Testing

of portable earthing and short-circuiting devices

Contents

Introduction
Description of the test method
Test setup
Practical measurement
Results of the test method
Practical examples
Summary

Translated White Paper

published at the
17th ELEKTROTECHNIK 2014
lecture in Kassel

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1. Introduction

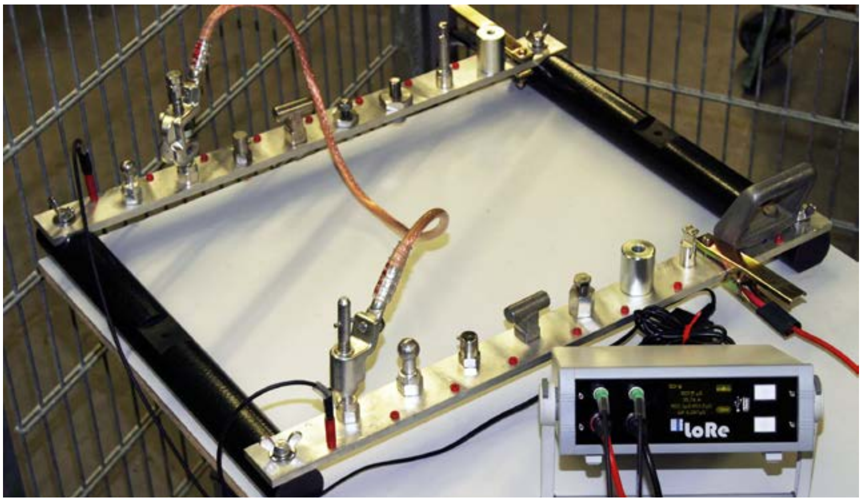

Figure 1 Test setup

An important measure when working on electrical installations according to the five safety rules is the fourth rule "Carry out earthing and short-circuiting". This ensures that the installation is dead for the duration of the work so that the worker is protected from interference voltages, atmospheric overvoltages, unpredicted feed back and accidental re-connection. However, this safety measure is only as good as the tools used [1].
Reduced cable cross-sections of portable earthing and short-circuiting devices resulting from copper corrosion and breakage of conductor strands or increased resistances in the connections may have fatal consequences when earthing and short-circuiting devices are subjected to short-circuit currents.
Based on the experience of the German professional association, faulty devices are a safety risk. Therefore, earthing and short-circuiting devices must be tested prior to each use and at regular intervals [2]. Up to now, only a visual inspection by the user or a service provider made economic sense.
The flyer published by the BG ETEM (German Professional Association for Energy, Textiles, Electrical Goods and Media

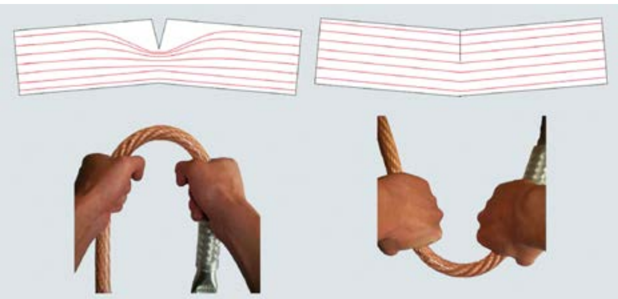

Figure 2 Bending a faulty cable

Products) "Arbeitstägliche Sichtprüfung von Erdungs- und Kurzschließvorrichtungen (EuK)" (Daily visual inspections of earthing and short-circuiting devices (EaS)) [3], which was prepared in cooperation with the VDE 0683-100 [6] standardisation committee, forms the basis for this visual inspection. However, a visual inspection is always a subjective assessment. Since particularly hidden damage cannot be detected, visual inspection only allows vague interpretations. Therefore, the BG ETEM entrusted the University of Applied Sciences in Dresden with the development of an objective test method. The test method developed was presented at the 16th ELEKTROTECHNIK 2012 lecture in Kassel [4].
This paper shows whether this test method has proven its worth in practice.

1.1 Description of the test method

The American ASTM F2249-3 standard [5] already describes an electrical measuring method for testing earthing and short-circuiting devices. In this process, a measured absolute resistance value is compared with a calculated ohmic reference value. This is a static method performed on a stationary device. However, fundamental research [7] has shown that local damage such as breakage of conductor strands in the cable can only be detected by bending the cable. Therefore, the new method consists of a static and a dynamic test component: The measurement of the relative change in resistance is new.

An earthing and short-circuiting device can now be tested in three steps:

- Step 1: Visual inspection for signs of damage to the earthing and short-circuiting device
- Step 2: Static test – Measurement of the absolute resistance value at a stationary earthing and short-circuiting device
- Step 3: Dynamic test – Measurement of the relative change in resistance when bending an earthing and short-circuiting cable

Step 3, the relative change in resistance ΔR is measured when bending the earthing and short-circuiting cable. This relative change in resistance ΔR occurs if the cable is bent at the fault

Testing of portable earthing and short-circuiting devices

location and the single strands are separated and contact one another again, thus influencing the electric flow field and changing the resistance correspondingly (Figure 1). For this relative change in resistance ΔR, limit values were theoretically determined and experimentally proven.
The following values are measured on used earthing and short-circuiting devices and compared with the limit values determined before:

- Total resistance at the stationary device
- Change in resistance at the cable by bending the cable
- Change in resistance in the vicinity of the connector by pulling the cable

It became obvious that new earthing and short-circuiting devices must have different limit values than used earthing and short-circuiting devices. In the practical tests, particularly used cables were tested for signs of damage. Since the single strands of used devices are more heavily oxidised than that of new devices, a considerably poorer transverse conductivity is achieved when bending the cable. This is considered in the table by means of different limit values (Figure 2).

