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CLEANING OF MEDIUM-VOLTAGE SYSTEMS BY SUCTION

EK/E

Special Publication No. 40/E
Based on an article
from EVU-Betriebspraxis
Issue 12/96, revised version
10/98

With the compliments of
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LIVE WORKING – CLEANING OF MEDIUM-VOLTAGE SYSTEMS BY SUCTION

1. General Introduction

Preventative maintenance and care of indoor systems is of great importance. Cleaning of open system should be considered as a priority task. Depending on the kind of severity of conditions, cleaning at regular intervals, e.g. half yearly extended to a period of up to two years, is necessary. The cleaning method for open indoor systems considerably reduces the frequency of supply system interruption, compared to before the introduction of live working.

Live cleaning may only be performed by especially trained electrical engineers with several years experience in operation or maintenance of electrical installations. The training program should include theoretical and practical training, representing the work to be performed after completion of the program or to comply with the same safety principles.

The training program for live working specialists intends to meet the requirements as set out by The Trade Association for Precision and Electromechanical Engineers. The training comprises the theoretical and practical training, testing the capability of the skilled or instructed persons, and after successful completion, a certificate is issued confirming the level of training, (e.g. "Live working, Cleaning of installations up to 36 kV").

2. Equipment for Cleaning by Suction

Dry-cleaning measures consist of vacuum cleaning the dust, using vacuum nozzles or brushes for the components to be cleaned *(Figure 1)*. The vacuum nozzles and brushes couple to the suction pipe, which lengthens in units.

The equipment for live cleaning comprises:

A cleaning head (nozzle and brush), suction pipe with handle, extension pieces, a suction hose and a vacuum cleaner *(Figures 2 a and b)*.

Equipment for live cleaning by suction must be short-circuit-proof from the red ring to the upper adapter piece, including the cleaning head.

Nozzles, brushes, angle pieces as well as suction pipes and suction hoses are made of plastic and are fully isolated. The brushes and nozzles are designed to fit the shape of the parts of the installation to be cleaned. Semi-circle brushes are designed for the cleaning supporting insulators (e.g. supports and bushings, *see Figure 3)*.
In large installations, especially where the busbar installation cannot be seen from below, the work is performed from a raised location, e.g. a movable insulating platform *(Figures 4 a and b)*. The fully insulated mirror is designed to check obscured parts of the installation *(Figure 5)*. The vacuum cleaner must provide a minimum air speed of 20 m/s and an indication for monitoring the suction power.

Cleaning and visual inspections of the equipment is to be performed after use, in compliance with the instructions for use supplied with the equipment.

Switchgear equipped with disconnection devices that can accidentally be activated by contact with the cleaning equipment must be deactivated before the cleaning work starts. The appropriate deactivating devices for switch-disconnectors and circuit breakers

Figure 1:
Cleaning of an operational unit by suction

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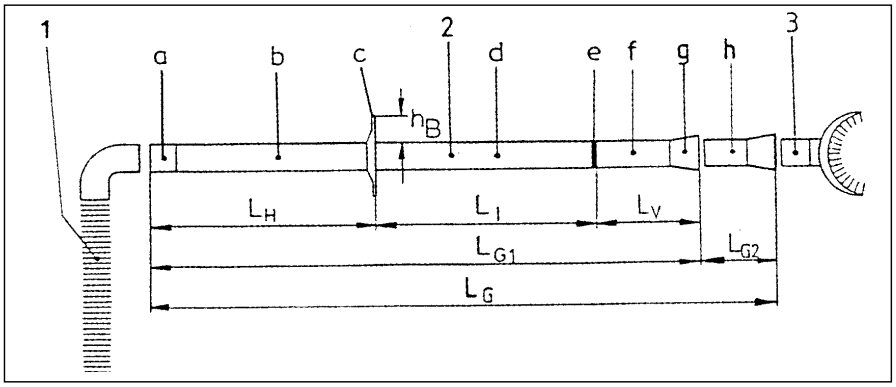


1 Suction hose
2 Suction pipe with
- *a Lower adapter*
- *b Handle*
- *c Hand guard*
- *d Isolating element*
- *e Red ring*
- *f Extension piece*
- *g Upper adapter*
- *h Suction pipe with extension piece*

3 Cleaning head
Dimension:
- L_G *Total length of suction pipe with extension piece*
- L_{G1} *Total length of suction pipe*
- L_{G2} *Length of extension piece*
- L_H *Length of handle*
- L_I *Length of insulating element*
- L_V *Length of extension piece*
- h_B *Height of hand guard*

Figure 2: Equipment for cleaning by suction
a) Cleaning head, suction pipe and suction hose

are available for each specific type of switchgear.
Live cleaning by suction is different from all other live work in that the tools are intended to get into contact with dust.

