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General

Despite the high level of reliability of machines and plants, faults can occur that can result in personal injury or damage to costly production material.
As stated in the applicable regulations for automation systems, the definition of safety is:
"The ability of a monitored unit, within prescribed limits and for a given period of tile, neither to cause nor to permit the occurrence of a hazard."
"Unit" here means the entire plant or machine.

The safety of a plant or machine relates to both its mechanical components and its electrical equipment. The electrical equipment consists of:

- All electrical apparatus within the plant or the machine, such as actuating devices, position switches, etc.
- The electrical control system
  This can be a hard-wired programmed controller (contactor or electronic modular control) or a programmable logic controller (PLC).

The subject of the safety considerations below are electronic control systems which include PLCs.

Category	Requirements	System behaviour	Safety principle
B	Safety-related parts and/or their safety mechanisms must be designed, built, selected, assembled and combined according to the applicable standards in such a way as to withstand any expected outside influences.	A fault can result in the failure of the safety function.	Through selection of components
1	The requirements of B must be fulfilled. Use of components with a proven safety track record.	As B, but greater reliability of safety functionality.	Through selection of components
2	The requirements of B and 1 must be fulfilled. The machine control system must check the safety function at appropriate intervals.	• a fault can result in the failure of the safety function between the test intervals. • Loss of safety function is detected by the test.	Through the structure
3	The requirements of B and 1 must be fulfilled. The control system must be designed so that: • a fault does not result in the loss of the safety function, and • the fault is detected in an appropriate way.	• The safety function is maintained in the event of a fault. • Some, but not all, faults are detected. An accumulation of undetected faults may result in the loss of the safety function.	Through the structure
4	The requirements of B and 1 must be fulfilled. The control system must be designed so that: • a fault does not result in the loss of the safety function, and • the fault is detected on or before the next demand on the safety function. Where this is possible, an accumulation of faults must not result in the loss of the safety function.	• The safety function is maintained in the event of a fault. • Faults are detected in time to prevent the loss of the safety function.	Through the structure

Fault analysis

A fault analysis forms the basis on which the safety requirements are considered:

- Statistics show that of all plant/machine faults only 5 % are caused by the electrical system.
- 95 % of all faults in the electrical system occur outside the controller on the command input and output level (external faults).
- The remaining 5 % (internal faults) occur within the control panel.
  - 90 % of internal faults occur within the many input and output circuit elements.
  - 10 % of all faults affect the CPU, functional modules and memory belonging to the CPU.
- Conclusion:
  Only 0.5 % of all electrical faults occur in the central PLC unit. In other words, this unit can be regarded as very reliable.

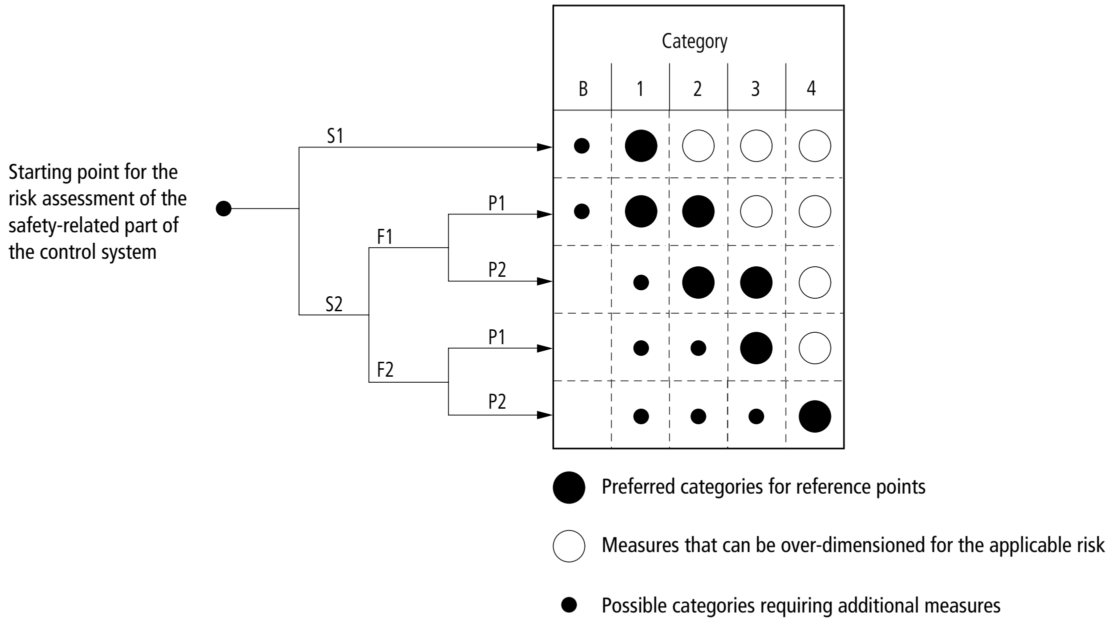
Emergency-stop function for machine control systems, general

Part 1 of the German VDE 0113 standard – which applied until 1994 – stipulated that safety-related auxiliary circuits (for example emergency stop circuits) containing contactor relays had to be equipped with at least two contactor relays in such a way as to ensure that the safety circuit remained effective if one of the relays failed. This was termed "relay safety combination".
Since the publication of IEC/EN 60204-1, this arrangement is no longer compulsory. Instead, a risk assessment must be carried out for every machine, including its electrical equipment. This risk assessment, which can only be properly carried out with the manufacturer of the machine is the basis on which to establish the requirements to be fulfilled by the respective control circuit (for control circuits provided for safety). The risk assessment must conform to EN 954-1.