1.2 Test setup

A specially adapted test setup is used to determine the absolute and relative resistance value. This test setup consists of a micro-ohmmeter [8], a rail structure made of aluminium with adequate fixed points for connecting the earthing and short-circuiting device (Figure 3) and a software for automatically evaluating the measured resistance values. The measured values are compared with the calculated limit values from Figure 2 and are evaluated.

Cross-section (mm²)	16	25	35	50	70	95	120	150
Change in resistance new $\Delta R_s (\mu\Omega)$	25	13	9	8	6	5	4	3
Change in resistance used $\Delta R_s (\mu\Omega)$	100	52	36	32	24	20	16	12
Change in resistance $\Delta R_V (\mu\Omega)$	267	171	120	86	60	45	36	27
Resistance load per unit length $R' = r (\mu\Omega/m)$	1935	1240	885	620	440	325	255	205
Temperature (°C)		- 20	- 10	0	10	20	30	40
Correction factor		0.84	0.88	0.92	0.96	1.00	1.04	1.08

Figure 3 Limit values for new and used earthing and short-circuiting devices

1.3 Practical measurement

After setting up the complete system and establishing a connection to the laptop, a reference measurement with known measured values is performed to check the operation of e.g. a single-pole earthing and short-circuiting device. The earthing and short-circuiting device to be measured (specimen) is prepared: The cable cross-sections are read off, the cable lengths are manually measured and these values are entered in the screen together with the ambient temperature (Figure 4). The software automatically determines the limit values of the device from these values and displays them.
The specimen is connected to the rails. To ensure that no test step or measured value is overlooked, the required measuring steps are stipulated by the software. At first, the absolute resistance value of a measurement section is measured. Then the relative resistance value of the cable and the crimp connections is measured by bending the cable.
The software automatically compares all measured values with the limit values. As soon as a measured value exceeds the limit value, the value field is marked in red, meaning that the earthing and short-circuiting device is faulty (Figure 4).

After that, the software prompts the user to visually inspect the device and to document the result. The overall test result is displayed and documented by the software. When practically assessing the measurement results, it can be seen that the common measured values are more favourable than the limit values. In case of tests whose measured values are close to the limit value, the reason for the deviation from the commonly expected value should be analysed.

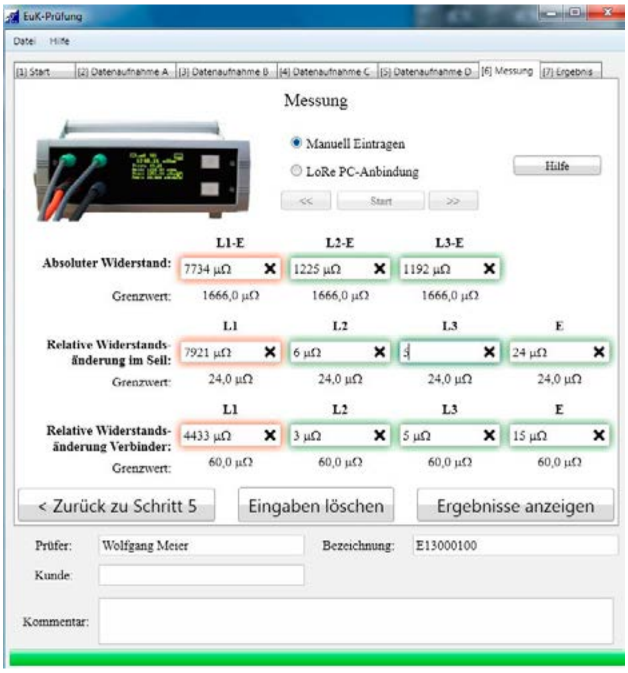

Figure 4 User interface of the software

Testing of portable earthing and short-circuiting devices

For preventive maintenance, the overall result is displayed in green / yellow / red and described in a protocol printout.

- Green: Limit values are perfectly kept
- Yellow: Limit values are still kept = Must be scheduled for maintenance
- Red: Limit values are not kept = Earthing and short-circuiting device must be repaired or removed from service

The overall result can be saved in the form of a protocol in pdf format and can be managed in an Excel file. To be able to clearly identify the tested earthing and short-circuiting device, it is labelled (Figure 5).

