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Diagnostics of overvoltage protection devices used in low voltage system

Streszczenie. *Ochrona przepięciowa urządzeń elektrycznych stosowana w systemach niskiego napięcia jest obecnie znana. Wzrasta liczba urządzeń stosowanych do ochrony przepięciowej wymagających badań diagnostycznych. W artykule przedstawiono niektóre pomiary wykonane wykonywane dla urządzeń ochrony przepięciowej. Mogą być one prowadzone bez konieczności stosowania złożonych systemów pomiarowych w miejscu zainstalowania ogranicznika. (**Ochrona przepięciowa urząd\eń elektrycznych stosowana w systemach niskiego napiecia**).*

Abstract*. The overvoltage protection of electric equipments used in low voltage systems is well known. The number of installed overvoltage protection devices has rising tendency hence need for testing and function verification result. In this article some measurements on overvoltage protection devices are described. These can be realized without difficult measuring accuracy system on the installation place.*

Słowa kluczowe: przepięcie, ochrona przepięciowa, ogranicznik iskiernikowy, ogranicznik, dioda supresyjna
Keywords: overvoltage, overvoltage protection, air gap arrester, suppressor diode

Introduction

The area concerning overvoltage protection of household electric equipments is well known for general public already. Rising number of installed overvoltage protective devices result in necessity of testing and function monitoring. Overvoltage protective devices installed inside the building installations are class B, C and D (according to the IEC: class I, II and III; according to the EN: class 1, 2 and 3). They are installed at the boundaries between the lightning protection zones into which the building to be protected can be subdivided in accordance with the EMC-oriented lightning protection zone concept [1, 2].

Overvoltage protective devices of different classes require both: time and energetic coordination in order to achieve proper protective operation. At the interface between lightning protection zones (LPZ) 0 and 1, all incoming and outgoing conductors are to be routed via class B protective device which absorb most energy of impulse current. They are normally of the air-gap type (fig. 1a). All conductors passing from LPZ 1 to LPZ 2 are to be routed by class C overvoltage protective devices. They are normally designed as zinc-oxide (ZnO) varistors (fig. 1b).

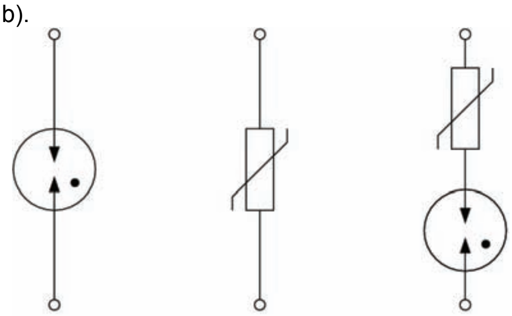

Fig.1. Examples of simple connected overvoltage protective devices

Likewise, all electric equipments passing from LPZ 2 to LPZ 3 are to be routed by class D overvoltage protective devices. They are normally designed as ZnO varistors or suppressor diode according to nominal voltage of protected electric device. Some manufacturers produce so called B+C overvoltage protective devices which are used with great success in all TN system variants. Simple connection consists of single air-gap or varistor, some design use air-gap with the varistor in serial which result in minimal stress by leakage current through the varistor during normal operation (see fig. 1c). In so called B+C design care needs to be taken to ensure that the individual overvoltage protective device operate selectively. For energetic coordination decoupling impedance is required. Two arrangements of the decoupling impedance exist: the first is made as an inductor, second take advantage of the existing cable impedance.

Overvoltage protective devices are connected between phase conductor and ground conductor, neutral conductor and ground conductor and between phase conductors each other in three-phase systems. Some manufacturers use in the overvoltage protective device filter and other auxiliary devices for signaling of normal operation or failure state. Knowledge of the internal connection of the complete overvoltage protective device before testing is then necessary.