Risk assessment

The EN 954-1 standard specifies a risk assessment using risk graphs resulting from the hazardous condition caused by the machine.

Risk graph to EN 954-1



S Severity of injury
S1 Slight (normally reversible) injury
S2 Severe (normally irreversible) injury, including death

F Frequency and/or duration of exposure to hazard
F1 Rarely to moderate and/or short duration of exposure
F1 Frequent to continuous and/or long duration of exposure

P Possibility of hazard avoidance
P1 Possible under specific conditions
P2 Usually not possible

Control functions to IEC/EN 60204-1/9.2 and safety measures

START
START operations must be effected by the energizing of the relevant circuit. In the case of digital electronic units, this can be achieved by setting a high signal (1 signal).
All safety devices must be fitted and operational before start of the operation is possible (not set-up mode).
Machines that require more than one control station for starting must fulfill the following criteria:
- Each control station must have a separate, manually operated start device
- All start devices must be in the off position before a start is possible.
- All start devices must be operated concurrently.
- Control stations are to be preselected by means of a lockable control switch.

Two-hand control
A simple and effective means of preventing (hand) injuries is command initiation using two hands. To prevent incorrect operation and manipulation, control panels must conform with the EN 574 special standard.
IEC/EN 60204-1 classifies two-handed control in three requirement levels (types):
- Type 1
  - Two actuating devices; requiring concurrent actuation by both hands
  - Continuous actuation during the hazardous condition
  - The releasing of either actuating device causes STOP
- Type 2
  - A type 1 control requiring both control and actuating devices to be released before machine operation can be restarted.
- Type 3
  - A type 2 control requiring concurrent operation of the control actuating devices.
  - Both actuating devices must be pressed within ≦ 0.5 s.
  - If this time limit is exceeded, both actuating devices have to be released before a restart can be initiated.

STOP
STOP operations must be effected by de-energizing the relevant circuit. In the case of digital electronic units, this can be achieved by resetting a signal (0 signal).
STOP functions must override START functions.
STOP functions are divided into three categories:
- STOP category 0
  Uncontrolled stopping by immediate removal of power to the machine actuators. Every control system must be fitted with a category 0 STOP function. This function must be functional irrespective of the operating mode.
  Typical category 0 STOP functions:
  - Actuation of the main switch
  - Disconnection of the entire control voltage
  - Disengaging, use of brake
- STOP category 1
  Controlled stopping in which the power supply to the machine actuators is available to achieve the stop.
  This function must be functional irrespective of the operating mode.
  Typical category 1 STOP functions:
  - Plugging of three-phase motors
  - Regenerative braking of DC variable speed drives
  - DC braking of three-phase motors
- STOP category 2
  Controlled stopping in which the power supply to the machine actuators is maintained.
  Typical category 2 STOP functions:
  - Moving to pressure position after the movement is completed
  - Stopping by mechanical means
  - Stopping by defining the zero reference value

The STOP category must be fixed on the basis of the risk analysis of the machine/plant concerned. Suitable measures are to be provided to ensure reliable stopping.

Measures for reducing risks in the event of faults in accordance with IEC/EN 60204-1

- Safety devices on the machine
  - Safety guards, light barriers, covers, ...
- The use of proven circuits and components
  - Chassis earth connection of control circuits for operational purposes
  - All switching functions on the non-earthed side
  - Stopping by de-energizing
  - Use of switching devices with positively opening contacts
  - Switching of all active conductors to the controlled device
  - Reduce undesirable operating states in the event of faults
  - Systematic observance of wire-break and earth fault protection
  - Faults (earth fault, wire breakage, short-circuit) must not result in unintentional starting or hazardous movements of the machine.
  - Control circuits must be connected to the protective circuit at one end, or control circuits fed by a transformer must be provided with an insulation monitoring device if one side of the control circuit is not connected to the protective circuit
  - Earth faults, such as wire breaks, must neither result in an unintentional signal input (switching on) nor prevent switching off
- Redundancy
  - Use of more devices than required for normal operation
    If one device fails, the other one establishes the safe state and the fault is detected
- Diversity
  - Design of control circuits using different working principles or different types of devices
- Function tests
  - Automatic function test where a self-monitoring redundancy system is used or individual tests in a defined time frame

Emergency-stop

If hazards can arise on the machine/plant for operators or for the machine/plant itself, an emergency-stop system is required. The emergency-stop system is not a substitute for a missing or defective system.
The emergency-stop system can be provided in the form of an emergency-stop switch in the main circuit and/or emergency-stop control device in the control circuit. Positive opening of contacts is required in both versions.

The following requirements apply to emergency-stop functions and systems:

- It shall override all other functions and operations.
- Available and operable at all times regardless of operating mode
- Prevent confusion of operative and inoperative emergency-stop systems
- Mechanical locking in OFF position
- Resetting must not cause a restart.
- Emergency-stop systems in sufficient quantity and easily accessible
- Positively opening contacts
- There must be no decision required by operating personnel with respect to function and effect.
- Safety devices and safety-related functions must remain operative.
- The state into which the machine is brought by an emergency-stop must not change accidentally.
- The correct function of the emergency-stop function must be tested and documented
- Where a system is split into several emergency-stop areas, the overall system must be arranged in such a way that it is easy to recognize which systems are allocated to which areas

Categories:

The effect of the emergency-stop must be that of STOP category 0 or 1. The choice is made on the basis of a risk assessment of the machine.

- STOP category 0
  Only hard-wired electromechanical components may be used, initiation must be effected directly and must not depend on a logic circuit or the transmission of commands via a communications network or data link.
- STOP category 1
  The final disconnection of the power supply must be guaranteed and must be effected by the use of electromechanical components. The disconnection process must not result in any other hazard.
- STOP category 2
  Not permitted for emergency-stop functions.

