after absorption of the rated energy.
- The continuous operating voltage (U_c) is the maximum voltage which can be applied continuously to the surge arrester under given ambient conditions.
- The nominal discharge current (I_n) is the peak value of the standard 8/20 lightning current impulse which is used to classify a surge arrester. It can be either 5 kA, 10 kA or even 20 kA : the lightning protective level of the surge arrester is defined at this current value.
- The energy absorption capability can be given for the high current impulse withstand (4/10 lightning current impulse) or for the long duration current impulse withstand (duration and peak value according to line discharge class requirements).

Advantages of MO over SiC surge arresters

Thanks to the high non-linearity and energy absorption capability of MO resistors, metal oxide surge arresters have many advantages over former silicon carbide technology :

- no follow current is absorbed
- the protective level is better controlled because it no longer depends on a sparkover voltage value which is submitted to fluctuations
- the residual voltage at high current values is much lower
- the behaviour under severe climatic conditions is well improved
- size and weight are far less.

Advantages of polymer housed MOSAs

This latest technology benefits by both the MO resistors and the polymeric housing performance. Such surge arresters still provide more advantages than conventional metal oxide surge arresters :

- the weight is about half the weight of the equivalent porcelain housed surge arresters, which facilitates both transportation and handling
- the dielectric strength is improved
- the safety is increased in case of failure since a violent shattering of the housing cannot occur
- the behaviour under very severe climatic conditions is much better thanks to the natural hydrophobicity and UV resistance of the polymer housing, especially if made of silicone rubber
- the reduced size allows installation closer to the equipment and in any position so as to improve the overvoltage protection.

Thanks to above significant advantages, polymer housed MOSAs prove to be ideal devices for surge protection of Distribution equipment.

2 ENSTO RANGE OF DISTRIBUTION METAL OXIDE POLYMER HOUSED SURGE ARRESTERS

2.1 VARISIL™ Type HE(-S) product range

VARISIL™ Type HE(-S) products are 10 kA metal oxide surge arresters for Distribution networks, specifically designed for areas with strong lightning exposure and high pollution level.

The range covers system voltages from 3 kV to 52 kV. Table on page 14 gives the main features of VARISIL™ Type HE surge arresters.

Different sizes are available and can be associated with various rated voltages.

2.2 VARISIL™ Type HE(-S) design

The active part is made of MO resistors wrapped in a fiberglass reinforced synthetic resin whose design is patented and whose thickness is tripled for the VARISIL™ Type HE-S extended range.

This core provides the mechanical resistance and is covered by a polymeric housing made of silicone rubber suitable to areas with high pollution level.

MO resistors

ENSTO uses MOV blocks which have been specifically developed for the VARISIL™ Type HE(-S) arrester range.

The raw materials and the processes are carefully controlled in order to guarantee high quality and reliability levels.

Composite wrapping

The surge arrester body is made of a fiberglass reinforced synthetic resin whose design is patented. This frame ensures a perfect encapsulation of the MOV blocks and a safe behaviour under fault conditions.

