WHITE PAPER

Reducing energy from arc faults and protecting maintenance personnel in accordance with standards

New possibilities for personal protection with the DAS+ maintenance mode in the 3WA air circuit breaker

SIEMENS

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What is an arc fault?

Uncontrolled arcs can occur in an electrical installation as a result of a short-circuit or if live parts are disconnected under load without any special precautions being taken. An arc of this kind can be described as a gas discharge with a high current intensity between two electrodes. It causes high temperatures of up to 20,000 K.
Gases and metals in the vicinity of the arc are ionized as a result of the high temperatures and a conductive plasma is formed between the conductors. Targeted use is made of this effect during arc welding, for example. If however an arc of this type occurs as a result of a fault in low-voltage power distribution equipment, it is referred to as an arc fault and poses an enormous risk to people and equipment.

Planning or assembly deficiencies	Operational faults	Handling errors
• Insufficient dimensioning • Excessively high packing density in the power distribution equipment • Poor contacting and loose contacts due to improper assembly • Insulation faults (caused by electrical cables being crushed or bent in too small a radius)	• Overvoltage • Formation of water condensation • Contamination and deposits (resulting in leakage currents, which can ignite in the event of an arc fault) • Loose cable ends between which arc faults can occur on account of ionized gases (caused for example by rodent damage and erosion)	• Failure to observe maintenance and inspection intervals • Operator error or unauthorized work on live electrical equipment or live parts • Bridging of different potentials • Short-circuit, e.g. by tools or other foreign bodies

Table 1: Frequent causes of arc faults

Effects of an arc fault

Power and combustion duration determine the effects of an arc fault; in the worst case, these are comparable to those of an explosion. Metals used in the installation are heated to such an extent that copper conductors evaporate, for example, and the material expands to 67,000 times its size (Jones & Jones, 2000). Individual parts of the installation can ignite and release toxic gases and vapors during combustion. On account of the increase in temperature and the evaporation processes, the pressure also rises dramatically within milliseconds (see Figure 1). Metal parts and equipment components are flung out of the arc like pieces of shrapnel at a speed of more than 1,000 km/h. The rise in pressure is also accompanied by an explosive boom. Another feature of an arc fault is that it does not remain contained locally. On account of the magnetic field surrounding the conductor, it "migrates" rapidly from its original location through the installation.

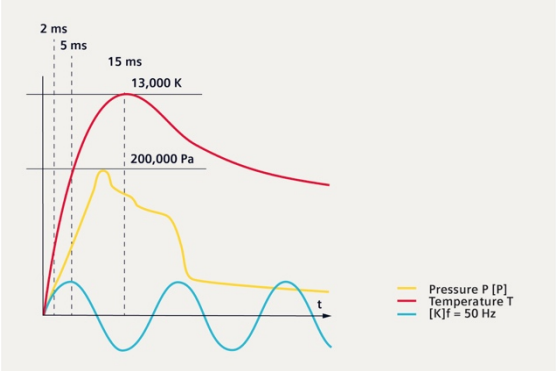


Figure 1: Typical temperature and pressure gradient during an arc fault

Operating personnel can sustain a wide range of injuries during arc fault incidents in low-voltage power distribution equipment because of the enormous physical forces involved (see Figure 2). Moreover, the uncontrolled combustion of an arc fault causes massive damage to the installation, resulting for example in production standstills lasting several days and incurring significant costs.