Therefore, the following basic experiments compared the influance of dust and humidity on the insulation capability of the tools.

- Conductivity of the dust dependent on the relative humidity and temperature.
  – In order to determine the behavior of extremely conductive materials, dust samples were obtained by cleaning transformer stations situated in polluted areas. Additional testing of materials included edible salt, flower fertilizer and extremly potassic dust. The influence of the quantity of dust on the leakage current was also determined.
  – Results:
  The leakage current increases with increasing quantity of dust or temperature rise, with the relative air humidity remaining constant *(Figure 6).*
- Influence of humidity on the insulating capability of clean and soiled insulating brushes.
- Leakage current on the suction tube when vacuum cleaned
  – Dust samples tested included the following: Cement dust, dust in rural areas, chemical dust, stone dust, dust in special underground power plants, stone salt, potashious dust, gypseous dust, carbonic dust and others.
  – Results:
  Even at a temperature of 35°C and with a humidity of 90 %, the leakage currents on the suction tube were far below the permissible value of 200 µA.
- Insulating capability of the network insulators while working with the dry cleaning equipment

The requirements for electrical safety are based on the "reduced values" of the minimum distances in accordance with DIN VDE 0101/1989-05, Table 1.
The cleaning equipment may only be used in factory assembled type tested installations subject to the permission of the manufacturer, who must be contacted by the user of the cleaning equipment or the operator of the switchgear.

Figure 2: Equipment for cleaning by suction
b) Live working cleaning equipment and accessories

3. Live Cleaning of 36 kV and 5 kV rated HV switchgear

3.1 Dry Cleaning of 36 kV rated, energized indoor switchgear

The internal power supply of an automotive company based in Western Germany consists of 62 operating units equipped with circuit breakers and the appropriate disconnecting devices. The units supplied from upper busbars directly fed by the Utility Company could not be cleaned for a period of 17 years as they could not be disconnected from the supply.

The process involved the vacuum cleaning of polluted busbars, insulators and the upper part of the disconnecting device. Two electrical engineers of the systems engineering department of the Siemens AG in Erlangen were selected to perform the cleaning procedure. While the nominated person in controll of the electrical installation was only responsible for the direct management of the work activity, the second skilled person performed cleaning from ground level or standing on an insulated platform *(Figures 4 a and b).*

The cleaning procedure is classified as live work in accordance with the VBG4, Table 5, Section 2. According to this procedure, the organizer explained and stated the reasons for live cleaning, in writing, besides ensuring technical, organizational and personal safety precautions, prior the starting of work. The workers were skilled and trained for the work activity and the person in control of the work activity nominated. With the basic regulations of VBG4 fulfilled, the cleaning work activities were recorded. *Figure 7* shows the cleaning procedure at busbar supports.