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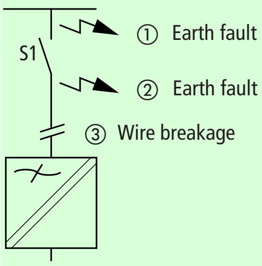
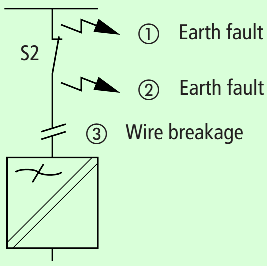
Causes of faults and safety-oriented measures

External faults
Control stations, actuators and their cabling are the main source of external faults. It is important to remember that the required safety measures could be inoperative if the connection between the conductive components of the equipment and the protective circuit, as described in IEC/EN 60204-1, is absent or interrupted.

Effects of earth fault and/or short-circuit in earthed and non-earthed control systems

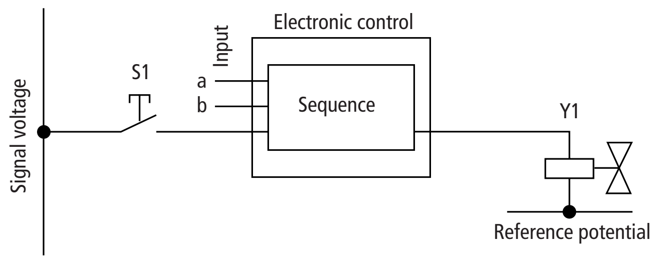
			**Remarks**
External fault, control system earthed			
Earth fault	① or ② ≙ short-circuit • Short-circuit trip • No signal input	① or ② ≙ short-circuit • Short-circuit trip • Immediate stop	• Safe state
Open circuit	③ • No signal input	③ • Immediate stop	• Safe state
External fault, control system not earthed			
Earth fault	① or ② • No effect	① or ② • No effect	• Hazardous state • Use insulation monitoring device to detect ① and/or ②
	① and ② • Unwanted starting	① and ② • No stopping possible	
Open circuit	③ • No signal input	③ • No signal input	• Safe state

Fail-safe wiring of PLC input signals
PLC input signals that are subject to stringent requirements on operational safety, such as protection against open circuits, must be handled appropriately by the associated hardware and software.
Contacting in the hardware is to be effected by means of a break contact, in the user software, these signals are to be programmed as make contacts.
However, this measure is not permissible as a safety function for the protection of persons and/or machinery/plants.

Internal faults
Despite all of the design measures and elimination of the early failures through the artificial ageing of electronic assemblies, components such as output transistors can sometimes fail. The physical characteristics of transistors and Triacs does not allow their behaviour on transition into the fault state (destruction) to be foreseen. The failed component can be permanently conducting or permanently blocking.
Faults in input and output modules/cards arise through:
- Overvoltage
- Improper use
- Reverse voltage to semiconductor outputs if no precaution is taken

Wherever faults may cause material damage or personal injury, the applicable standards and any additional accident prevention regulations must be observed.
In electromechanical control devices, an active fault cannot occur because:
- A contactor does not pick up if there is no actuating voltage present.

Welding of relay contacts can be prevented through design.



S1	Control system	Y1
L H	OLK	L H
L H	Passive fault Type 1 fault	L L
L H	Active fault Type 2 fault	H H

Section 4.2.1: "Injury to persons" of EN 50178 "Electronic Equipment for Use in Power Installations" covers the untypical malfunction behaviour of electronic control systems. The same requirements as for other apparatus apply to electronic equipment regarding the limitation of the impact of malfunctions.
However, when making an assessment in connection with electronic components, the open circuit and short-circuit behaviour of electronic components such as semiconductor junctions must be taken into account.
The safety measures to be taken must be defined when designing the overall plant and the engineer should take into account that there are no special safety measures built into electronic components.
To prevent personal injury, EN 50178 also refers to appropriate safety devices, such as:
- Arrangement of electromechanical safety position switches
- Use of proximity switches as non-contacting position switches for safety functions to VDE 0660 Part 209 (1/88)
  (This is a German national standard wioch still applies.)
- Safety guards with and without position switches
- Mechanical stops
- Protective device against overtravel according to IEC/EN 60204-1
- Use of safely controlled, two- or multi-channel control systems

Contactless proximity switches
Compliance with VDE 0660 Part 209 is ascertained through prototype testing and on the basis of the production documents and testing instructions by the authorized TÜV, VDE and – if applicable – employers liability insurance association testing laboratory and confirmed with the issue of a certificate.
Commercial proximity switches, regardless of their mode of operation (inductive, capacitive, optical) are not usually designed for restricting dangerous movement. Their solid-state outputs can exhibit active or passive malfunctions in respect of component failure. An additional position switch with positive opening contacts that stops the movement must be fitted.
A further requirement for position sensors is defined in IEC/EN 60204-1:
- Position sensors must be arranged so that they are not damaged in the event of overtravel.

Safety devices that prevent overtravel
Where overtravel can result in a hazardous state, a limiting device that interrupts the main circuit of the corresponding machine actuator(s) must be fitted.

Safely controlled two- or multi-channel control system
Safely controlled two or multi-channel electronic control systems contain the necessary safety measures against malfunctions in the event of a component failure.
This solution is very expensive in most cases. For this reason, the required safety functions are removed from the electronic system and assigned to the control level of the electromechanical switching devices.

It is not always possible to implement the required safety functions through the control system. This means that both the control system supplier and the machine manufacturer have additional responsibilities.

Responsibility of the control system supplier
If the required safety measures can not be met in the overall control system alone, the control system supplier must point out to the customer at the tendering stage that additional measures must be implemented.