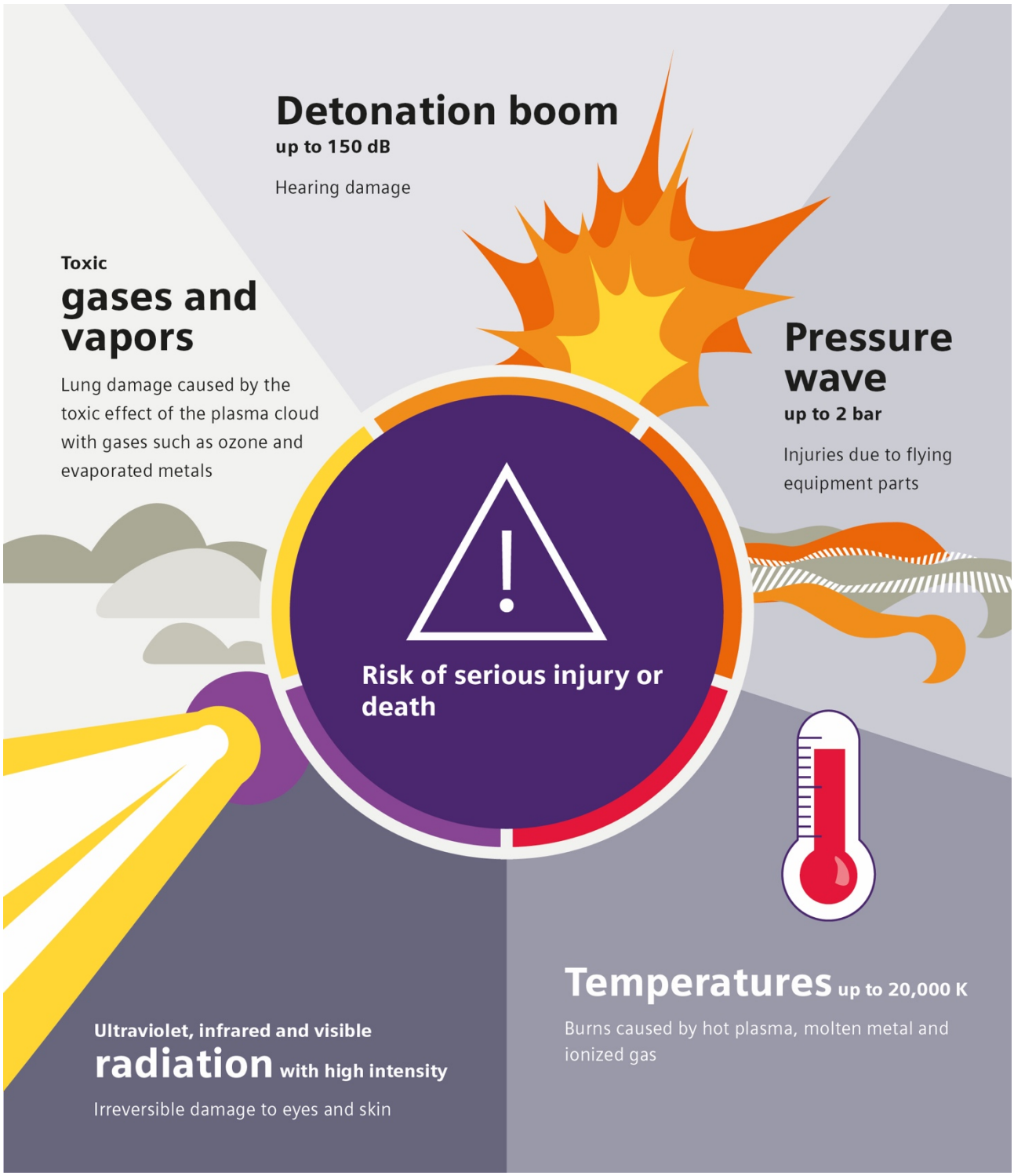


Figure 2: Hazard sources and possible effects on personnel in the event of an arc fault in low-voltage power distribution equipment

Protecting personnel against arc faults

Applicable standards

In recent years, requirements for effective arc fault protection that prevents arcs from forming or limits their effects have been featuring increasingly prominently in the applicable standards. In the USA in particular, great importance is being attached to the issue of hazards caused by arc faults. Documents such as the National Electrical Code (NEC), the NFPA 70E Standard for Electrical Safety in the Workplace, but also DIN EN 50110-1:2013 governing the operation of electrical installations focus in particular on the safety of personnel whose job involves them working in the vicinity of live parts. Although it is recommended as a general principle that work on low-voltage power distribution equipment should be carried out only if the equipment has been de-energized, this is not always feasible in practice. Test runs, troubleshooting or the control of continuous processes can make it necessary to carry out work on live parts.

