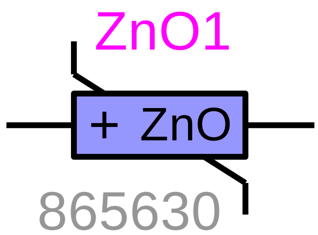
ZnO arrester device



Jean Mahseredjian, 12/29/2013 1:53 AM

1 Available versions

This device accepts both 1-phase and 3-phase signals. The 3-phase version is the equivalent of 3 decoupled branches (one for each phase). The only difference is that in the 3-phase version it is allowed to request scope data for the extra phases.

1.1 When changing phases

It is allowed to switch from 1-phase to 3-phase or from 3-phase to 1-phase. The user must only verify the scope requests according to requirements.

2 Description

The objective of a surge arrester is to protect the insulation of other equipment without putting itself at risk. The protected devices are devices with non self-restoring insulation. The arrester must sparkover at a given level and carry the impulse current to ground. The arrester must be able to reseal when the applied voltage returns to nominal. The energy handling capabilities of an arrester must be studied to avoid thermal runaway problems.

Typical applications are protection against switching surges, protection against fast rising surges and protection against temporary overvoltages. Arresters can be used instead of preeinsertion resistors for line switching. In the protection against fast rising surges the energy dissipation problem is usually not a concern because of short duration times. It is needed to place the arrester as close as possible to the protected device. If the arrester is protecting a transformer, for example, then the transformer voltage can rise well above the arrester voltage during the wave traveling back and forth on the line connecting the arrester to the transformer. This is not the case when this line is sufficiently short.

Typical temporary overvoltage events are single-line-to-ground fault, ferranti rise, load rejection and ferroresonance. The energy consumption of the arrester is a major concern when temporary overvoltages occur.

There are two types of arresters: Metal Oxide (MO or ZnO) and Silicon Carbide SiC. Figure 1 shows the typical characteristics of a Metal Oxide arrester. There are three distinct operating regions. The first region is called the MCOV region (Maximum continuous operating voltage), the arrester current is less than 1mA and it is mostly capacitive. The second region is the TOV (temporary overvoltage) region and the arrester current located between 1mA and 2kA is mostly resistive. In the lightning region (third region) the current is purely resistive and ranges from 1kA to 100kA. It is shown in region 1, that as the arrester temperature increases (increasing temperature is from left to right) the power dissipated in the arrester increases. Complete data on the arrester's thermal behavior is more complex.

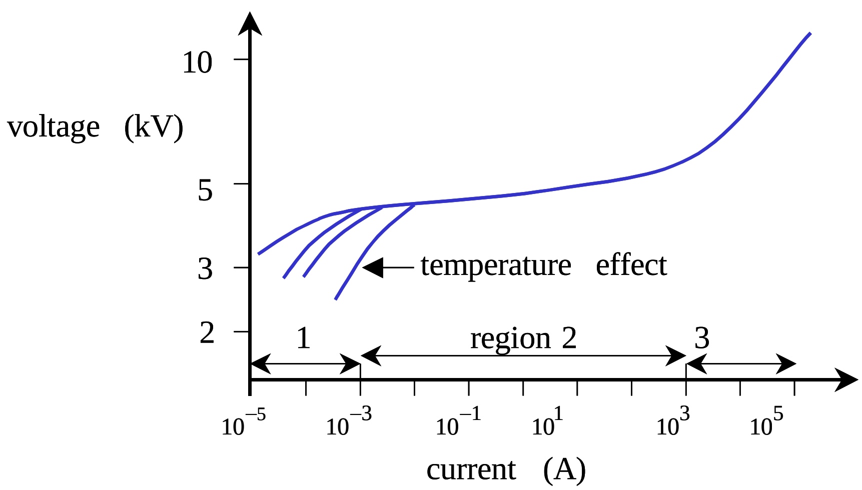


Figure 1 Typical characteristics of a metal oxide arrester

A comparison between MO and SiC arrester data indicates that MO has a much flatter characteristic than SiC. Its sharp turn-on avoids the gap requirement to isolate the material from power frequency operation. It is the contrary for SiC, since its steady-state current would fail the arrester, and thus gaps are required in series with the material. This explains why SiC devices are less popular.