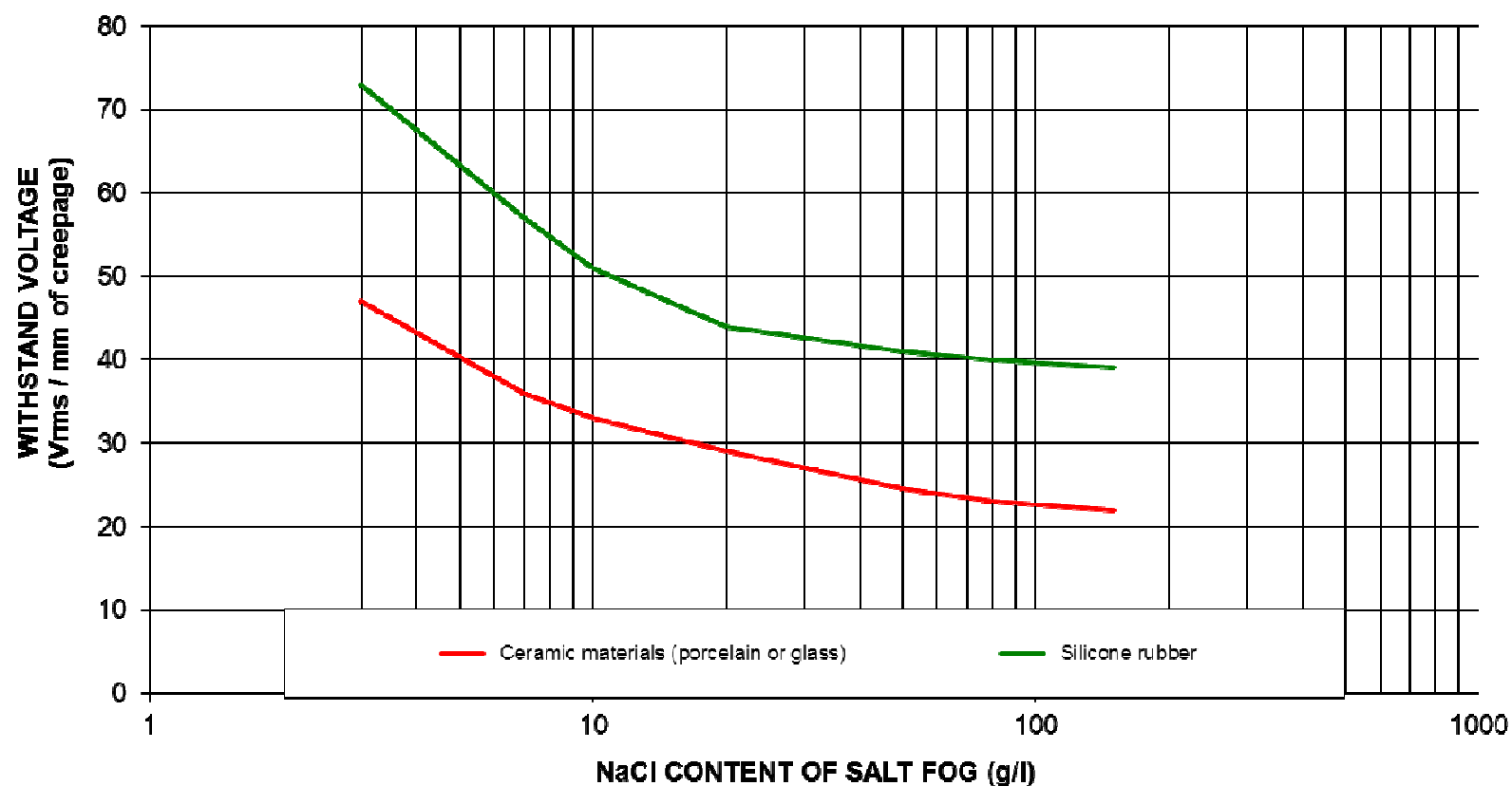
Silicone rubber housing

The silicone rubber used for external insulation has shown satisfactory performance in high voltage applications.

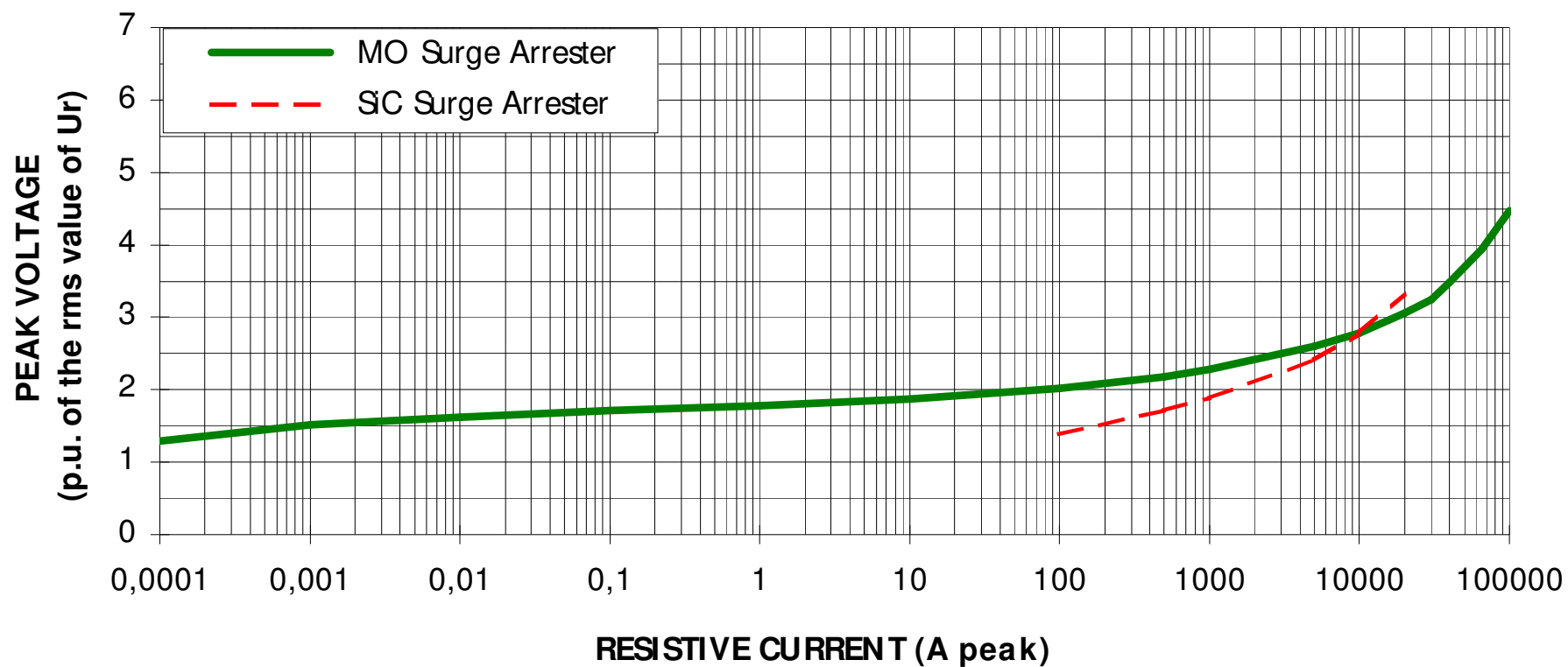
The key point to silicone rubber success in these applications is its ability to maintain a hydrophobic surface, even when contaminated, and to recover hydrophobicity if it is temporarily lost during periods of extreme electrical activity. Hydrophobicity is the fact to capture water under spread drops of water avoiding any large surface conductive areas. In contaminated environments, silicone rubber has demonstrated significant advantages over ceramic materials such as porcelain with respect to flashover performance (see figure on page 12)