General protective measures

The possible effects of the arc faults outlined above make it essential to establish a comprehensive safety concept to protect personnel and equipment. Active and passive measures can be taken to prevent personal injury and damage to equipment as a result of arc faults. Passive measures are all precautions that reduce the risk of arc faults occurring in the installation. They include for example the correct dimensioning of the installation during electrical planning but also design measures relating for example to internal separation. Active measures make it possible to detect an arc fault as quickly as possible and extinguish it before more significant damage occurs. Special arc fault protection systems comprising arc fault detection and short-circuiting devices are used for this purpose.

Circuit breakers as part of the safety concept

Circuit breakers as central power distribution components must be configured such that they contribute to a comprehensive system of protection against arc faults. The primary aim here is to ensure rapid deactivation in the event of an arc fault during maintenance work. NFPA 70E stipulates that, with effect from 2014, components with a rated current of 1,200 A or higher must be equipped with one of the following safety precautions for this purpose:

- Zone-selective interlocking (ZSI)
- Differential relay protection (DRP)
- Energy-reducing maintenance function with local status indication
- Energy-reducing active arc fault protection system
- Instantaneous short-circuit protection with a tripping threshold lower than the potential arc current
- An approved equivalent

The DAS+ maintenance mode in the 3WA air circuit breaker – an energy-reducing function

When planning measures to protect against arc faults, it is important to bear in mind that an arc itself acts as a high-impedance electrical resistor. In contrast to a "saturated" metallic short-circuit, an arc is often not detected by normal short-circuit protection because the arc limits the possible uninfluenced short-circuit current by between 20 and 50%. Under normal circumstances, components such as circuit breakers therefore do not respond to the fault or respond only with a significant delay (Cater, 2007). An energy-reducing function with local status indication is integrated as standard in the 3WA air circuit breaker with the DAS+ maintenance mode. The air circuit breaker therefore complies with the following standards:

NEC	NFPA 70E	DIN EN 50110-1
National Electrical Code Section 240.87 (B)(3) Arc-Flash energy reduction (Energy-reducing maintenance switching with local status indicator)	Standard for Electrical Safety in the Workplace	Operation of electrical installations/ B.6 Arc hazard

The purpose of the DAS+ maintenance mode is to ensure that the air circuit breakers trip more rapidly in the event of a fault during work being carried out in the immediate vicinity of live parts. If the DAS+ maintenance mode is active, the current settings of the instantaneous short-circuit protection (INST) and the ground fault protection (GF) are reduced to the minimum values.

As a result, the short-circuit current generated by an arc fault is detected more rapidly in the event of a fault and the air circuit breaker trips at lower limiting values without a delay time. In this way, the arc energy and thus the energy released in the power distribution equipment room is reduced. The use of ground-fault protection is a special feature of the DAS+ maintenance mode. This detects arc fault currents to grounded installation parts in which the arc fault current lies within the rated current range.

Using the DAS+ maintenance mode

For working on live parts, the NFPA 70E guideline recommends defining three zones as illustrated in Figure 3. Different protective measures are mandatory for working in these three zones. The safety distances to be maintained and the appropriate personal protective equipment are determined by means of extensive calculations and simulations. The factors influencing the location of the zone boundaries and the hazard potential include:

- Mains voltage
- Short-circuit current likely to be available at the point under consideration in each case
- Protective equipment used (or lack thereof)
- Enclosure type

Figure 3: Protection zones for working on live parts

Arc flash boundary
The arc flash boundary, in other words the distance from the live parts of an installation, varies according to the hazard potential. It is the distance from an arc source at which the incident energy in the event of an arc fault still amounts to no more than 5 joules per square centimeter. At this energy level, a person without protective equipment could sustain second-degree burns in the event of an arc. Only instructed personnel with corresponding protective equipment should enter this zone.

Limited approach boundary
The limited approach boundary designates the zone in which there is a risk of electric shock. Only specially trained technicians wearing suitable protective clothing should enter this zone. No untrained personnel may approach live parts within this boundary without being supervised by a qualified employee and using suitable protective equipment.

Restricted boundary
Any work carried out within this boundary is deemed contact with live parts. Only qualified personnel having completed special training for working on live parts may cross this boundary and work in the restricted zone. It is mandatory to wear suitable personal protective equipment and to use insulated gloves, tools and special equipment within this boundary. The work must be documented and under certain circumstances a special work permit may be required.