Figure 2 shows the three basic MO arrester types. In the case of the shunt gap usage, the complete characteristic obtained from both columns, is available during normal operation. When a surge is applied, the gap can sparks over and part of the characteristic becomes shorted thus providing a lower discharge voltage. In the series gap case, the capacitor creates a voltage divider and lowers the voltage appearing across the arrester. Modern arresters do not require gap usage.

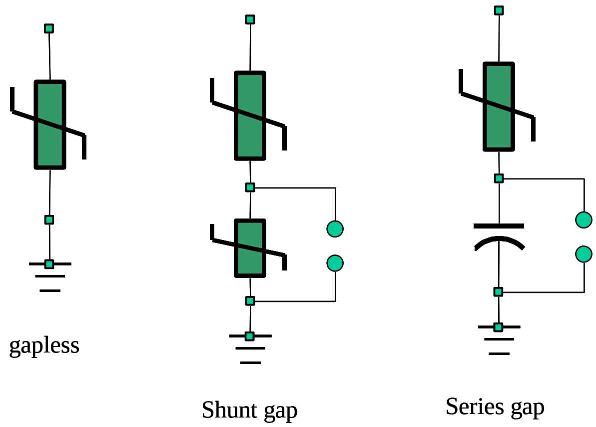


Figure 2 Types of MO arresters

The basic arrester model equation is given by:

$$i_a = kv_a^{\alpha} \tag{1}$$

Where i_a is the arrester current and v_a is the arrester voltage. For SiC arresters the value of α is between 2 to 6. For MO arresters $10 \le \alpha \le 60$. The SiC α is almost constant, in contrast the MO α varies with the operating region, it reaches a maximum of around 60 in the TOV region and decreases to about 10 in the lightning region. It means that a single exponential can be used for most SiC, but several exponential segments are needed for MO. The k parameter is a constant used in fitting the arrester characteristic.

A fitting function allowing to convert manufacturer data to the ZnO model data is available through the “ZnO data function” device.
A model based on equation (1) can be constructed for MO arrester by fitting the $8/20\mu s$ discharge voltage test data available from manufacturers. Such a model does not account for thermal runaway. Energy must be calculated and checked separately. It is a static representation since it does not account for the effect of time to crest. In reality the discharge voltage magnitude and time to crest are proportional to the impulse current amplitude and time to crest. The arrester model can be used however as a building block to construct more complex models. An example of such usage in combination with the “ZnO data function” device usage is available in EMTPWorks Examples directory in the design lightning\arrester_model\ Zno_OB_258kV.ecf.

A generic view of the ZnO model is shown in Figure 3. The “after sparkover” characteristic is optional. Several exponential segments can be used to represent the arrester characteristic. The characteristic is symmetrical. The segment connecting the first exponential segment to the origin is assumed symmetrical. The voltage V_{ref} is used as a scaling factor to avoid numerical overflow and equation (1) is rewritten to become:

$$i_j = p\left[\frac{v_j}{V_{ref}}\right]^q \tag{2}$$

where j is the segment number starting at the voltage V_{min_j}.