Testing of overvoltage protective devices

Some electric parameters by measurements on the overvoltage protective devices in laboratory conditions can be performed. Some of them need special testing devices e.g. measurement of the voltage protective level at nominal discharge current; some are applicable only on the air-gap type overvoltage protective devices or on the varistor type overvoltage protective devices. On the air-gap type overvoltage protective devices following tests can be performed:

- measurement of the insulation resistance,
- measurement of the voltage protection level,
- measurement of the frequency response characteristic,
- measurement of the ignition voltage.

The measurement of the ignition voltage with d.c. voltage, a.c. voltage with power frequency and normalized impulse voltage should be realized. The protection level is usually measured with normalized impulse current.

On varistor (or suppressor diode) type overvoltage protective devices following tests can be performed:

- measurement of the 1 mA reference voltage,
- measurement of the current-voltage characteristic,
- measurement of the voltage protection level,
- measurement of the residual voltage,
- measurement of the frequency response characteristic.

For varistors the term reference voltage is used, however for the suppressor diode (some authors are using the term transil diode) the term breakdown voltage is used. Current-voltage characteristic with d.c. or a.c. voltage is measured. Measurement of the residual voltage for different amplitudes and shapes of the impulse current is realized. Generally, the frequency response characteristic for high frequency applications is important.

Testing of air-gapped overvoltage protective devices

Measurement of the insulation resistance up to ignition voltage is possible. In the range up to the ignition voltage high values of the insulation resistance occur. If flash-over under the value of the ignition voltage occur the air-gapped overvoltage protective device does not work properly. Again if the insulation resistance in the voltage range much higher than the value of the ignition voltage is very high, the air-gapped overvoltage protective device does not work properly.

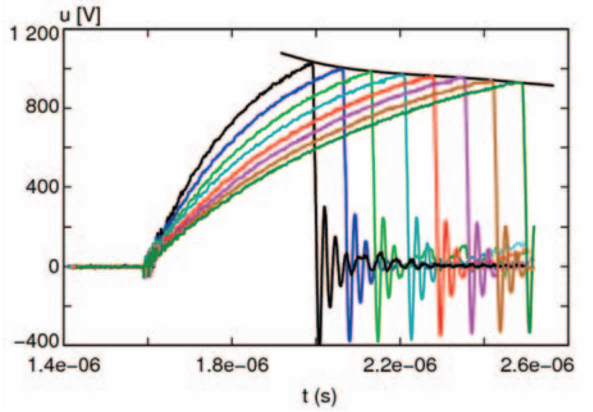

Fig.1. Voltage-time characteristic of air-gapped overvoltage protective device for low voltage systems

Measurement of the ignition voltage by d.c., a.c. and impulse voltage source are performed. The requirements on the power of the voltage source are not very high. In the figure 1 the dependence of the magnitude of the ignition voltage on the steepness of the testing impulse voltage is shown. With voltage steepness decreasing the amplitude of the ignition voltage decreases.

Table 1. Measured data on air-gap and varistor type overvoltage protective device

Parameter	Air-gap type	Varistor type
Virtual front time [µs]	Ignition voltage [V]	Protection level [V]
0.36	–1 152	–698.4
0.70	–1 080	–626.4
1.06	–1 064	–608.0
1.38	–1 032	–592.8
1.71	–1 008	–584.8
1.95	–992	–576.8
2.25	–976	–574.4
2.58	–968	–567.2
2.81	–960	–566.4
3.12	–944	–562.4
3.39	–928	–560.0

For the virtual front time T_1=0.36 µs the amplitude of ignition voltage –1 152 V was reached; for T_1=3.39 µs the amplitude was –928 V. Results presented in the figure 1 with negative voltage impulses were obtained; the range of the virtual front time T_1 is from 1.38 µs to 3.39 µs. Repeated testing of the ignition voltage with the impulse voltage source requires normalized impulse voltage source. Oscillations after air-gap ignition is related to the electric parameters of the measuring circuit.

However measurement of the voltage protective level requires impulse current source with high energy.

Testing of varistor type overvoltage protective devices

DC voltage source with output current at least 1 mA for the measurement of the current-voltage characteristic is required. However, higher current margin than 1 mA is better solution. For measurement of the 1 mA reference voltage this current limit is sufficient. During ageing process of the varistor the magnitude of the reference voltage moves to lower value. From the current-voltage characteristic the insulation resistance can be computed.

