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Inspection of the efficiency of conductive clothing examination

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ABSTRACT

High voltage live-line maintenance (LLM) is a commonly applied method worldwide to execute planned works in the grid economically [1]. In case of bare-hand technique workers wear a so-called conductive clothing acting as a Faraday-cage which protects them against the high electric fields during the work.

1. Introduction

Conductive clothing has to be examined periodically [2]: the most important aspects of these measurements are the inspection of the electrical resistance and the screening efficiency of a given clothing. Experiences of the measurements executed in the High Voltage Laboratory of Budapest University of Technology and Economics (BUTE) show that the way of screening efficiency inspection is not effective enough. Numerous calculations, simulations and measurements were made to suggest modifications in the current arrangement to increase the efficiency of the inspection and to guarantee the maximal safety of the workers: not only the position of the electrodes, but the principle of the measurement has been changed. Results of the researches were revised by the responsible committee of IEC and are proposed to be included in the next edition of the related standard, IEC 60895.

2. Inspection of conductive clothing

By the current guidelines of International Commission on Non-Ionizing Radiation Protection (ICNIRP), limits for both public and occupational exposures have been defined. Current limits for electric fields are summarized in Table 1 [3,4,5,6].

As Table 1 shows, extra-low frequency electric fields shall not exceed 10 kV/m, even in case of occupational cases.

In the High Voltage Laboratory of Budapest University of Technology and Economics, several calculations, simulations and measurements have been executed to inspect the critical opening size of the conductive clothing, as Faraday-cages. Results show that above a given “Faraday-hole” size, electric field strength inside the clothing exceeds its limits – even with orders of magnitudes.

Fig. 1 shows the maximal electric field strength values as a function of the nominal voltage level of the power line in the vicinity of an energized conductor: the distance between the high voltage conductor and the face was supposed to be 15 cm. As it can be determined from the figure, in case of large openings, electric fields may endanger the safety of the worker by exceeding their limits significantly [7,8].

During the inspection of conductive clothing it is crucial to identify personal protective equipment which may endanger the health of the worker. In case of conductive clothing, screening efficiency describes the protective effect of the Faraday-cage [9]. This kind of examination has to simulate worst-case working conditions and has to separate acceptable and unacceptable results clearly from each other.

3. The current way of measurement

The related European standard, IEC/EN 60985 defines the acceptance criteria based on the ratio of leakage currents. During the screening efficiency measurement, a mannequin – with a conductive surface – shall be dressed in a conductive clothing, insulated from the body. The conductive clothing shall be energized and leakage currents shall be measured in the high voltage side of

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Table 1
Valid electric field limits for 50/60 Hz (extra-low frequency).

Type of exposure	Valid electric field limits [kV/m]
Public exposure (24 h/day)	5
Occupational exposure (max. 8 h/day)	10

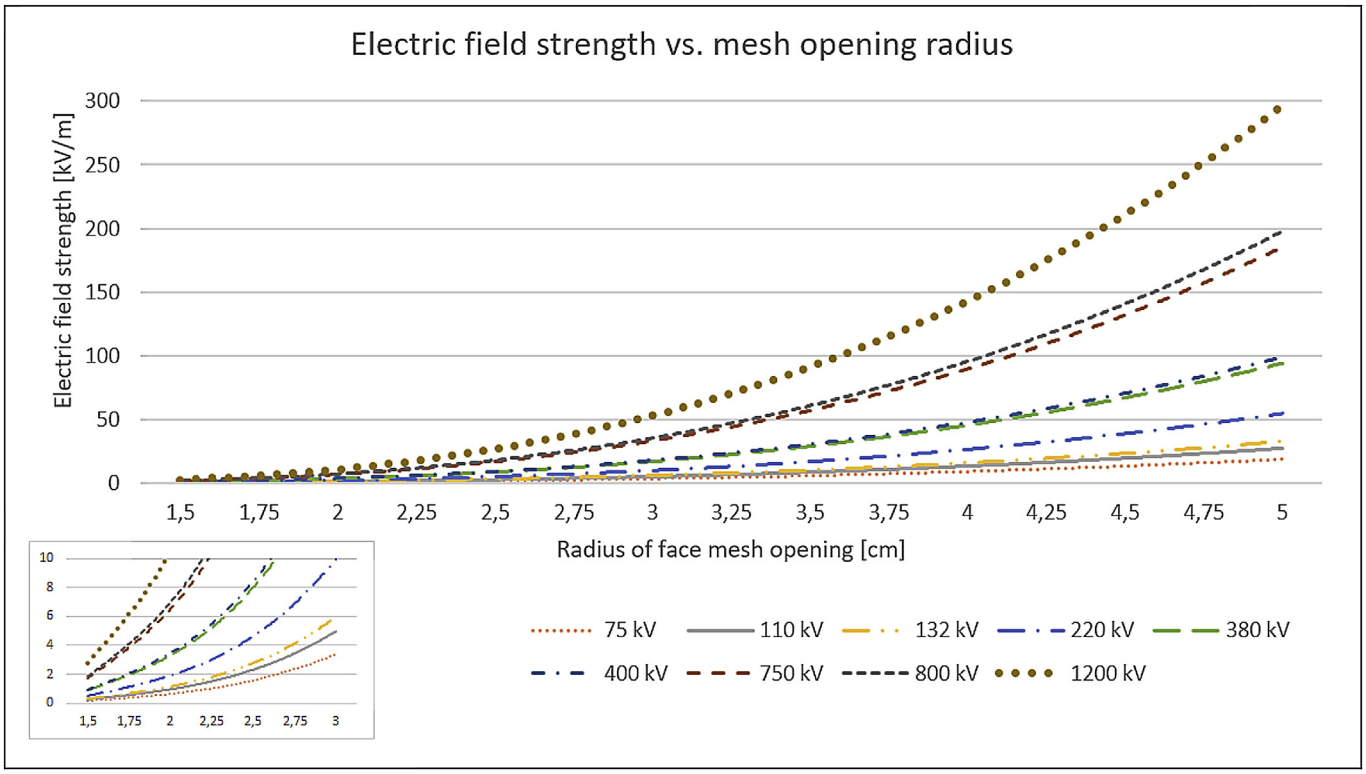

Fig. 1. Electric field strength as a function of face mesh opening radius.

Fig. 2. Dangerous and inaccurate way of leakage current measurement by "shielded" micro-ammeters.

the arrangement. Fig. 2 shows an example for this way of measurement during a conductive clothing inspection in the High Voltage Laboratory of Budapest University of Technology and Economics.

In this case one of the main issues is that – in case of the application of conventional micro-ammeters – results are basically determined by the efficiency of the shielding of the instruments, so the measurements are inaccurate; it is even dangerous to read the measured values. Fig. 3 shows the variation of electric field distribution – so measured leakage current values – as the base of determination of screening efficiency. As it can be seen, the vicinity of the arrangement (especially the distance and the position of the grounded parts) may distort the results significantly; even so-called "shielded" areas may be formed, as it can be seen in the figure above the mannequin. These phenomena make measurements hard to compare and repeat.

The main issue with the current way of measurement is that conductive clothing may pass the test without any face mesh, even with a large opening in front of the face. Measurement results show that screening efficiency may be above the limit, specially in case of the complete lack of any face protection. As the result of issues regarding to the current way of measurement, many of the poorly designed conductive clothing may pass the test.