In addition, the outstanding resistance of silicone rubber to ultraviolet radiation, oxidation and ozone ensure that the material will remain functional through prolonged environmental exposure. This is mainly due to the fact that silicone rubber is an inorganic material with Silicon-Oxygen (Si-O) molecular links far less sensitive to UV radiation than carbon – carbon molecular links of EPM, EPDM and XLPE (Cross-linked Polyethylene).

TYPICAL FLASHOVER PERFORMANCE : SILICONE RUBBER vs STANDARD CERAMIC MATERIALS



COMPARISON OF CURRENT vs VOLTAGE CHARACTERISTIC CURVES for MO and SiC SURGE ARRESTERS having the same protective level



MAIN CHARACTERISTICS OF ENSTO VARISIL™ Type HE(-S) SURGE ARRESTERS

Type HE(-S)	05	06	09	10	12	15	18	21	24	27	30	33	36
Rated voltage Ur (kV rms)	5	6	9	10	12	15	18	21	24	27	30	33	36
Continuous Operating Voltage Uc (kV rms)	4.25	5.1	7.65	8.4	10.2	12.7	15.3	17.5	20	22.5	25	27.5	30
Maximum residual voltage at In (kV)	15.2	16.4	28.1	29.3	32.8	43.3	49.1	59.7	65.1	76.8	81.1	92.8	97.5
Nominal discharge current In	10 kA with 8/20 waveshape												
High current impulse withstand (energy absorption)	100 kA with 4/10 waveshape (3.2 kJ/kV of Ur)												
Long duration current impulse withstand (energy absorption)	300 A with 2000 µs rectangular waveshape (1.2 kJ/kV of Ur)												
Short circuit withstand	20 kA / 0.2 s - 600 A / 1 s												
Creepage distance	480 mm					650 mm		800 mm		1200 mm			

3 ACCESSORIES FOR VARISIL™ Type HE(-S) SURGE ARRESTERS

3.1 Disconnecter or fault indicator

Ground lead disconnecter (S3D2 option)

The ground lead disconnecter is a device able to automatically open the connection of the surge arrester to earth.

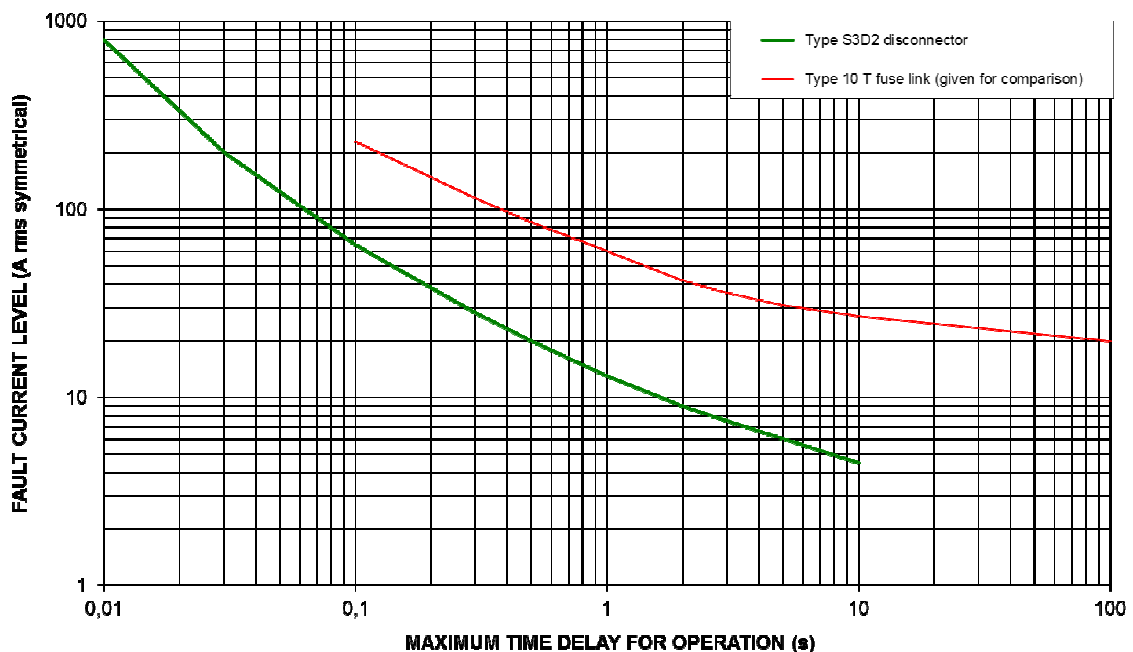
In case of failure of the surge arrester, the internal blank cartridge operates because of the electrical and thermal effects. The disconnecter enclosure breaks out and separates the earth connection of the surge arrester, avoiding the maintained fault conditions.