In many cases, the zones would theoretically be so big that the operator would have to make personal protective equipment available to maintenance personnel even before they entered the equipment room. If the energy of a potential arc fault is reduced, however, the zone boundaries also shift. Maintenance work on live parts is simplified and can be carried out more quickly.

No compromises when it comes to selectivity and system availability
Selectivity is used in many applications as a means of maximizing system availability. In this context, the power distribution is configured such that, in the event of a fault, only the protective equipment located closest to the fault trips. Branches unaffected by the fault remain in operation. In circuit breakers, short-time delayed short-circuit release is often used to achieve selectivity. The user sets time intervals of typically 70 to 400 ms, after which the protective devices trip in stages. However, what increases the reliability of the power supply in normal operation has a negative impact on the calculation of the required safety distances.

With the DAS+ maintenance mode, the tripping time is only shortened if work is being carried out on live parts. In normal operation, selectivity and system availability remain unaffected.

Practical guide: the DAS+ maintenance mode in the 3WA air circuit breaker – system integration, activation, status indication

Integrating multiple circuit breakers into the DAS+ maintenance mode

In larger installations with multiple circuit breaker panels, the circuit breakers can be connected for integration into the DAS+ maintenance mode. This makes it possible to activate and deactivate the maintenance mode simultaneously for all circuit breakers. For this purpose, it is possible for example to use a central switch/auxiliary switch or a higher-level signal transmitted via a communication module. It is also possible to integrate a central display, for example in the form of an indicator lamp, which informs maintenance personnel quickly whether the installation is in the maintenance mode.