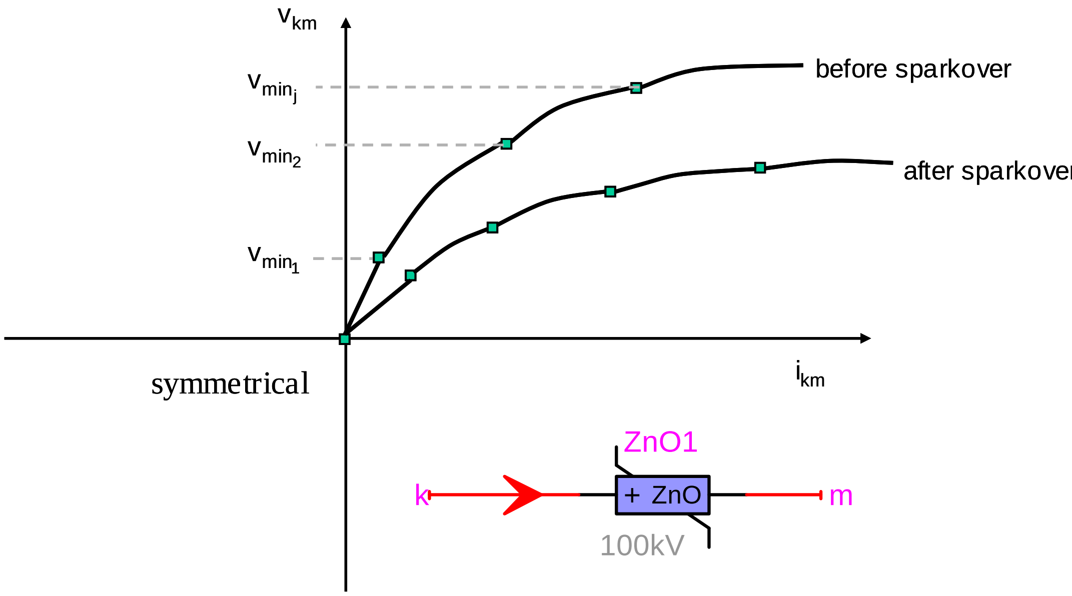


Figure 3 ZnO model characteristic

2.1 Parameters and Rules

The Data tab allows entering all required parameters to model the ZnO arrester:

- V_{ref} is the reference voltage of the arrester. It must be greater than 0. It is used in pu conversions and for scaling in equations.
- Steady state resistance (R_{ss}) is the steady-state solution model of the arrester. It can be used to create connectivity or to model the steady-state operating condition.
- V_{flash} is the gap flashover voltage. If this value is greater than 0, then the extra section for entering "Exponential segments after flashover" is enabled.
- **Exponential segments before flashover** are used for specifying the arrester nonlinear characteristic given by (2). The characteristic is symmetrical. At least one segment must be entered. Each segment is defined through the coefficients of equation (2):
  - Multiplier (p)
  - Exponent (q)
  - Vmin (pu) is the segment starting voltage. This value must be greater than 0 for the first segment. The first segment is connected to the origin using a linear segment.
- **Exponential segments after flashover** are entered only if V_{flash} is greater than 0. At least one segment must be entered.

The default number of data rows for the exponential segments is 50, but the user can increase this size by selecting a row (click on the row number) and hitting the key "Insert". Blank rows (empty rows) will be automatically eliminated at the following opening of device data forms.

It is allowed to delete the m-pin of this device. A device named "ZnO grounded" (only k-pin) is available in the library.

3 Netlist format

The Netlist format is described through an example:

```
_ZnO;ZnO1;2;2;s1,s2,
100kV,,,1e-06,15,5,1,?v,?i,?p,>v,>i,>p,>e,
1500 26 .5
```

Field	Description
`_ZnO`	Part name
`ZnO1`	Instance name, any name.
`2`	Total number of pins
`2`	Number of pins given in this data section
`s1`	Signal name connected to k-pin, any name
`s2`	Signal name connected to m-pin, any name
V_{ref}	See Parameters above
`Steady-state resistance`	See Parameters above
`tolerane`	Convergence tab data relative tolerance
`Panic`	Convergence tab data Panic iterations
`Max tolerane factor`	Convergence tab data Max tolerance factor
`Use guess correction`	Converge tab data guess correction method selection when 1
`?v, ?i, ?p`	Optional scopes
`>v, >i, >p, >e,`	Optional observable variable requests
`Characteristic before`	Characteristic before flashover. 3 values per row, blank character separator.
`Optional comma ","`	Appearing in column 1. Before the following optional characteristic.
`Characteristic after`	Optional characteristic after flashover. 3 values per row, blank character separator.

In the 3-phase case EMTPWorks automatically appends the phase characters to device names and signal names and creates 3 separate devices sharing the same data. The extra phase lines are used to carry scope and observe requests in addition to connectivity.

The comma separated data fields are saved into ParamsA, ParamsB and ParamsC attributes of this device. The characteristic segments are saved into the ModelData attribute.

4 Steady-state model

The arrester is an open-circuit in the steady-state solution unless R_{ss} is specified. R_{ss} is only used in the steady-state solution and disconnected when moving into the time-domain solution.

5 Frequency Scan model

The arrester is an open-circuit at all frequencies unless R_{ss} is specified.

6 Time domain representation

In the time-domain solution this device is a nonlinear function. It is solved through the iterative process of EMTP until convergence according to the relative tolerance option given in the Convergence data tab. A true simultaneous solution with network equations is achieved.