Thanks to this device, the continuity of service is ensured.

Operation under 20 mm thick ice

Sensitivity to fault currents

**OPERATION CHARACTERISTIC CURVE of Type S3D2
DISCONNECTING DEVICE intended for VARISIL surge arresters**



Immunity to current impulses

Lightning 4/10 : > 2 subsequent impulses at 110 kA

Switching 30/80 : > 2 subsequent impulses at 35 kA

Rectangular 2000 μ s : > 5 subsequent impulses at 300 A

Fault indicator (IF option)

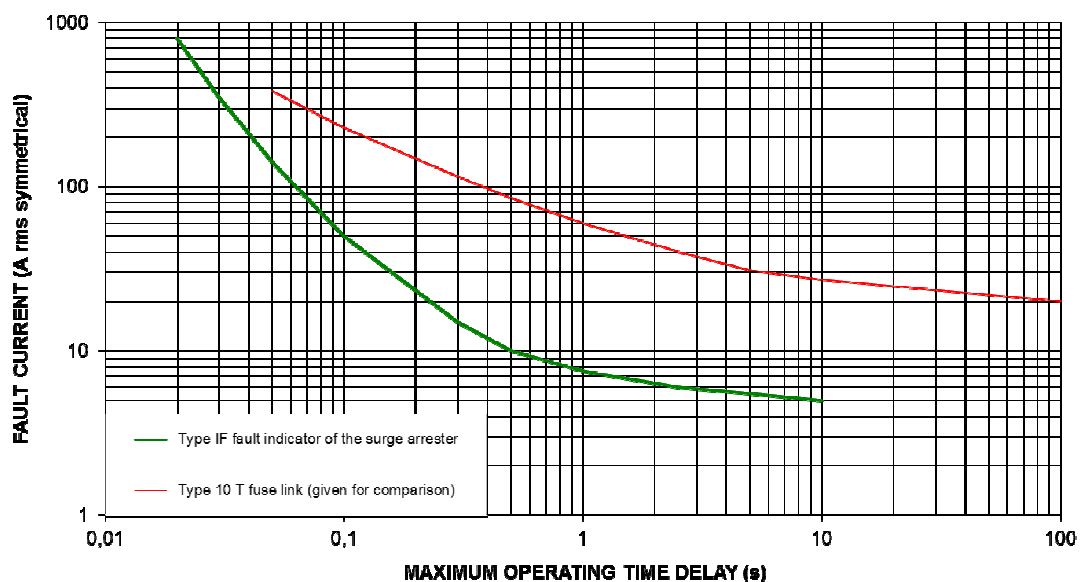
Whenever the operator requests continuity of protection, a failed surge arrester has to remain connected to the network in order to maintain protection.

The IF option includes a fault indicator module. In case of stress exceeding the energy absorption capability of the surge arrester, the short circuit current causes a red flag to appear. Any failed surge arrester can then be easily detected on site.

Operation under 20 mm thick ice

Sensitivity to fault currents

**CURRENT vs TIME CHARACTERISTIC CURVE of type IF FAULT INDICATOR
for Distribution VARISIL surge arresters
(refer to CESI Test Report MP-97/026984)**



This option is recommended for networks with low fault currents (isolated or compensated neutral point grounding conditions).