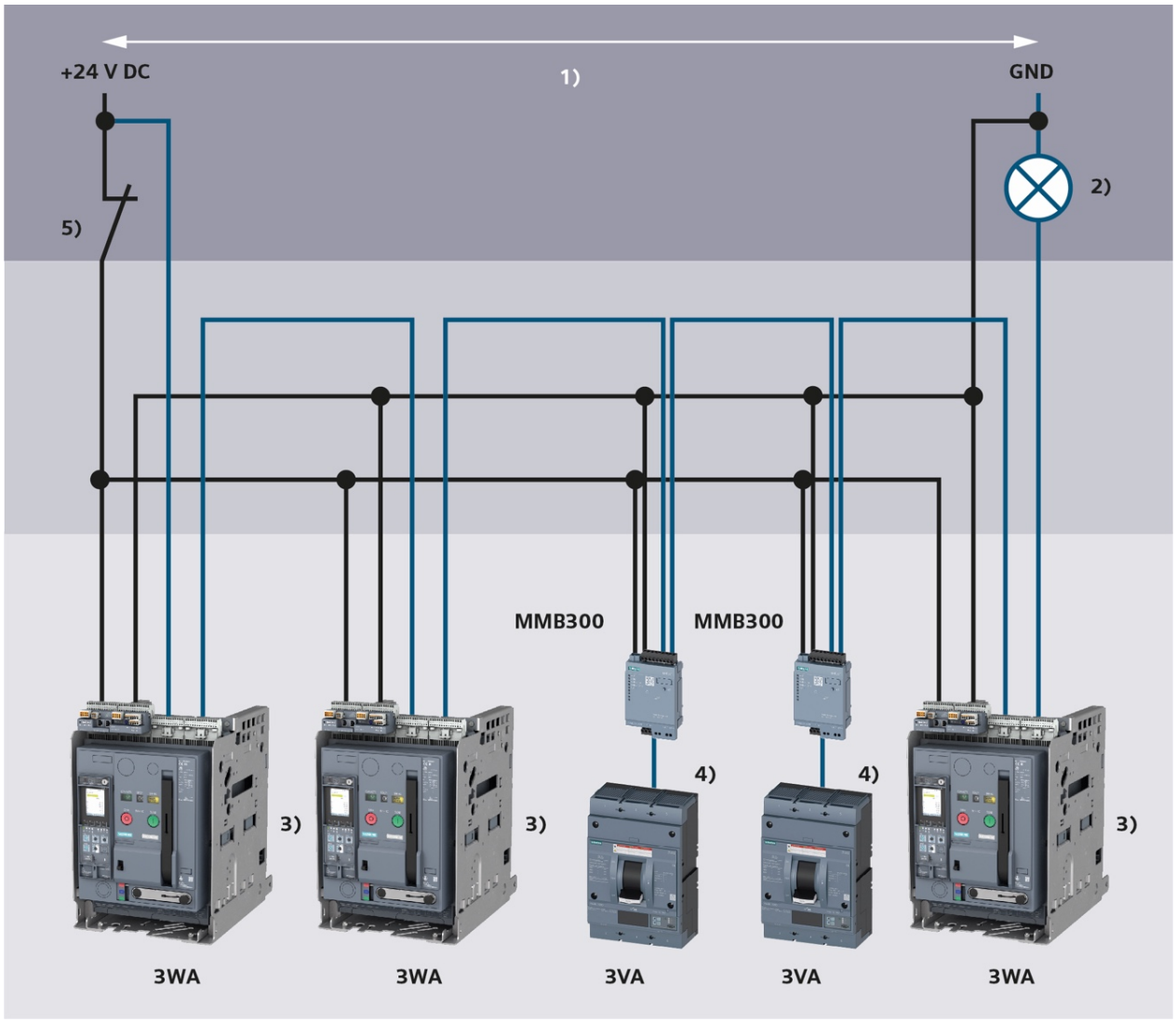


Figure 4: Integrating multiple circuit breakers into the DAS+ maintenance mode. The function is integrated as standard in the 3WA air circuit breaker (3). The MMB300 maintenance module is additionally required to integrate the 3VA6 molded-case circuit breaker (4) (certified according to UL489 and IEC60947-2). The maintenance mode is activated via a central switch (5) for all connected circuit breakers. The central display (2) lights up only if the maintenance mode is active for all circuit breakers. For this to work properly, the length of the system cable must not exceed 50 m (1).

Flexible activation options

There are several ways to activate the DAS+ maintenance mode in the 3WA air circuit breaker for maximum flexibility when planning, retrofitting and operating the power distribution equipment. The different options are summarized in Table 2. For safety and security reasons, the DAS+ maintenance mode can only ever be deactivated using the same method by which it was previously activated.

Activation type	Implementation on the 3WA air circuit breaker	Application examples
Local	Button on the display of the ETU600, via USB or Bluetooth with the SENTRON powerconfig software	On-site activation, e.g. by maintenance personnel directly before carrying out unscheduled work.
Remote	Using the COM190 communication module as module A or B with the PROFINET IO and Modbus TCP communication protocols	In preparation for work to be carried out e.g. before entering the power distribution equipment room or managed centrally via control room/higher-level systems, if for example plant-wide work is to be carried out and several installations are to be switched to the maintenance mode.
Via digital inputs with flexibly selectable triggers	Via the digital input of the air circuit breaker. The input can be parameterized on the ETU600 as a normally open contact or a normally closed contact, for example on the door of the power distribution equipment or in front of the electrical equipment room.	Activation on entry to the power distribution equipment room via switch or automatic activation, for example when a person opens the cabinet door or steps on a pressure-sensing safety mat.
	Via digital input/output modules (IOM230 module)	Activation on entry to the power distribution equipment room via switch or automatic activation, for example when a person opens the cabinet door or steps on a pressure-sensing safety mat.

Table 2: Overview of the options for activating the DAS+ maintenance mode on the 3WA air circuit breaker