Figure 3: Use of a semicircle brush

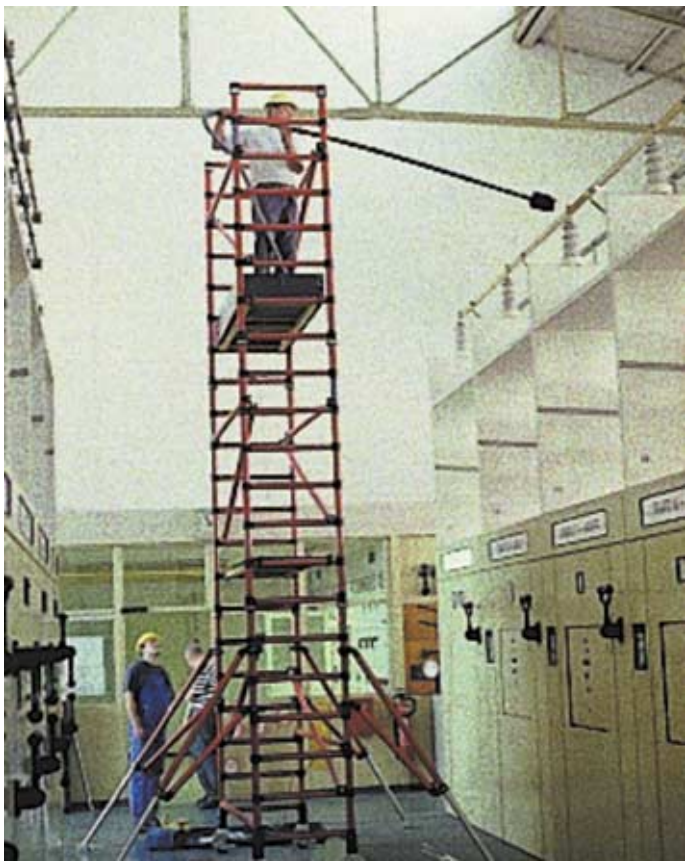
3.2 Dry Cleaning of 5 kV rated, energized indoor switchgear

The process involved the vacuum cleaning of 44 energized, 5 kV operational switchgear. Again, two electrical engineers of the systems engineering department of Siemens AG in Erlangen were selected to perform the cleaning procedure.

Conclusive test results proved that partial discharge reduced from 55 dBA to 40 dBA after the cleaning work was completed, ensuring technical, organizational and personal safety precautions, before the dry cleaning started.

4. Current Standardization and Regulations on Live Working

Regulations for live working are presented in current and draft standards or regulations for the prevention of accidents providing information on equipment and devices as well as on the operation of electrical installations. They specify the aims of protection, permitted work activities including the required pre conditions and are bound to the nominal voltage of the installation. The organization of work activities dependent on the qualification level of the personnel and applicable technical and organizational safety precautions.



Figures 4 a and b: Cleaning of 30 kV rated switchgear from an insulated platform

4.1 Live Working: K 214 Opinion "Protection against Electric Shock, Protective Equipment and Devices for Live Working"

The document "Equipment for cleaning by suction" was completed by the VDE-subcommittee UK214.4 of 6th August, 1996. The document is based on the former GDR-TGL-regulations, adapted to DIN VDE 0681 Part 1 "Devices for operating, testing and separation of live parts under nominal voltages above 1 kV, General regulations".

4.2 Live Working: K 224 Opinion "Operation of Electrical Installations"

VDE 0150, Part 100, Section 6.3 considers and describes three groups of live working:
a) generally accepted live working activities;
b) work activities which can only be performed in the energized state due to technical reasons;
c) additional work activities which may be performed in the energized state, supporting certain preconditions.

Cleaning of medium-voltage systems is, on one hand, considered in group a). Among others, the following is said:
"Approaching of tools for moving easily portable parts using insulating rods at nominal voltages above 1 kV."
On the other hand, the following is said in Section 6.3.12 "Special live working activities: For work activities like cleaning, washing of