Responsibility of the machine manufacturer
According to Section 3 of the German Technical Plant and Equipment Act, the responsibility for safety requirements rests with the machine manufacturer.
According to Section 1:
"The manufacturer or importer of technical equipment may market or exhibit this equipment only if it is manufactured in accordance with the general technical regulations and the occupational safety and accident prevention regulations in such a way that when used as intended, users and third parties are protected against all types of hazards to life and limb to the extent permitted by proper use. A departure from the general technical regulations is permissible provided the same level safety is guaranteed by other means."

General

Definition:
"Electromagnetic compatibility is the ability of an electrical device to function satisfactorily in an electromagnetic environment without having an impermissible effect on this environment to which other devices also belong."

This formulation clearly shows that electrical devices can affect each other in varying degrees.
This effect happens through:

- Electrical fields
- Magnetic fields
- Electromagnetic fields
- Currents in commonly used cables

In this context, the terms "transmitter" and "receiver" are also used. Transmitters and receivers intentionally exchange electromagnetic signals, which has the unwanted side-effect of causing interference emissions and also makes them susceptible to interference.
It is therefore important to minimize devices' emissions and susceptibility.
The necessary measures can be implemented either at the interference source, at the susceptible equipment, or along the transmission path of the interference signal.

Interference
Interference can be electrical, magnetic or electromagnetic.
Interference is triggered by changes in current, voltage or frequency over time (di/dt; du/dt).

Coupling mechanisms of interference
Overcoupling of interference can be caused by:

1. Inductive coupling (H field)
   Inductive – or magnetic – coupling occurs between at least two live conductor loops. The magnetic field that forms around a conductor through which current is flowing induces an undesirable voltage across the adjacent conductor loop.
2. Capacitive coupling (E field)
   Capacitive – or electrical coupling – occurs between two circuits with conductors at different potentials.
3. Conductive coupling:
   Conductive coupling occurs when two circuits share a current path.
4. Electromagnetic or radiation coupling:
   Here, the electrical and magnetic fields are in a fixed ratio to each other.

In practice, interference is always caused by several types of coupling, and its minimization therefore requires the use of several different measures.

Propagation of interference
In practice, there are two different mechanisms for propagating interference signals (undesired propagation).
Propagation takes place along a conductor as low-frequency interference and through radiation by antennas (higher/high-frequency interference). Antennas include not only devices developed for this purpose but also any conductor with current flowing through it and capable of transmitting and receiving the unwanted parasitic interference.

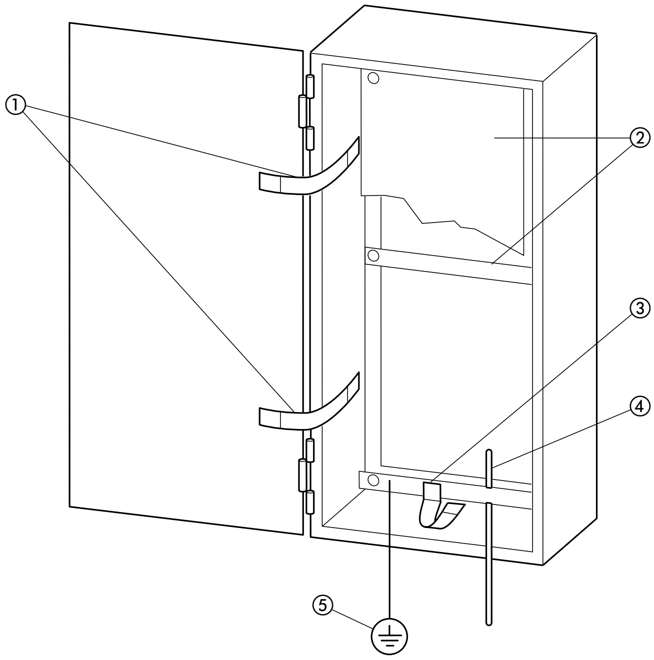
EMC measures

EMC measures are aimed at reducing the unwanted propagation of interference signals. The following measures are used to achieve this.

Designing for interference protection

Pay special attention to the control panel design, the arrangement of devices, the cable routing, earthing, screening, the use of filters, suppressor circuits and electrostatic discharge.

Control cabinet (design)



- Use metal control cabinets.
- Connect all inactive metal structures (mounting plate, control panel enclosure and door) to an earthing surface ensuring large contact areas and low-impedance connections (①, ②, ③) and establish a large-area, low-impedance connection to the protective earthing system (earth potential) (⑤). Split mounting plates are also connected to each other and to the protective earthing system with a large contact area and low-impedance connection.
- Use galvanized mounting plates.
- Avoid painted metal surfaces as the paint coat prevents a low-impedance connection, or remove the paint over a large area at the connection points.
- To prevent corrosion at the connection points, use suitable conductive grease.
- Connect all inactive metal parts with tin-plated earthing strips with large cross-section, as these have better HF properties.
- Connect the screen (④) of shielded cables to the reference potential surface with a low-impedance connection with suitable fixing material (such as metallic gland plates). Make sure that the gland plate contacts the cable screen all round across a large area.
- If insulated (plastic) enclosures are used, also use a galvanized metal mounting plate. Connect the mounting plate with the earth reference potential.

Device arrangement
In the control cabinet, components (control and switching devices, terminal strips) are arranged separately for the control and power sections. If this is not possible, severely interfering or susceptible devices are to be separated off with partition plates. These partition plates are in turn to be connected to the earth potential with a low-impedance connection.