2 Results of the test method

In total, 261 earthing and short-circuiting devices from national and international utilities and industrial users were tested. Renowned manufacturers provided 41 % three-pole and 59 % single-pole earthing and short-circuiting devices. Since particularly old and used earthing and short-circuiting devices were tested, the overall damage result is relatively high (68 %). It can be assumed that fewer devices are faulty under normal operating conditions.
41 % of the damaged devices show global cable damage (absolute total resistance value of the device is too high). Local cable damage (increased resistance value when bending the cable) amounts to 22 %, local connector damage (increased resistance value when pulling the connector) is 31 %. About 40 % of the devices would have to be removed after a visual inspection, however, they were nevertheless used to test the method in practice.
In practice, the requirements of the BG ETEM [3] are interpreted quite differently and subjectively for visual inspection. Experience has show that many earthing and short-circuiting devices, which would have to be removed from service after thorough visual inspection, are still used in practice.

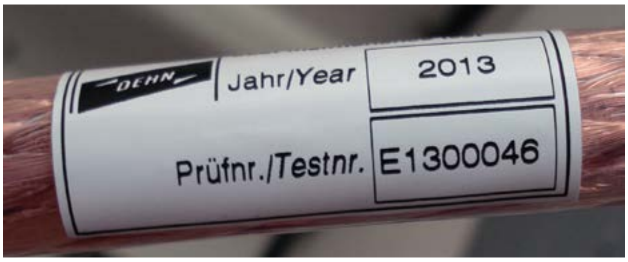

Figure 5 Label of a tested earthing and short-circuiting device

This was confirmed in a blind study with 17 earthing and short-circuiting devices during which two measuring engineers performed the visual and electrical test independent of each other and without knowing each other. Only 76 % of the results of the visual inspection were in agreement, while 94 % of the results of the electrical measurements were in agreement.

Figure 6 Fault detected by means of the method

2.2 Practical example A

When testing a single-pole earthing and short-circuiting device (Figure 6), the resistance value ΔR was abruptly increased in a certain cable section when bending the cable and by far exceeded the limit value. This abrupt increase indicated that a fault may be present. No significant damage was visible. After removing the PVC sheath and untwisting the copper core, the inner copper cable was black. This colouration indicates considerable copper corrosion and thus a reduction of the effective cross-section. The device would presumably not have been capable of withstanding the nominal data (rated short-circuit current and time) in the event of a fault, resulting in a risk for the installer in the installation.

2.3 Practical example B

A computer tomography (CT) provides sectional views of earthing and short-circuiting devices and evaluates them. Selected earting and short-circuiting devices which were recognised as faulty by means of the new test method were tested with the METROTOM® 1500 from the company Carl Zeiss. However, the geometrical measuring range of this CT device is only about 3.5 cm (Figure 7).

Testing of portable earthing and short-circuiting devices

Figure 7 Test setup for the 3D computer tomography (red: measuring range, blue: axis of rotation)

Figure 8 shows the result of the tomography. Constriction of the individual copper strands, large cavities in the cable and interruptions of the single strands can be seen. The same cable damage is detected by the earthing and short-circuiting procedure. This confirms that faults detected by the more complex and expensive computer tomography can also be found by means of the new and relatively simple earthing and short-circuiting test method.

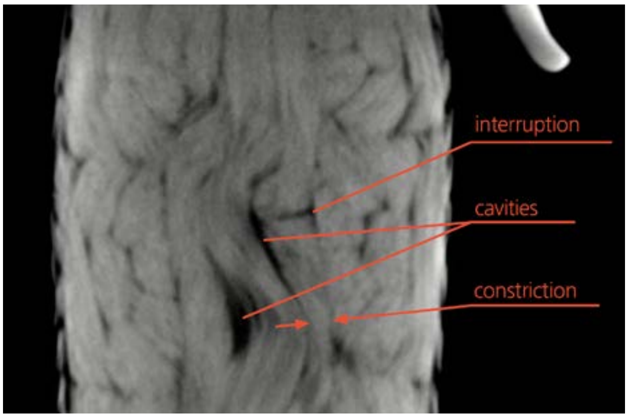

Figure 8 Result of the computer tomography

3 Summary

Visual inspections alone are not sufficient to detect all damage to earthing and short-circuiting devices since hidden damage is not visible. It can be assumed that earthing and short-circuiting devices with hidden damage are used in practice. To obtain objective and reproducible test results, it is necessary to use the measuring method with a micro-ohmmeter and the corresponding test setup.
The results show that a combination of a visual inspection and a measurement increases the safety of earthing and short-circuiting devices. During the practical test, the measuring procedure, micro-ohmmeter and software were continuously improved to ensure practical and efficient use. Compared to the known non-destructive test methods (thermography, 3D X-ray testing, ultrasound testing), the new earthing and short-circuiting method offers practical advantages. It can not only be performed in the laboratory, but also on site by an electrically skilled person.
The protocol, which is automatically created by the software, documents the technical test which must be performed at regular intervals which are required depending on the operating conditions on site such as stress, frequency of use and ambient conditions.
Based on the test intervals for capacitive high-voltage detectors, an interval of six years is recommended. The new test method for maintenance tests of earthing and short-circuiting devices can be performed by competent users or can be provided as a service by manufacturers.

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