Examples of activation options

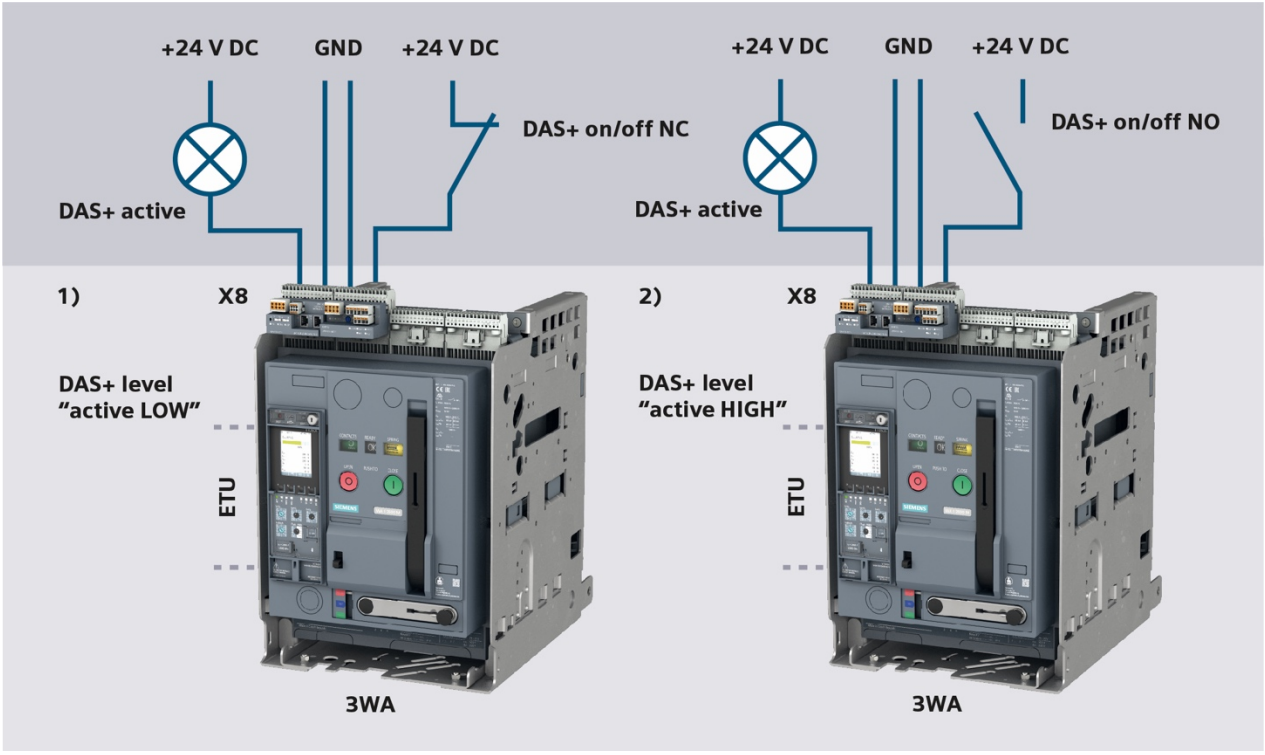
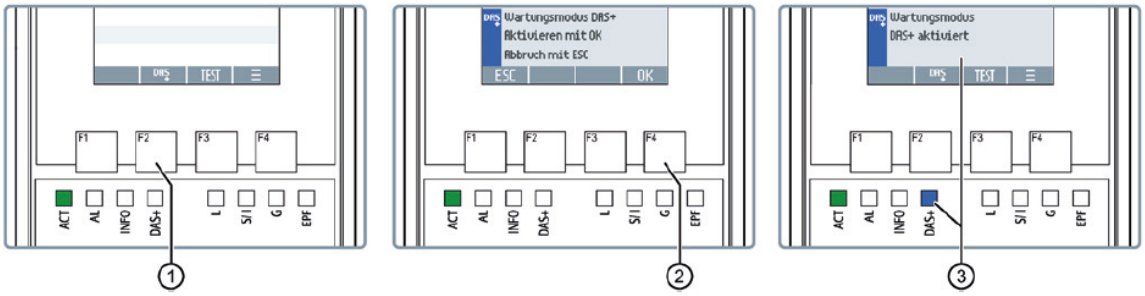


Figure 5: The digital ETU input on the 3WA air circuit breaker can be used flexibly as required with a normally closed (NC) contact or a normally open (NO) contact for activating the DAS+ maintenance mode.
Left: LOW signal (NC): The DAS+ maintenance mode is active when there is no signal present at the secondary disconnect terminals X8-5 and X8-6.
Right: HIGH signal (NO): The DAS+ maintenance mode is active when there is a signal present at the secondary disconnect terminals X8-5 and X8-6.



(1) Start of the activation

(2) Confirmation

(3) DAS+ maintenance mode on

Figure 6: The DAS+ maintenance mode is activated directly on the ETU600 by way of a two-stage process. Activation is started using the F2 operating key and then confirmed explicitly using the F4 operating key. The blue LED then immediately indicates that the maintenance mode has been activated. In addition, the DAS+ symbol is shown in the status bar and the plain text message "DAS+ maintenance mode activated" appears on the display. The clear display makes an additional contribution to the protection of personnel. A blue LED has been chosen to ensure that even people with a red-green color vision deficiency can tell immediately whether they are able to work on the installation safely.