Cable routing
Wires should always be run so that they are physically separate from each other. This applies to the cable routing both within and outside the control panel.
When laying cables, always observe the following:
- DC and AC cables should be separated.
- Cables with large potential difference should be placed apart.
- 10 cm spacing between heavy current and digital signal cables.
- 30 cm spacing between heavy current and analog signal cables.
- Avoid parallel arrangement of cables with different potentials and functions.
- Cross cables with different potentials and functions at right angles if possible.
- Supply and return cables of a circuit should be laid in the same cable duct and close to earth potential; no floating cables.
- Use sheet steel cable ducts and connect these to earth via a low-impedance connection.
- If possible, twist the supply and return cables (about 30 turns/metre).
- Avoid cable loops.
- Use screened cables.

Earthing
Earthing is the connection of all inactive conductive metal parts in an electrical system. In the event of a fault, the earthing will not carry any contact voltage. The potential difference should ideally be the same for all earthing points and should be at 0 V. This requires all earth connections to have a low impedance, i.e. a large surface area (skin effect). Tin-plated earthing strip is the best material for this purpose. The earth connection also acts as functional and protective earth (observe minimum cross-sections).

Screening
The screening of cables fulfills two functions:
- it prevents interference signals acting on the cable;
- it prevents the emission of interference signals by the cable.

To divert interference, the cable screening is connected to earth. Observe the following rules:
- Run cable screening separately to the central earth point and connect to earth using a large contact area and low-impedance connection.
- Use appropriate accessories, such as metal gland plates or spring-loaded wire clamps, to establish large-surface, low-impedance connections between cable screen and earth reference potential.
- Run the cable screen right up to the device terminal.
- Do not route screened cables via terminals.
- Avoid pigtails, which work only with low-frequency interference. Pigtails that are longer than about 5 cm act as aerials.
- Connect all unused cores of a screened cable at both ends to earth.
- Connect the cable screen of analog cables (low-frequency signal cable) to earth at one end only if there is unsatisfactory equipotential bonding between the start and end of the cable, otherwise both ends.
- Always connect the screen of bus cables (high-frequency signal cable) to earth at both ends.
- Connect the screening of cables coming from outside directly after entry into the system (control cabinet, switch rack, mounting plate) to the local earth, ensuring a low-impedance connection.
- Signal cables between buildings must always be shielded against lightning strike.
- Cables between buildings included in the potential equalization scheme must be laid in metal pipes, which must be earthed at both ends. The IEC/ENV 61024-1 specify the following minimum cross-sections for the lightning protection potential equalization cable:
  - 16 mm^2 for copper
  - 25 mm^2 for aluminium
  - 50 mm^2 for iron
- The cable screen must not act as potential equalization conductor between two earthing points. If the two earthing points have different potentials, either an additional copper potential equalization cable with a cross-section of $\geqq$ 10 mm^2 must be laid, or cables with dual screen must be used, whereby one screen must be conductive.
- For lightning protection according to ENV 50142, use suitable protective elements, such as devices from Dehn & Söhne or Phoenix Contact.

Use of filters, ferromagnetic components and suppressor circuits
The purpose of a filter (mains or device filter) is to divert interference from a plant or device. Filters conduct interference to earth through their housing or their earth connection. The connection to earth must be low-impedance, i.e. made over a large surface area.
In order to prevent overcoupling of interference within the enclosure, mains filters must be arranged directly after entry of the power cable into the enclosure.
With device protecting filters, the cable length between filter and device must be kept as short as possible.
Ferromagnetic components form a ring around the signal cable to be protected. This ferromagnetic ring attenuates both the useful and perturbing signals. To minimize the effect on the data signal, select ferrite rings according to the undesired, frequency-dependent interference spectrum.
Inductive consumers generate overvoltage peaks when switching. These can interfere with or destroy electronic devices connected to the same circuit. Suppressor circuits attenuate such unwanted voltage peaks.

Electrostatic discharge
Electrostatic charge occurs through friction between different materials. Their discharge gives rise to voltage peaks of up to 15 kV, which ultimately cause the destruction of electronic devices. This can be remedied with systematic potential equalization.
To protect electronic devices from discharging static electricity, discharge yourself against an earthed surface (for example a control panel) before touching operator controls and interface or data plugs.

Note

Manual AWB27-1287-GB, EMC Engineering Guidelines, describes in detail the relevant EMC measures required for PS4 and PS416.

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This glossary contains brief explanations of some of the standard terms used in this catalogue. Because the new terms used in IEC/EN 60947 can be open to interpretation, it is always advisable to refer to the relevant standard as well.

To help you find the relevant section more easily, the standard in which each term is defined is given below each term, e.g. IEC/EN 60947-1. In addition, IEV numbers are given to help you find foreign-language equivalents in the International Electrotechnical Vocabulary (IEC 50), e.g. IEV 441-17-31.

Further definitions of technical and other standard terms can be found in the "Lexikon Schaltgeräte and Automatisierung" (available in German only). (Order ref.: TB0-012, Article no. 031954).

Altitude

The density of air decreases with increasing altitude, and this reduces its insulating capacity as well as its heat transfer capability. This affects the **rated operational voltage** and **rated operational current** of switching devices, conductors and motors , as well as the tripping behaviour of thermal overload relays. On request, Moeller can supply information about the suitability of equipment for operation at altitudes above the standard-specified 2000 m.

Ambient temperature, enclosed
(see also IEV 441-11-13)

Temperature at which the switching device is capable of being operated within a closed housing. The elevated temperature inside the enclosure due to the device's **heat dissipation** must be taken into account here.

Ambient temperature, open
(see also IEV 441-11-13)

Room temperature (for example of the shopfloor or control room) in which the device is located.

Back-of-hand proof

A device whose live parts cannot be touched by a sphere of 50 mm diameter is regarded as back-of-hand proof.