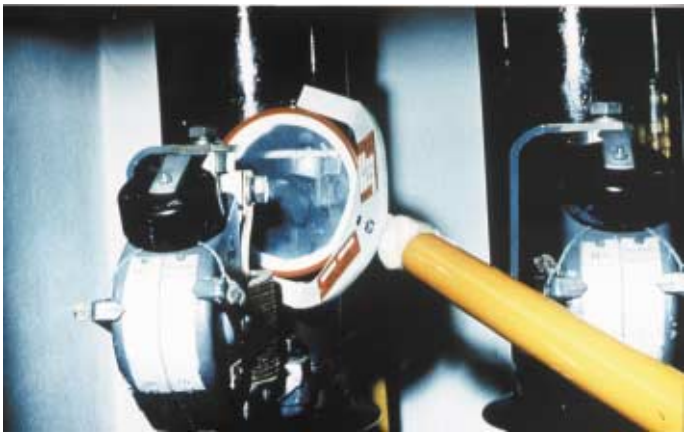


Figure 5: Inspection of hidden system parts, using a fully insulated mirror

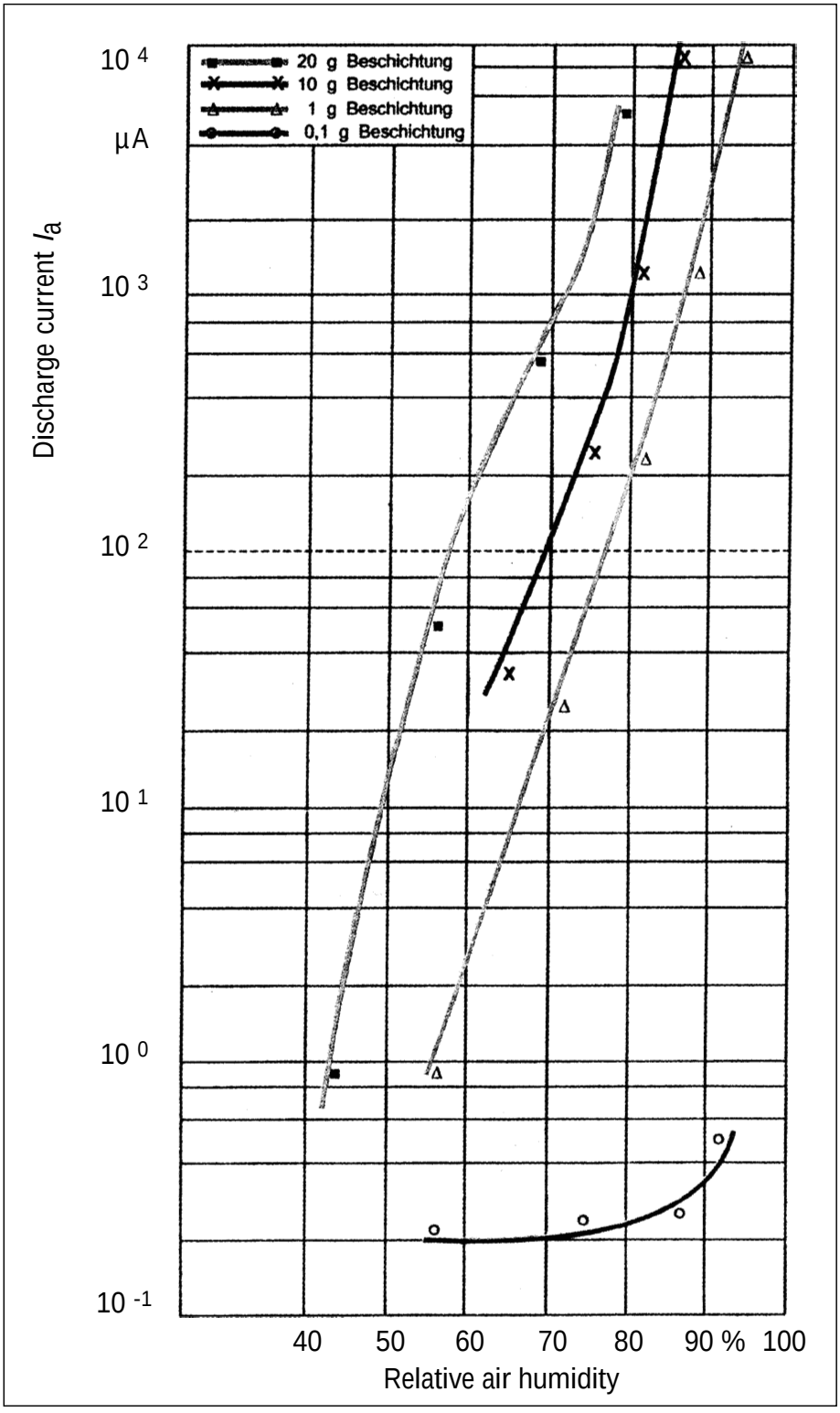


Figure 6: Influence of potassic dust on the leakage current

insulators, removal of roar-frost deposits, special instructions for work must be given. These work activities may only be carried out by electrically skilled or electrically instructed persons."

An essential part of this standard is also Section 6.3.11 "Special regulations for electrical power installations:
All selected methods and tools must be checked for their suitability regarding the installation where the work activity is to be done. The electrical and mechanical characteristics of tools as stated in their specifications or in the applicable standard must fulfil the physical requirements of the work location.
If the nominated person in control of the work activity is not able to supervise the work location on his own due to its extension, he must instruct other personnel to do this task."