3.2 Bracket and terminals

3.2.1 Bracket

- Individual bracket (1 pc per surge arrester) : standard bracket for mounting on crossarm (very similar to NEMA type)

3.2.2 Terminals

- Line side : stainless steel HM12 screw, spring washer and clamp
- Earth side : Stainless steel hardware depending on the selected option

4 PROCEDURE TO SELECT A VARISIL™ Type HE(-S) SURGE ARRESTER

The selection of an appropriate surge arrester is based on four major parameters :

- Nominal discharge current
- Protective level
- Continuous phase-to-earth voltage of the network
- Temporary overvoltage on the network under fault conditions

4.1 Nominal discharge current

IEC 60099-4 and IEEE C62.11 standards define two main types of Distribution surge arresters :

- 5 kA / Distribution Normal Duty relating to a high current impulse of 65 kA
- 10 kA / Distribution Heavy Duty relating to a high current impulse of 100 kA

Selection of the type depends on the isokeraunic level of the installation area i.e. the frequency of occurrence and the peak current level of lightning strokes. Tropical regions have a higher isokeraunic level, thus needing 10 kA surge arresters. For temperate regions, 5 kA surge arresters are generally suitable, but more severe local conditions might require a 10 kA type (mountains for instance).

In the following example, we will choose a VARISIL™ Type HE surge arrester which is of 10 kA / Distribution Heavy Duty type.

4.2 Protective level

The purpose of the surge arrester is to avoid flashover or puncture of the equipment insulation. To check that this requirement is actually fulfilled, two values must be compared :

- insulation withstand of the equipment under 1.2/50 lightning voltage impulse (BIL or LIWL)
- residual voltage of the surge arrester at the nominal discharge (U_p)

In order to take into account possible higher discharge currents and length of connection leads, it is recommended to get a minimum ratio of 1.4 between these two values, i.e. keep the safety margin above 40 %.

1st criterion :

$U_p < BIL / 1.4$

All surge arresters meeting this requirement can then be selected from the table given on page 14.

The example is a network with 11 kV system voltage and a BIL of 75 kV.

The first criterion then leads to all VARISIL™ Type HE surge arresters having a protective level lower than $75 / 1.4 = 53$ kV, i.e. with a rated voltage $U_r \leq 18$ kV.

4.3 Continuous phase-to-earth voltage of the network

Under normal conditions, the continuous operating voltage U_c of the surge arrester shall be higher than the maximum phase-to-earth voltage of the network, adding a 5 % margin for possible distortion.

The maximum system voltage U_s must then be known.

2nd criterion :

$$U_c > 1.05 \times U_s / 1.732$$

In our example, the maximum system voltage is 12 kV, which leads to a maximum phase-to-earth voltage of $12 / 1.732 = 6.9$ kV.

All VARISIL™ Type HE surge arresters with $U_r \geq 9$ kV then meet the case.

4.4 Temporary overvoltage conditions

Under single phase fault conditions, the phase-to-earth voltages are unbalanced. The grounding mode of the neutral point at the substation influences the actual voltages applied to the surge arresters connected to healthy phases.

4.4.1 Grounding mode of the neutral point

Four modes of neutral point grounding can be used :

- solid
- impédant (resistive and/or inductive)
- isolated
- compensated (Petersen coil)

The earth fault factor K_d characterizes the unbalanced effect. It is the ratio between the maximum phase-to-earth voltage on healthy phases under single phase fault conditions and maximum phase-to-earth voltage under normal conditions ($U_s/\sqrt{3}$).

It can be derived from the network features like short circuit power, earth resistances, transformer and line impedances, etc...

Typical values for this factor are given in table below :

Neutral point connection	Kd
Solidly grounded	< 1.4
Through impedance	1.4 à 1.73
Isolated	1.6 à 1.8
Through Petersen coil	1.73 à 1.9

The operation time delay of the circuit breaker must also be considered.
The table below gives typical tripping values :

Neutral point connection	Response time
Solidly grounded	0.1 to 0.5 s
Through impedance	0.2 to 1 s
Isolated	0.5 s to 8 h
Through Petersen coil	0.5 s to continuous

The temporary overvoltage (TOV) applied to the surge arresters will then vary according to the grounding mode of the neutral point.

Manufacturers should provide a TOV withstand curve which characterizes the performance of the surge arresters under such stresses.

The curve on page 21 relates to VARISIL™ Type HE(-S) surge arresters.

Appropriate surge arresters shall then be selected as follows :

<u>3rd criterion :</u>
<ul style="list-style-type: none"> • Multiply the maximum phase-to-earth voltage of the network ($U_s/1.732$) by the Kd factor • From the TOV curve, determine the withstand voltage ($k \times U_r$) for the maximum duration of fault conditions • Calculate the required minimum rated voltage U_r

In the example, the neutral point is connected to earth through an impedance with an earth fault factor of 1.55 and a maximum fault duration of 1 s.