Clearance in air
(see also IEC/EN 60947-1; 2.5.46/IEV 441-17-31)

The distance between the two conductive parts at the point at which they are closest to each other. The clearance in air is determined by the **rated impulse withstand voltage**, the **overvoltage category** and the **pollution degree**.

Closing delay

The interval of time between the instant of command and the first make operation of the contacts of the first pole to close. The closing delay is made up of the response time and the closing time.

Control circuit reliability

Measures the probability of switching states arising during the lifespan of a contact, that would be interpreted as faults by downstream electronic controllers (PLCs). Control circuit reliability is expressed in values based on tests using standard limit values for signals to IEC/EN 61131-2.

Conventional free air thermal current I_{th}
(see also IEC/EN 60947-1; 4.3.2.1)

The maximum value of current that a device is capable of carrying for a maximum of eight hours without thermal overloading. As a rule, it corresponds to the maximum rated operational current.

Coordination type

State of a switchgear combination (motor starter) during and after testing at **rated conditional short-circuit current**:
Type "1" coordination:
– No risk to persons or installations
– No need for immediate operational readiness
– Damage to the starter is admissible
Type"2" coordination:
– No risk to persons or installations
– Starter is capable of renewed operation
– No damage to the starter except for light contact welding that can be easily separated without significant deformation

Creepage path/distance
(see also IEC/EN 60947-1; 2.5.51/IEV 151-03-37)

Shortest distance along the surface of the insulating material between two conductive elements.
The creepage distance is determined by the **rated insulation voltage**, the **pollution degree** and the creepage current resistance of the material used.

Damp heat, constant

This test subjects the equipment to an ambient temperature of 40 °C at a constant humidity of 93 %. At set intervals during the test, the electrical and mechanical function of the equipment are examined.

Damp heat, cyclic

This test subjects the equipment to cyclically changing climatic conditions.
a cycle consists of 12 hours at 40 °C and a relative humidity of 93 %, followed by 12 hours at 25 °C ambient temperature and a relative humidity of 95 %. At set intervals during the test, the electrical and mechanical function of the equipment are examined.

Emergency-Stop switching device

Switching device within an Emergency-Stop circuit that is intended to prevent danger to persons and damage to machinery or materials.

Finger-proof

A device whose live parts cannot be touched by the operator during actuation is termed finger-proof. This applies also to operator activity in adjacent switching devices. The finger-proof area of a push-actuated operating medium is a circular area of at least 30 mm radius around the actuating element, and vertical to the direction of actuation. Within this circular area, touch-critical parts must be located at not less than 80 mm below the actuating level.

Interlocked opposing operation
(see also IEC/EN 60947-1; 2.4.11 / IEV 441-16-12)

Interlocked opposing contacts of a contactor are mechanically connected so that the break contact and the make contact can never be closed at the same time. Contact gaps of at least 0.5 mm must be guaranteed throughout the device's entire service life, even in the event of a fault (such as welding of a contact). The employers liability insurance association demands the use of contactors with interlocked opposing contacts for controllers of power-operated presses in the metal processing industry.

Isolating function
(see also IEC/EN 60947-1; 2.1.19)

Devices are deemed to possess this isolating function if, in the open position, their switching contacts achieve the separation distance specified for the isolation of electrical circuits, and their **creepage paths** and **clearance distances** are of the required magnitude. This allows the power supply of the entire installation or a section of the installation to be isolated for safety reasons, for example during maintenance.

Losses
(see also IEV 151-03-18)

The difference between the input power and the output power of a device. The main type of loss in switching devices and electrical power distribution equipment is current heat loss.

Mechanical shock resistance

The ability of a device to withstand pulse-like movement without changing its operating state or sustaining damage. No contact lifting must take place on devices in the On position, the main contacts must not knock against one another in the Off position. A protective switch must not trip, and control circuit switches must not change their switching state.

Minimum command time

Minimum period of time for which a trip-initiating factor (such as a control pulse or a short-circuit current) must be present to cause the corresponding reaction, for example the short-circuit duration necessary to initiate tripping.

Mirror contact
(see also IEC/EN 60947-4-1 Appendix F)

A mirror contact is an auxiliary break contact that can not be closed at the same time as the contactor's main make contacts.

Motor rating, rated power
(see also IEC/EN 60947-1; 4.3.2.3)

The power output of a motor at its **rated operational voltage**.

Opening delay
(see also IEV 441-17-36)

The interval of time between the specified instant of initiation of the opening operation and the instant when the arcing contacts have separated in all poles. The opening delay is the sum of the tripping delay and the inherent delay of the contacts.

Overvoltage category
(see also IEC/EN 60947-1; 2.5.60)

Classification figure for prospective overvoltages at the point of installation, such as might be caused by the effect of lightning or switching processes. The overvoltage category for industrial switchgear is III. **The overvoltage categories are defined as follows:**
Overvoltage category IV:
Use allowed directly at the termination point of the installation (directly affected by any lightning), e.g. at an overhead line connection point.
Overvoltage category III:
Apparatus with special serviceability requirements for connection in fixed installations that are protected by overvoltage diverters, e.g. switches in low-voltage distribution systems or in control systems for industrial use.
Overvoltage category II:
Consumers for connection to fixed installations, e.g. household appliances or electrical tools.
Overvoltage category I:
Apparatus for connection to circuits with overvoltage protection, e.g. electronic devices.