Measurement of the voltage protection level requires impulse voltage source. As it was mentioned in former section the magnitude of the voltage protection level depends on the steepness of the testing impulse voltage (tab. 1). For the residual voltage measurement impulse current source with normalized parameters is required.

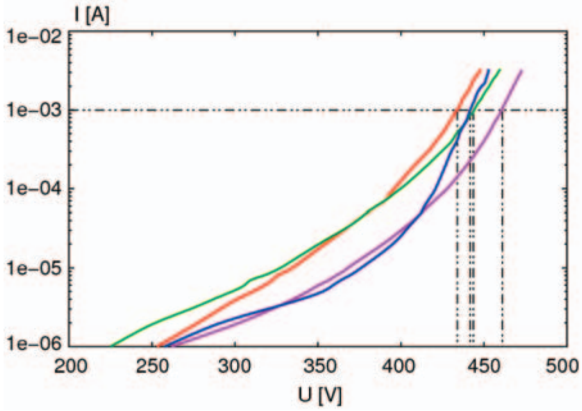

Fig. 2. Current-voltage characteristic of varistor type overvoltage protective devices

Frequency response characteristic for high frequency applications is important – data and information lines, computer networks, mobile radio stations (e.g. GSM or UMTS) etc.

In the figure 2 the current-voltage characteristic on different varistor type overvoltage protective devices is shown. The 1 mA reference voltage marked with double dot-and-dashed line varies from 434 V to 461 V. This difference is due to different varistors type used in the overvoltage protective devices.

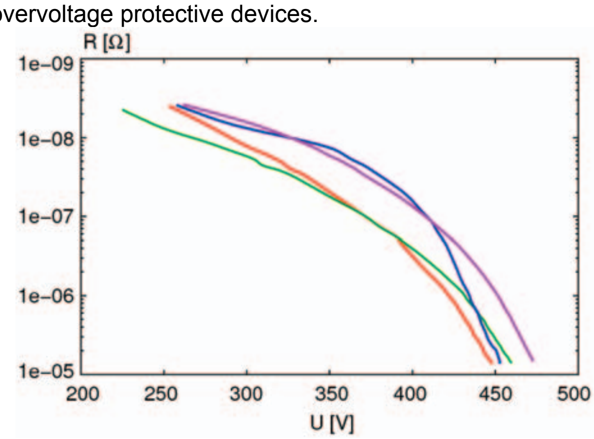

Fig. 3. Insulation resistance of varistor type overvoltage protective devices in dependence on the test voltage

In the figure 3 insulation resistance of varistor type overvoltage protective devices in dependence on the test voltage is shown. From the figure it is clear that the insulation resistance measured at 250 V (d.c.) is higher than 0.1 GΩ for all tested specimens. At test voltages higher than 500 V the magnitude of the insulation resistance is less than 100 kΩ. Currents higher than 1 mA flowing through the varistor will heat the varistor block, so the magnitude of the insulation resistance will decrease.

Testing of complete overvoltage protective devices

Some complete overvoltage protective devices are designed with indicators and auxiliary circuits. Indicators consist of passive elements with some active elements. These indicators usually indicate normal operation or failure of the overvoltage protective device or its component. Another designs, as mentioned above, are combined e.g. B+C overvoltage protective devices.

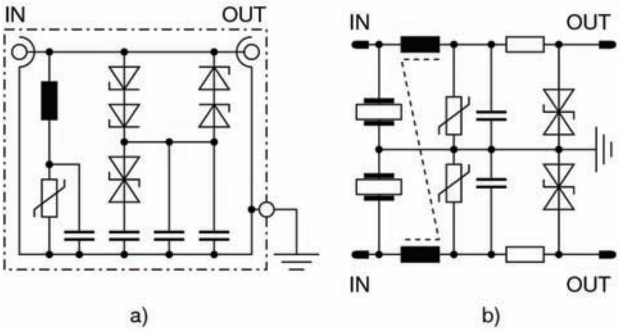

Fig. 4. Basic circuit diagram of complete overvoltage protective devices for high frequency applications [4]