- $K_d = 1.55$: temporary overvoltage = $6.9 \times 1.55 = 10.7$ kV
- k for 1 s : $k = 1.14$ i.e. $U_t = 1.14 \times U_r$

Selection criterion : $1.14 \times U_r > 10.7$ i.e. $U_r > 9.4$ kV.

The minimum rated voltage required for the surge arrester is then $U_r = 10$ kV.

4.4.2 Footing resistance of the pole

If the earth resistance is locally high, the system behaves as if the neutral point was grounded through a high impedance. The calculations must then be made with a Kd factor increased accordingly (see clause 5.2 for more information).

Final selection :

**If more than one arrester type fulfil all 3 criteria,
the surge arrester with the lowest rated voltage shall be preferred
so as to improve the protection performance.**

**Only particular local conditions (high footing resistance, ferroresonance phenomena)
might justify the selection of a higher rated voltage.**

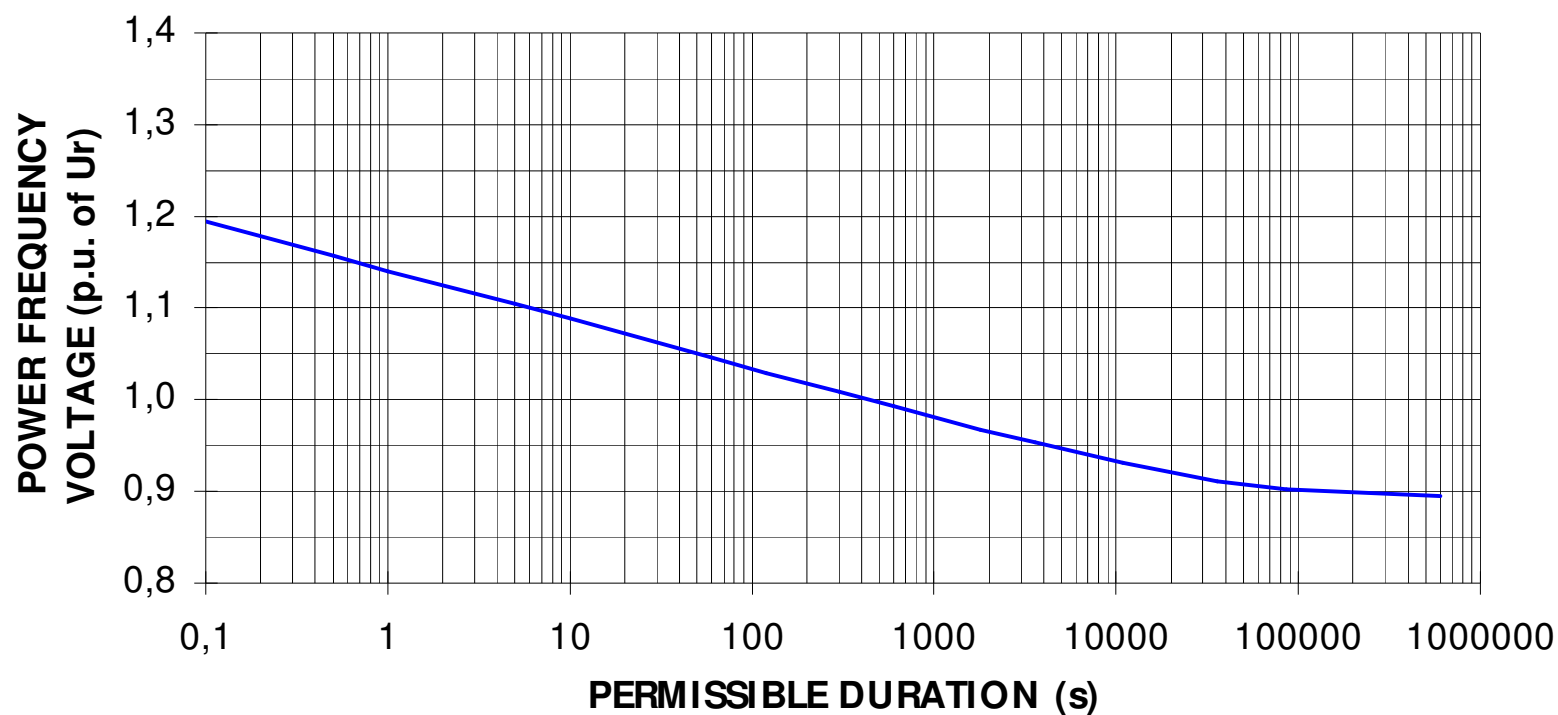
*In the example : 1st criterion : $U_r \leq 18 \text{ kV}$
2nd criterion : $U_c > 7.3 \text{ kV}$
3rd criterion : $U_r > 9.4 \text{ kV}$*

*4 models could then be used : rated voltage of 10 kV, 12 kV, 15 kV or 18 kV.
The 10 kV rated surge arrester shall be preferred as it provides the lowest protective level.*

*Note : for a Distribution network with high local earth resistances (earth fault factor of 1.732),
the selection criteria would rather lead to a rated voltage of 12 kV.*

The table on page 22 indicates the typical rated voltages to be used for common Distribution system voltages.