Indication via the active DAS+ maintenance mode

In addition to the local status indication on the ETU600 (see Figure 5), the indication can also be signaled in various ways through activation of the DAS+ maintenance mode:

- Digital ETU output of the air circuit breaker
- Via an output of a digital input/output module
- By way of communication via PROFINET IO and Modbus TCP

Conclusion

Statistics of the German social accident insurance institution for the energy, textile, electrical and media products sectors (BG ETEM) show that the accident rate in the low-voltage range is particularly high (Figure 7). From these statistics, it can be concluded that the hazards associated with electricity at low voltages are often underestimated.

Arc faults, which can occur in particular during maintenance work on live parts, represent a potential hazard source. In the worst case, they result in serious injuries and even death. Operators of power distribution equipment have a legal and moral duty to protect their personnel against hazards.

The foundation for effective arc fault protection is laid during the installation planning stage. Factors including design measures and precise dimensioning play a part here. Equally influential is the selection of components that round off the protection concept. Circuit breakers as central power distribution elements must trip as rapidly as possible during maintenance work on live parts in order to contain the effects of an arc fault and thus protect personnel.

Various protective devices are approved to ensure rapid deactivation. One of the options available is an energy-reducing maintenance function with local status indication. It is precisely this kind of function that has been established as standard with the DAS+ maintenance mode in the 3WA air circuit breaker. This enables operators to protect their personnel effectively at no extra cost while reducing maintenance effort. At the same time, selectivity concepts with short-time delayed tripping can continue to be used for normal operation.

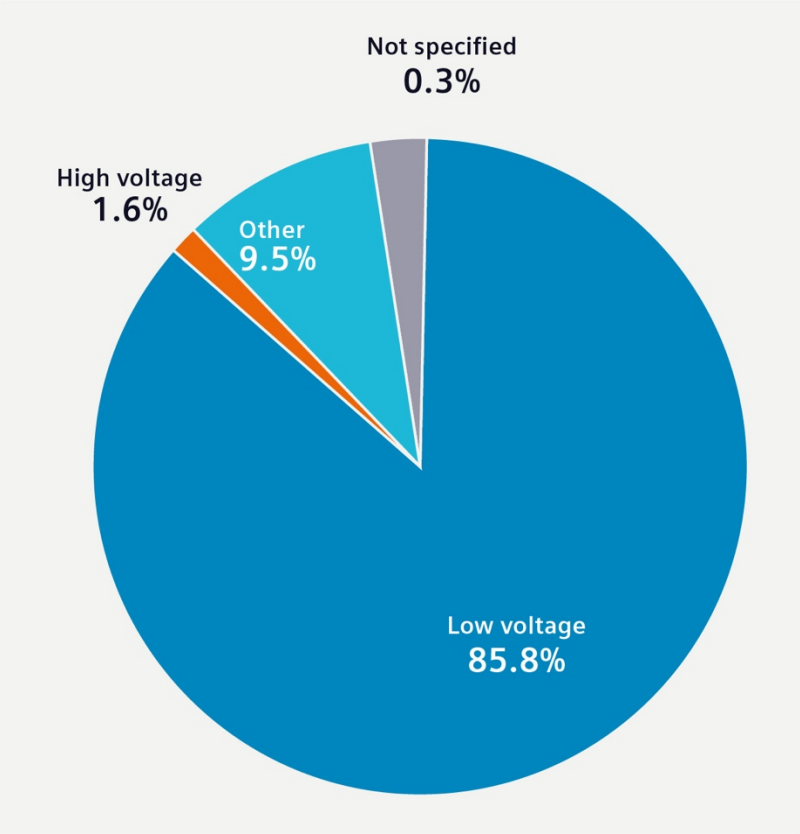


Figure 7: Reported electrical accidents by voltage range in percent (2018)
(Source: BG ETEM Berufsgenossenschaft Energie Textil Elektro, 2020)

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More information

All information on the 3WA air circuit breaker is available at
siemens.com/3wa

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