Furthermore the following is demanded:

- special training program;
- continuous practice;
- tools, equipment, protective devices and auxiliary devices,
- conditions of the environment
- organisation of the work activity
  - preparation for work,
  - action of the nominated person in control of the electrical installation,
  - action of the nominated person in control of the work activity.

4.3 Live Working in Accordance with Regulations for the Prevention of Accidents of the Trade Asso-ciation of Precision Mechanics and Electrical Engineers „Electrical Installations and Equipment“ (VBG 4)

In accordance with § 6 of the regulations for the prevention of accidents "Electrical installations and equipment" (VBG4 of 1st April 1979), including the "Instructions for work" (April 1986 and the Annex of April 1995), work activities at energized parts of electrical installations and equipment are not allowed without complying with the regulations in § 8:

§8
Permissible exceptions

Deviation from the rules and regulations as specified in section 6 and 7, is allowed when

- *Electrocution and exposure to arcing can be excluded due to the type of installation*
- *The de-energized state cannot be achieved due to*
  - Electrocution or exposure to arcing are excluded
  - The employer nominates only electrically skilled staff, trained for live working
  - The employer implements additional technical, organizational and personal

Nominal voltage	Work activity	EF	EUP	L
up to 50 V AC up to 120 V DC	All work activities where danger of arcing can be excluded.	●	●	●
above 50 V AC above 120 V DC	1. Approaching of suitable test and measuring equipment, e. g. voltage detectors, suitable tools for moving easily portable parts	●	●	
	2. Approaching of suitable tools and equipment for cleaning and the installation of suitable covers or barriers;	●	●	
	3. Removal and insertion of fuse bases which are not protected against direct contact using suitable equipment, if danger cannot arise from this;	●	●	
	4. Spraying of live parts for fire fighting or for cleaning of outdoor installations;	●	●	
	5. Working at batteries while providing suitable safety precautions;	●	●	
	6. Working in test cabinets or laboratories while observing suitable safety precautions when required by the working conditions;	●	●	
	7. Removal of hoarfrost deposits with the help of suitable insulating poles;	●	●	
	8. Location of faults in auxiliary circuits (e. g. signal transmission in circuits, short-circuiting of partial circuits) as well as functional tests of equipment and circuit installations;	●	●	
	9. Other work activities when – 1. Compelling reasons were noted by the user of the installation – 2. Persons authorized to give instructions, responsibilities, working methods and procedures (instruction for work) were nominated in writing. These persons must be especially trained for the work to be done.	●		
All other	All work activities when the circuits are intrinsically safe and no special risk is evident (e. g. hazards of explosion).	●	●	●
	Work activities to exclude hazards, e. g. to life and health of persons, or hazards of fire or explosion.	●		
	Working at telecommunication systems with remote control, when the current is below 9 mA AC or 60 mA DC.	●	●	

Table 5: Marginal conditions for live working with regard to the appropriate choice of personnel depending on the nominal voltage of the installation.
Electrically skilled person: ESP
Electrically instructed person: EIP
Ordinary person: OP

precautions to ensure the protection of the personnel against electric shock and arcing.

The following "compelling reasons" from part of VDE 0105 Part 1 in Section 12.3.1 were adapted in the draft Standard EN 50110 Part 100 (German normative annex EN 50110 Part 1). However, after several discussions and changes, this paragraph was excluded. This decision was imposed due to the comprehensive regulations referred to in European Standard EN 50110 Part 1, regarding the qualification of the personnel and the equipment. These changes incorporated the revised edition of the operating instructions VBG4 in 1995/ 1996.

The revised version was published in 1996 and states:

§ 8 No. 2:
Compelling reasons in de-energized systems:

- *Risk to lives and health of people*
- *Considerable economical damage to companies,*
- *When working in power supply networks, especially when installing connections, replacing lines, ripple control receivers or time switches while the power supply is interrupted,*
- *When working on or near traction lines while the rail transport is disturbed or interrupted*
- *When working on communication lines including information processing systems or essential parts of the system, while the power supply would have had to be interrupted, risking the lives and health of people.*
- *When causing disturbances of traffic signal systems which may result in risking the lives and health of people or damage to equipment.*

