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Quality of switch cabinets and wiring

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1. Introduction

This technical guideline addresses requirements on quality of (work) execution, unless they are not addressed by any other documents. The aspects listed in this document are to be understood as a minimum scope to ensure proper and long-term safe operation.

It may also be necessary to consider additional aspects. Unless otherwise stated, all specifications and designs shall fulfill the actual state of the art.

Deviations due to specifications or requests from FAIR or GSI must be taken into account, unless they do not contradict the requirements of this document. Otherwise deviations must be justified.

This document does **not** replace a qualification and experience of the manufacturing personnel according to the respective work task!

1.1. Scope

The scope of this document is GSI GmbH, FAIR GmbH, FAIR Project and their contractors and manufacturers.


1.2. Purpose

The purpose of this document is to create a (discussion) basis for a consistent and identical manufacturing of switch cabinets and wirings and to define this base by means of directives and standards, descriptions and good/bad sample pictures.

1.3. Directives and standards

The following directives and standards are recommended. There is no claim for completeness. It is depending on the respective risk assessment, which directives and standards are to be adhered to in particular.

- EN (IEC) 61439-1 "Low-voltage switchgear and controlgear assemblies - Part 1: General Rules"
- EN (IEC) 61439-2 "Low-voltage switchgear and controlgear assemblies - Part 2: Power switchgear and controlgear assemblies"
- IEC 60364-4-43 "Low-voltage electrical installations - Part 4-43: Protection for safety - Protection against overcurrent"
- IEC 60364-5-54 "Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors"
- IEC 60364-6 "Low voltage electrical installations - Part 6: Verification"
- DIN EN IEC 60204-1 "Safety of machinery – Electrical equipment of machines – Part 1: General requirements"
- DIN EN IEC 60204-11 "Safety of machinery - Electrical equipment of machines - Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV"
- DIN EN 60529 (VDE 0470-1) "Degrees of protection provided by enclosures"
- DIN EN 60947-3 "Low voltage switchgear - Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units"
- DIN EN IEC 62444 "Cable glands for electrical installations"

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- DIN VDE 0105-100 Operation of electrical installations Part 100: General requirements“
- Rittal "EMC-compatible enclosure assembly, Practical assembly tips"
- Colours according RAL
- IPC-A-610 – "Acceptability of Electronic Assemblies"
- IPC/WHMA-A-620 "Requirements and Acceptance for Cable and Wire Harness Assemblies"
- DIN EN 60352-2 "Solderless connections - Part 2: Crimped connections - General requirements, test methods and practical guidance"
- Molex "Industrial Crimp Quality Handbook"
- Helmholtz Guideline „Sicherheit bei Errichtung, Betrieb und Prüfung elektrischer Anlagen im Forschungsbetrieb“ (see EDMS No. 1718499)

Depending on the case, applicable specifications for the following components must also be observed and these must be specified for the corresponding requirements (according to the data sheet):

- Type and materials of low voltage switchgear cabinets or low voltage rooms
- All types of devices
- Cable types
- Wire cross-sections
- Terminal clamps
- Stop elements for cable mounting and preparation
- Crimping tools (hand pliers, semi-automatic or fully automatic hand pliers, tools for machine processing etc.)
- Wire identification
- Labeling of conductors
- Cable ducts
- Many other utilised components and materials

2. Structure and development of switch cabinet with door

2.1. Paint and colour of switch cabinets

Paint of switch cabinets and wall housings

Examples from GSI department GAT (building and technical facilities) (of 2017):

1. Infrastructure – Main distribution panel and sub distribution panel: RAL 5007 brilliant blue
2. Infrastructure – Building automation (ICE*): RAL 5012 light blue
3. Medium-voltage switchgear (normal and pulsed grid): RAL 2004 pure orange
4. Power supplies of all kinds and other control or switch cabinets: e.g. RAL 7035 light grey





*ICE: Instrumentation and Control Engineering

2.2. Rivets, rivet nuts, setting bolts

If possible, standardised sheet metal parts shall be used. Rivets, screws, setting nuts or setting bolts are used for assembly. These must comply with a DIN/IEC/ISO standard.

Clear manufacturing specifications are to be specified in the design documents for this purpose (parts list, drawings, list of torque values).

"Any sharp edges, burrs, rough surfaces or threads with which the insulation of the conductors can come into contact must be removed from the ducts and their connections." - acc. DIN EN IEC 60204-1. Therefore, plastic rivets shall be used if possible.

 <p>Fig. 1: Example of simple rivet tool for plastic rivets</p>	 <p>Fig. 2: Example of plastic rivet</p>
 <p>Fig. 3: Example of pneumatic rivet tool</p>	 <p>Fig. 4: Example of pneumatic setting bolt and nut tool</p>

Commercially available manual or pneumatic screwdrivers can be used for all screwdriving procedures, whereby a correct torque adjustment must be ensured for the pneumatic screwdrivers and cordless screwdrivers. All pneumatic screwdrivers must be calibrated.