MINIMUM OVERVOLTAGE WITHSTAND CAPABILITY of VARISIL Type HE SURGE ARRESTERS according to Annex D of IEC 60099-4



SIMPLIFIED GUIDE for the selection of the suitable rated voltage U_r for VARISIL™ Type HE(-S) surge arresters

Depending on the neutral point grounding conditions, the more severe stresses are either of continuous or temporary type.

Nominal system voltage U_n (kV)	6	10	11	13.8	15	20	22	30	33
Maximum system voltage U_s (kV)	7.2	11	12	15	17.5	22	24	33	36

Solidly earthed neutral point	6	9	10	12	15	18	21	27	30
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Grounding through impedance	9	10 / 12	12	15	18	21 / 24	24 / 27	33 / 36	36
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Isolated neutral point	9	12	15	15 / 18	18 / 21	24	27	36	39 / 42
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Grounding through Petersen coil	9	12 / 15	15	18	21	27	30	39 / 42	42 / 45
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Note : values in **italics red** need be validated according to the actual earth fault factor or/and maximum fault duration.

5 RECOMMENDATIONS FOR INSTALLATION

To obtain an effective overvoltage protection, a minimum ratio of 1.4 shall be kept between the insulation level (BIL or LIWL) of the equipment and the protective level (Up) of the surge arrester so as to take into account possible higher discharge currents and the length of connection leads.

5.1 Length of connection leads

It is generally considered that the specific inductance of cables is around 1 $\mu\text{H}/\text{m}$.

Under a 40 kA (moderate value) lightning current impulse with 4/10 waveshape, the induced voltage U_i is then :

$$U_i = L \times di/dt = 1 \mu\text{H}/\text{m} \times 40 \text{ kA} / 4 \mu\text{s} \quad \text{i.e.} \quad U_i = 10 \text{ kV}/\text{m} \text{ of cable length}$$

For higher rates of rise or peak values (100 kA for instance), this value could be much greater (up to 25 kV/m or even more).

Recommendations

The connection length to be considered is the total length where the discharge current flows, i.e. the length of leads between the surge arrester and the common connection point to the line, as well as between the surge arrester and the common connection point to earth.

In case of pole mounting, a usual practice is to connect the earth side of the surge arrester to the earth terminal of the transformer tank which is installed below. This shall be avoided in order to improve the efficiency of the overvoltage protection.

Instead, it is strongly recommended to connect the earth terminal of the transformer tank directly to the earthed fixing point of the surge arrester. At least 10 kV can be saved through this mode of connection to earth.

The shorter the connection leads, the better is the overvoltage protection.

5.2 Footing resistance of the pole

Lightning conditions

If the ohmic resistance of the local earth is pretty high (mineral characteristics of the soil, lack of humidity), the voltage at the common earthing point of the transformer and the surge arrester might reach a very high value under lightning current impulses.

In this case, the major risk is flashover between the transformer tank and secondary windings (low voltage neutral point solidly earthed and distributed). Whatever the voltage rating, Distribution surge arresters are not intended to deal with such a phenomenon. However, an air spark gap connected between the LV neutral point and the transformer tank can solve this problem.

Fault conditions

In case of fault conditions due to the system itself (earth fault or insulation damage), the fault current value remains pretty low as limited by the high ohmic resistance of the earth.

In such a particular case, the surge arresters connected to the healthy phases will be more stressed on the voltage point of view. The highest possible rated voltage shall then be preferred (earth fault factor in the higher range of values, see clause 4.4.2).

As a conclusion, it is recommended that earthing resistances be as low as possible. In the particular case of pole mounting, the footing resistance shall not exceed 30 Ω .

5.3 Clearances

At the installation stage, clearances shall be respected so as to guarantee correct operation of VARISIL™ Type HE(-S) surge arresters.

The distances between the live parts of surge arresters and any earthed element (distance d) and between the live parts of surge arresters connected to adjacent phases (distance D) shall be carefully checked.

The table below advises clearances for the most common rated voltages :

Type HE(-S)	05	06	09	10	12	15	18
d (mm)	46	50	86	89	100	132	150
D (mm)	50	54	92	96	108	143	163

Type HE(-S)	21	24	27	30	33	36
d (mm)	182	199	234	247	283	297
D (mm)	199	217	258	272	313	330

5.4 Electrical connections

5.4.1 *Connection to earth*

For VARISIL™ Type HE(-S) surge arresters equipped with a disconnecting device (S3D2 option), a copper lead (either bare or insulated) having a minimum cross section of 16 mm² must be used for connection to earth. A cable without terminal lug can be used on condition that the diameter does not exceed 15 mm : if so, it can be directly clamped using the metal clamp supplied.