Work performed on live equipment involves an increased risk of electric shock and arcing. It is, therefore, necessary to take special technical and organizational precautions in order to reduce the residual risk (see DIN VDE 31000 Part 2: 1987-12, for risk of occurrence and severity of injury) to an acceptable level. Observing the following requirements and Electrical Engineering standards can ensure this.
Whenever work is to be performed on live equipment, the employer must state the reasons for live working pertraining to all the work in question, in writing, talking into account the chosen method of work, the frequency of the work and the qualifications of the staff responsible for performing it. It is required that work instructions be implemented for the tasks and suitable protective equipment and tools are provided. By using NH fuse handles with permanently fitted sleeves and wearing a visor (face shield), the risk of electrocution and exposure to arcing while removing and inserting live fuse links in the l. v. h. b. e. system, without protection against electrocution and load-break appability, is virtually eliminated.
Insulated tools and insulated equipment used for working on live parts of an electrical system are suitable for live work if they bear the symbol of the insulator or a double triangle incorporating the voltage range or class.
The requirements, regarding technical qualifications for working on live parts, comply with the conditions as stipulated in Table 5, are observed and appropriate training is given for the task to be performed. The knowledge and skills of the staff concerned are tested of regular intervals (e.g. once a year) and, if necessary, the training extended or repeated. As part of the organizational safety precutions, someone who has been trained in First Aid and who has at least received instructions concerning Electrical Engineering should monitor the work (see § 7 of UVV (accident prevention regulations), "First Aid" VBG 109)). The safety precautions must be defined in writing for individual tasks or certain regularly recurring tasks, and must take into account the provisions supported by Electrical Engineering standards.

Table 5 has also been structurally revised (see page 6).

Figure 7: Cleaning of 30 kV busbar supports

4.4 Note

The European Standard VDE 0105, i.e. EN 50100, was published as a valid regulation in October 1997. It was published as a single regulation, i.e. the parts 1 and 100 of EN 50110 were combined in the interest of "user-friendliness".

In April 1998, as a comment of DKE K 224 a revised version of the VDE publication series volume "Operation of electrical power installations - General regulations, Explanation of DIN VDE 0105, Part 1: 1983-07" was published in volume 13 by the VDE publishing house Berlin and Offenbach.

The revised procedural instructions pertaining to Operating instructions VBG 4 were published in October 1996. Committee K 214 requested the Professional Association for Precision Mechanics and Electrical Engineering to revise the current adition of VGB 1 (it has been valid for a period of 17 years). Additionally, in view of the harmonized operating instructions EN50110, but also with the aim to ensure that the "compelling reasons" no longer appear in the text of the accident prevention regulation.

5. Scope of Application

Till 1990, approximately 12000 live working maintenance and repair projects have been completed in East Germany, with the work performed by 1700 trained technicians. The "Cleaning by suction" method was not only applied for power supply utilities but especially in various branches of industry. Deliberate live working does not increase the risk to safety. This was confirmed by statistics compiled over a period of 20 years, since the introduction and practical application of live working methods.

The risk when doing routine work is that safety regulations are not always strictly complied to. This can successfully be prevented by the introduction of continuous training programs for live working, regular instruction of the staff and control mechanisms. To date, live cleaning work in medium and high voltage installations has reported no accidents.

6. Economical Aspects

The advantages of live working becomes evident by uninterrupted supply of power to utility companies and consumers.
When compared to working in de-energized state, live working (e.g. cleaning work) is generally of better quality, faster and less expensive for the following reasons:

- Less coordination of activities necessary
- Switching operation or earthing and short-circuiting precautions are not necessary (adherence of the 5 safety rules),
- Continuity of activity is possible.

The costs for live cleaning medium voltage installations is equivalent to only about 20 % to 25 % of the costs incurred for cleaning de-energized installations.
Live working in medium voltage indoor systems is of greater importance than live working on medium voltage overhead lines, as the frequency of cleaning medium voltage indoor systems is the primary maintenance task. Working to the principle of indirect contact has proved to be effective, economical and safe when complying with the safety rules and regulations. Last but not least, the positive results experienced during the past 20 years of live working confirms that the methods are suitable with regard to both safety regulations and training programs.

Further information on live working can be obtained from the VDE Publication No. 48 "Arbeitsschutz in elektrischen Anlagen" [Hasse, P.; Kathrein, W.]. The third edition, a completely revised and extended edition of this publication, was published in October 1996.

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