2.3. Cable ducts

"Any sharp edges, burrs, rough surfaces or threads with which the insulation of the conductors can come into contact must be removed from the ducts and their connections." - acc. DIN EN 60204-1.

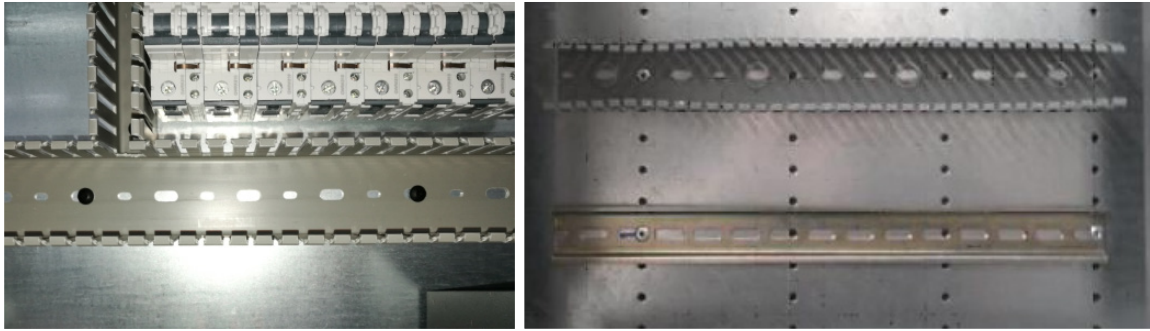


Fig. 5: Cable duct (preferably insulated fixing material) and mounting rail on rear wall



Fig. 6: Avoid sharp edges on mounting rails



Fig. 7: Mounting rail with mit protective cover

Signs, pushbuttons, illuminated pushbuttons and devices with adjustable or movable housing parts on the doors of the switch cabinets must be aligned vertically and perpendicular to each other.

For series switch cabinets, the uniformity of the complete series must be ensured, unless otherwise agreed.

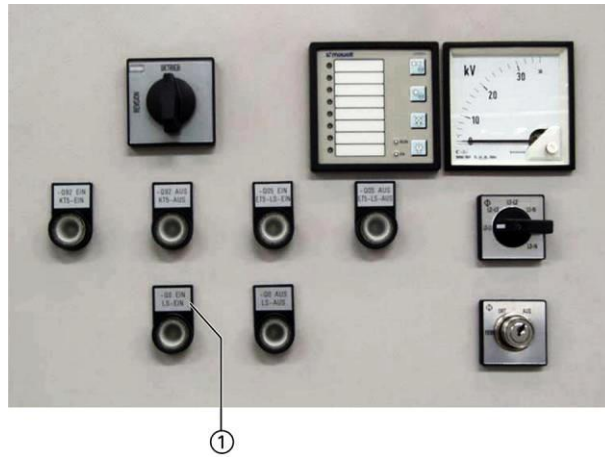


Fig. 8: Door with engraved labels (1 label holder)

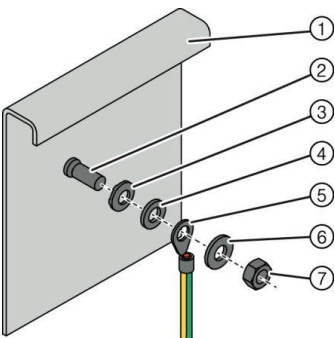
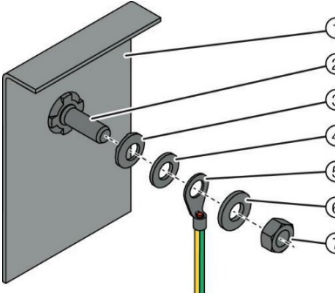
2.4. Grounding variants with grounding cable or ground strap

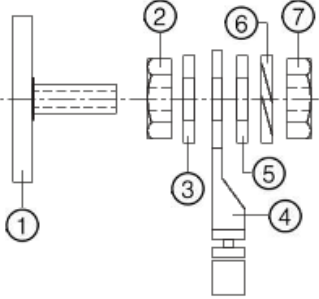
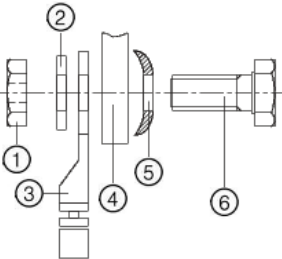
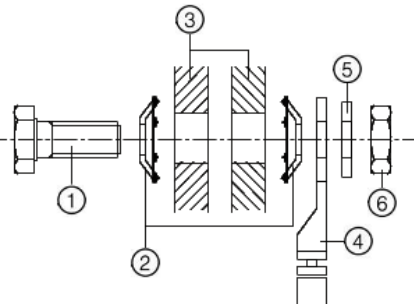
Protective conductors or protective conductor connections (grounding cables) must be protected by suitable means against mechanical damage and chemical or electrochemical destruction. This also applies to possible electrodynamic and thermodynamic forces that can occur in the system.