Pollution degree
(see also IEC/EN 60947-1; 5.5.58)

Classification figure for the likely amount of conductive dust and humidity, which can lead to a reduced electric strength of a switching device. Pollution degree is defined as follows:
Pollution degree 1:
No pollution or only dry, non-conductive pollutants occur. **The pollution does not affect electric strength.**
Pollution degree 2:
Normally only non-conductive pollution, **but temporary conductivity due to condensation is possible.**
Pollution degree 3: (switchgear for industrial use)
Conductive pollution or dry, non-conductive pollution that is made conductive through condensation.
Pollution degree 4:
Pollution leading to continuous conductivity, for example conductive dust, rain or snow.

Positive opening
(see also IEC/EN 60947-1; 2.4.10/IEV 441-16-11)

An opening operation which ensures that the main contacts of a mechanical switching device have attained the open position when the actuator is in the Off position.

Positive/enforced operation/actuation

This describes an arrangement where a mechanical link between the actuator and the switching element ensures that the force exerted on the actuator is exerted directly, i.e. without the intervention of spring-loaded parts, onto the switching element.

Protection against direct contact

Design measures incorporated into equipment to prevent direct contact (i.e. without tools) with live parts of a system (**finger-proof, back-of-hand proof**).

Rated actuating voltage U_c
(see also IEC/EN 60947-1; 4.5.1)

The voltage that is applied to the actuating make contact in a control circuit.
Due to the presence of transformers or resistors in the control circuit, this voltage may differ from the **rated control voltage**.

Rated breaking capacity
(see also IEC/EN 60947-1; 4.3.5.3)

The r.m.s. value that a switching device is capable of breaking according to its **utilization category**. This value refers to the **rated operational voltage** and the **rated operational current**. Equipment must be capable of breaking of current up to and including its specified rated breaking capacity.

Rated conditional short-circuit current I_q
(see also IEC/EN 60947-1; 2.5.29/IEV 441-17-20)

The short-circuit current that a switching device, e.g. a circuit-breaker, protected by a short-circuit protective device, such as a motor-protective circuit-breaker, can carry for the duration of the tripping delay of the protective mechanism.

Rated control voltage U_s
(see also IEC/EN 60947-1; 4.5.1)

The voltage applied to the input terminals of the control circuit of a device. Due to the presence of transformers or resistors in the control circuit, this voltage may differ from the **rated actuating (control circuit) voltage**.

Rated current I_n (of a circuit-breaker)
(see also IEC/EN 60947-2; 4.3.2.3)

For circuit-breakers, this current value is equal to the **rated uninterrupted current** and the **conventional free air thermal current**.

Rated frequency
(see also IEC/EN 60947-1; 4.3.3)

The frequency for which a device is designed and to which the other characteristics relate.

Rated impulse withstand voltage U_{imp}
(see also IEC/EN 60947-1; 4.3.1.3)

Measure of the stability of the internal clearances of a device against overvoltage peaks. The utilization of suitable switchgear can ensure that overvoltages are prevented from transferring from the mains to de-energized system sections within it.

Rated insulation voltage U_i
(see also IEC/EN 60947-1; 4.3.1.2)

The voltage to which insulation tests and **creepage distances** of a device relate. The highest **rated operational voltage** must not be greater than the rated insulation voltage.

Rated making capacity
(see also IEC/EN 60947-1; 4.3.5.2)

The value of current that a device is capable of switching On in accordance with the **utilization category** and at the **rated operational voltage**.

Rated operational current I_e
(see also IEC/EN 60947-1; 4.3.2.3)

The current that a device is capable of carrying, taking into account the rated operational voltage, duration of operation, utilization category and ambient temperature.

Rated operational voltage U_e
(see also IEC/EN 60947-1; 4.3.1.1)

The voltage to which the characteristics of a device relate. The highest rated operational voltage must not be greater than the **rated insulation voltage**.

Rated power, (AC) rating
(see also IEC/EN 60947-1; 4.3.2.3)

The operational power that a device is capable of switching at the associated **rated operational voltage** in accordance with the utilization category, e.g. contactor utilization category AC-3: 37 kW at 400 V.

Rated service short-circuit breaking capacity I_{cs}
(see also IEC/EN 60947-2; 4.3.5.2.2)

The prospective short-circuit current which, depending on the **rated operational voltage**, a circuit-breaker is capable of breaking repeatedly (test cycle O-CO-CO, previously P-2). After interrupting this short-circuit current value, the circuit-breaker must be capable of continuing to carry the **rated uninterrupted current** and disconnect it in the event of an overload, despite an increase in its own thermal level.

Rated short-circuit breaking capacity I_{cn}
(see also IEC/EN 60947-1; 4.3.6.3)

The maximum value of current that a device is capable of switching Off at rated operational voltage and rated frequency, and without sustaining damage. It is expressed as r.m.s. value.

Rated short-circuit making capacity I_{cm}
(see also IEC/EN 60947-1; 4.3.6.2)

The maximum value of current that a device is capable of switching On at rated operational voltage and rated frequency, and without sustaining damage. Unlike for other characteristic values, it is expressed as maximum prospective peak value.

Rated short-time withstand current I_{cw}
(see also IEC/EN 60947-1; 4.3.6.1)

The short-time withstand current that a device is capable of carrying for a specified time without damage, e.g. due to excessive heating.

Rated ultimate short-circuit breaking capacity I_{cu}
(see also IEC/EN 60947-2; 4.3.5.2.1)

The maximum prospective fault current that a circuit-breaker is capable of interrupting (test cycle O-CO, previously P-1). After interrupting this short-circuit value, the circuit-breaker must be capable of disconnecting in the event of overload, but at a higher tolerance level.

Rated uninterrupted current I_u
(see also IEC/EN 60947-1; 4.3.2.4)

The value of current that a device can carry in uninterrupted operation (for weeks, months or years).