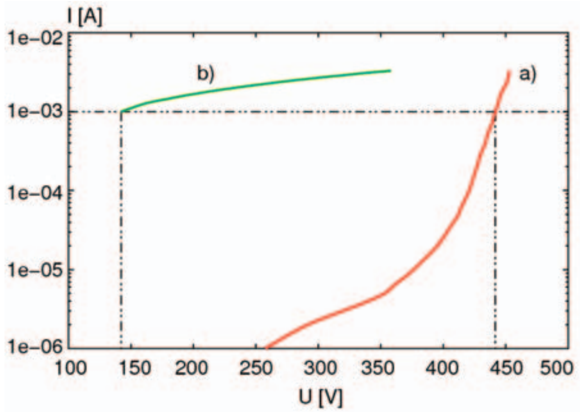

Fig. 5. Current-voltage characteristic of varistor type overvoltage protective devices

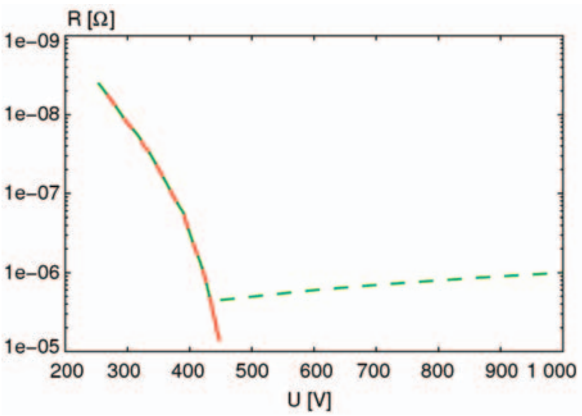

Fig. 6. Insulation resistance of varistor type overvoltage protective devices in dependence on the test voltage

In the figure 4 basic circuit diagrams of complete overvoltage protective devices for high frequency applications is shown. They consist of varistor, suppressor diode and auxiliary elements (fig. 4a) or air-gap, varistor, suppressor diode and auxiliary elements (fig. 4b). In this case it is impossible test overvoltage protective elements individually. In this case of measurement of the voltage protection level should be satisfactory. Some manufacturers developed special measuring equipments for diagnostics of the complete overvoltage protective devices.

In the figure 5 current-voltage characteristic of varistor type overvoltage protective devices is shown. In the case (a) only single varistor type overvoltage protective device was measured. The magnitude of the 1 mA reference voltage is 442 V. In the case (b) complete overvoltage protective device with auxiliary circuits was measured. In this case the magnitude of the 1 mA reference voltage is 137 V. This measured value can be interpreted incorrectly as defective overvoltage protective device.

In the figure 6 insulation resistance measurement of varistor type overvoltage protective devices in dependence on the test voltage is shown. Solid line represents data measured correctly in all voltage range. On the contrary, dashed line represents incorrect measured data due to current limiting to 1 mA only.

Conclusions

Nowadays the application of the overvoltage protective devices is well known. Most of manufacturers inspect its products therefore it is no need to test new overvoltage protective devices before installation. For successful start the observation of the electrical installation and verification of the project before putting in operation is recommended. However, because of impeccable and safe long-term operation periodical testing is needed. In addition, testing of the overvoltage protective devices after each storm activity is recommended. The storm activity depends on geographic and ambient conditions too.

For the user (consumer) the determination of each overvoltage event is not simple because it includes more complex effects, e.g. atmospheric, switching, electrostatic, etc. But the detection of overvoltage events by impulse counter is possible.

The diagnostics of overvoltage protective devices depend on its design and class. Some electrical parameters can measure with simple electric devices. Before testing the design of the overvoltage protective device must be known in order to prevent from mistakes and bad interpretation of the measured data. Some measured data differ in specific range according to manufacturer of the overvoltage protective device. Hence usage of appropriate data base for measured data is useful.

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