This cable has to be flexible and long enough to provide the required clearance in case the disconnecter operates. It is also important to check that no element can interfere with the cable movement under such conditions.

For VARISIL™ Type HE(-S) surge arresters fitted with either NO option or IF option, connection to earth shall be made through earthing of the mounting bracket.

5.4.2 *Connection to line*

Line connection of VARISIL™ Type HE(-S) surge arresters must be achieved with either a copper or an aluminium cable (either bare or insulated) having a minimum cross section of 16 mm². This cable shall be connected to the M12 line terminal of the surge arrester. A cable without terminal lug can be used on condition that the diameter does not exceed 15 mm : if so, it can be directly clamped using the metal clamp supplied.

It is also recommended that no significant mechanical stress be applied to the surge arrester through excessive tension of the line cable.

5.4.3 *Tightening torques*

Torques applied to secure screws and/or nuts of VARISIL™ Type HE(-S) surge arresters shall never exceed :

- **20 N.m** for M12 terminals (applicable to all options)
- **30 N.m** for M16 terminals (IF option)

5.5 Packaging

VARISIL™ Type HE(-S) surge arresters are packed inside individual cardboard boxes which can be easily opened without any tool.

5.5.1 Handling and transport

Thanks to their soft polymer housing, VARISIL™ Type HE(-S) surge arresters can be handled with less care than required for porcelain housed products. However, attention must be paid to avoid damage to :

- the polymeric housing (cut or tear by sharp objects)
- connecting bolts and threaded studs
- accessories if any (insulating bracket, disconnecter or fault indicator)

If damaged, those parts may prevent correct mounting and/or operation.

It is then recommended that the surge arresters remain inside their original packaging till installation.

5.5.2 Storage

Before use, the surge arresters shall be kept inside their original packaging.

The boxes shall be stored in sheltered premises at an ambient air temperature in the range -20 °C to +70 °C.

5.5.3 Maintenance

VARISIL™ Type HE(-S) surge arresters are maintenance free.

If surge arresters with disconnecting device are used (S3D2 option), the operator is advised to perform periodical inspections on site in order to detect any surge arrester which would be disconnected (drop of the earth lead) and to replace it as soon as possible.

In case of disconnection, the complete assembly (surge arrester element and insulating bracket with built-in disconnection module) shall be replaced.

6 STANDARDS AND TESTS

The VARISIL™ Type HE(-S) range fulfils all applicable IEC requirements.

6.1 Reference standard

IEC 60099-4 : "Surge Arresters / Part 4 : Metal-oxide surge arresters without gaps for a.c. systems" – 2nd & 3rd editions.

6.2 Other applicable standards

ANSI/IEEE C62.11 : "IEEE standard for metal-oxide surge arresters for alternating current power circuits"

IEC 60071-1 : "Insulation co-ordination / Part 1 : Definitions, principles and rules"

IEC 60099-5 : "Surge Arresters / Part 5 : Selection and application recommendations"

IEC 60270 : "Partial discharge measurements"

IEC 60507 : "Artificial pollution tests on high-voltage insulators to be used on a.c. systems"

IEC 60815 : "Guide for the selection of insulators in respect of polluted conditions"

IEC 61109 : "Composite insulators for a.c. overhead lines with a nominal voltage greater than 1000 V – Definitions, test methods and acceptance criteria"

6.3 Type tests

Most type tests have been performed in CESI (Centro Elettrotecnico Sperimentale Italiano) independent laboratory located in MILANO - Italy.

The table of the type tests which have been carried out and the corresponding test reports are available upon request.

6.4 Standard acceptance tests

The table below reminds the standard acceptance tests which are required by IEC 60099-4 :

Test description	Clause of IEC 60099-4	Test samples
Measurement of the power frequency voltage at the reference current (1 mA peak a.c.)	§ 9.2.1.a	Surge Arresters
Verification of the residual voltage at the nominal discharge current (10 kA 8/20)	§ 9.2.1.b	MO resistors
Check of the absence from partial discharge	§ 9.2.1.c	Surge Arresters

6.5 Routine tests

The table below indicates the routine tests which are performed during the manufacture of VARISIL™ Type HE(-S) surge arresters :

Test description	Clause of IEC 60099-4	Test samples
Measurement of the lightning residual voltage at 10 kA	§ 9.1.b	MO resistors
Measurement of the reference voltage at 1 mA peak a.c.	§ 9.1.a	Surge arresters
Verification of the absence from partial discharge and contact noise ⁽¹⁾	§ 9.1.c	Surge arresters

⁽¹⁾ This test is performed at the same time than the measurement of the reference voltage