Safe isolation
(see also VDE 0106 Part 101)

Isolation of circuits not carrying hazardous voltage, e.g. protective extra-low voltage, from circuits in which hazardous voltage flows. Such isolation is achieved by means of reinforced or double insulation, which reliably prevents voltage transfer from one circuit to another. This might otherwise take place between main circuits and control circuits in switching devices or between the primary and secondary sides of safety transformers. "Safe isolation" is a priority requirement for safety circuits and functional low-voltage circuits.

Tamper-proof

An **Emergency-Stop switching device** is regarded as tamper-proof if it cannot be reset without tools or using specified procedures after tripping. The device remains locked in the switching position, ruling out accidental or deliberate manipulation (inching).

Utilization category
(see also IEC/EN 60947-1; 2.1.18/IEV 441-17-19)

A combination of specified requirements relating to the condition in which the switching device or fuse fulfills its purpose and selected to represent a characteristic group of real-life applications. The specified requirements may, for example, relate to the values of making and breaking capacity and other characteristic values, data concerning associated circuits and the applicable conditions of use and operational behaviour.

(see also IEC/EN 60947-2; 4.4)

For circuit-breakers, the utilization category denotes whether the equipment is designed for selectivity using time delay (category B) or not (category A).

Symbols used in technical data and formulae

DF	Duty factor
$I_{\Delta n}$	Response value of earth-fault release
I_{cm}	Rated short-circuit making capacity
I_{cn}	Rated short-circuit breaking capacity
I_{cs}	Rated service short-circuit breaking capacity
I_{cu}	Rated ultimate short-circuit breaking capacity
I_{cw}	Rated short-time withstand current
I_e	Rated operational current
i_k''	Transformer initial short-circuit AC current
I_L	Load monitoring response value
I_n	Rated current
I_{NT}	Transformer rated current
I_{PK}	Rated peak withstand current
I_q	Rated conditional short-circuit current
I_r	Overcurrent release set value
I_{rm}	Response value of non-delayed short-circuit release
I_{rmf}	Response value of fixed, non-delayed short-circuit release
I_{rmv}	Response value of short-time delayed short-circuit release
I_T	Response value of earth-fault release
I_{th}	Conventional free air thermal current
I_{the}	Conventional thermal current of enclosed devices
I_u	Rated uninterrupted current
S_{NT}	Transformer rating
t_r	Time delay of overload release response
t_T	Time delay of earth-fault release response
t_v	Time delay of short-circuit release response
U_c	Rated actuating voltage
U_e	Rated operational voltage
U_i	Rated insulation voltage
U_{imp}	Rated impulse withstand voltage
u_k	Transformer short-circuit voltage
U_s	Rated control voltage

General

Moeller HPL0213-2004/2005

Internet

On the Internet you can find up-to-date notes, product information (such as documentation and version lists), software service packs and updates, user modules and configuration files for automation and drives applications.

http://www.moeller.net/automation

This address takes you to the **Automation Support** – the Moeller product support for automation systems.

Preconditions for the use of the Internet

You do not have to register to access the information on the Automation Support pages.
All you need is a PC with Internet access.

FTP (File Transfer Protocol) server

Under **ftp://ftp.moeller.net**, additional information for automation and drives products is available.

Accessing and using Automation Support via FTP

You do not have to register to access Automation Support information via FTP.
All you need is a PC with Internet access.
The root directory of **ftp://ftp.moeller.net** currently contains information relating to the following subjects:

AUTOMATION	→ **Automation support and drives**
ENGENEERING	→ Engineering tools for plant construction
TRAINING	→ Moeller Training Centre
SWITCHING_AND_CONTROL_DEVICES	→ Switching and control devices (EASY)

If you have any further questions or comments, or need information about Moeller automation and drive products, write to us at the following e-mail addresses for a fast reply:

automation@moeller.net	for automation systems
drives@moeller.net	for drives engineering

Workshops for our future

No progress without expertise
Today's rapid technological and scientific advances require us to continually adapt our knowledge in many subject areas. More than ever before, ongoing education and training after an initial qualification are vital in many professions.
Moeller has contributed to this progress over several decades with numerous innovations that still help shape the world markets today. But progress also requires the acknowledgement, utilization and further development of new technologies to set new standards. This role is performed by our Research and Development team, and the knowledge and expertise gained through its activities continually flow into our training curriculum.

Workshops in the Moeller Training Centre
The workshop timetable contains all workshops on offer at the Moeller Training Centre.
In the field of automation, the following workshops are available:
- Control engineering
- Automatic control engineering (FUZZY)
- Networking
- Visualization
- Drives engineering

Training for the PLC technician qualification of the ZVEI/VDMA.
This package provides detailed theoretical and practice-related training in automation engineering. Beside the main topic of PLCs, the automation components of visualization and drives engineering are addressed.

MK-A26	Programming compact PLCs (basic)
↓	
MK-A63	Electromagnetic compatibility (EMC)
↓	
MK-S20	Safety requirements
↓	
MK-A60	Designing switchgear assemblies
↓	
MK-A27	Programming compact PLCs (advanced)
↓	
MK-A70	Bus systems
↓	
MK-A62	Testing, commissioning and service
↓	
MK-AP1	PLC technician exam

Tailored location and content
Moeller holds workshops in Bonn, Berlin, Erfurt, Hamburg, Munich and on-site at your premises.
The Berlin, Hamburg and Munich locations hold workshops to train PLC technicians to ZVEI-/VDMA-level; all other workshops – with a few exceptions – are run in both Bonn and Erfurt. On request, we can also hold workshops on-site at your premises. The curriculum can be tailored to your specific needs.

Note

For further information about our workshops, order our training centre prospectus or visit www.moeller.net