The grounding of low voltage equipment, doors and ground collectors must be carried out and marked correctly.

Grounding in general

Below an example of the technical set-up of a technically proper grounding for powder-coated and non-coated sheet metal parts is shown. This may differ in details for the individual control cabinet variants. If there are no other specifications on parts lists, this set-up is mandatory.

 <p>Fig. 9: Grounding scheme for powder coated parts</p>	<ul style="list-style-type: none"> 1 Door of switch cabinet 2 Welding bolt 3 Contact washer 4 Flat washer 5 Grounding cable with ring cable lug 6 Clamping disc 7 Nut
 <p>Fig. 10: Grounding scheme for non-coated parts</p>	<ul style="list-style-type: none"> 1 Frame of switch cabinet 2 Setting bolt 3 Contact washer 4 Flat washer 5 Grounding cable with ring cable lug 6 Clamping disc 7 Nut

 <p>Fig. 11: Alternative grounding scheme (less mechanical stress on welding bolt)</p>	<ul style="list-style-type: none"> 1 Welding bolt 2 Nut 3 Flat washer 4 Grounding cable with ring cable lug 5 Flat washer 6 Spring washer 7 Nut
 <p>Fig. 12: Grounding scheme for ground conductor rail</p>	<ul style="list-style-type: none"> 1 Nut 2 Flat washer 3 Grounding cable with ring cable lug 4 Rail 5 Tension disc 6 Screw
 <p>Fig. 13: Grounding scheme for other construction parts</p>	<ul style="list-style-type: none"> 1 Screw 2 Toothed lock washer 3 Construction parts 4 Grounding cable with ring cable lug 5 Flat washer 6 Nut

Door grounding with ground cable

The type of door grounding depends on the type of control unit or display unit installed in the door.

For control or display units, a grounding cable must be installed both from the device to the door and from the door to the switch cabinet. The grounding cable must have at least one cross-sectional size higher than the conductor cross-section. The grounding cable must always be mounted with the prescribed torque.

Adhesive dots must be uniformly applied for each type of switch cabinet. If grounding symbols are embossed, gluing a grounding sticker is not necessary.

Grounding cables between the door and the mounting plate have to be routed downwards as standard from the grounding bolt.



Fig. 14: Grounding cable between door and cabinet wall

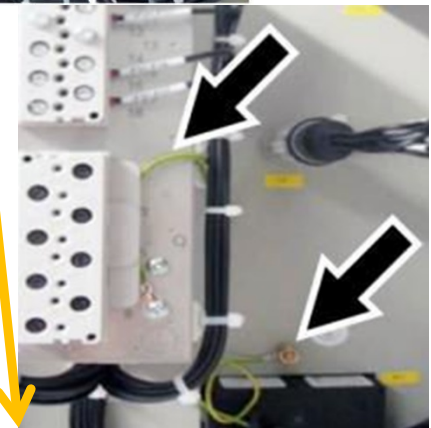
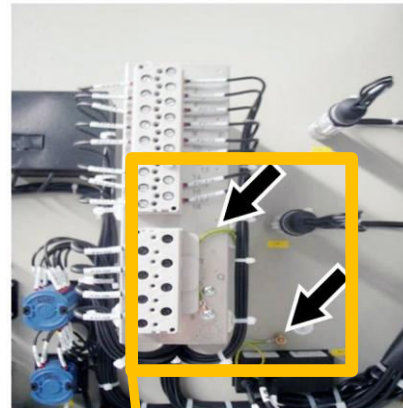


Fig. 15: Grounding cable between control/display unit and door

Door grounding with ground strap

The type of door grounding depends on the type of control/display unit, that is mounted in the door.

It can be necessary to make a ground connection from the door to the cabinet and also the ground connection from the control/display unit to the door with a green-yellow marked ground strap.



Fig. 16: Ground strap, marked green-yellow, for welding bolts



Fig. 17: Ground strap between control/display unit and door

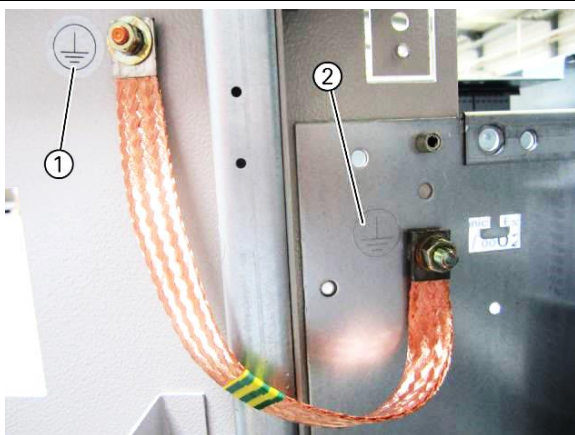


Fig. 18: Ground strap between door and cabinet
1 Grounding point sticker 2 Grounding point embossed

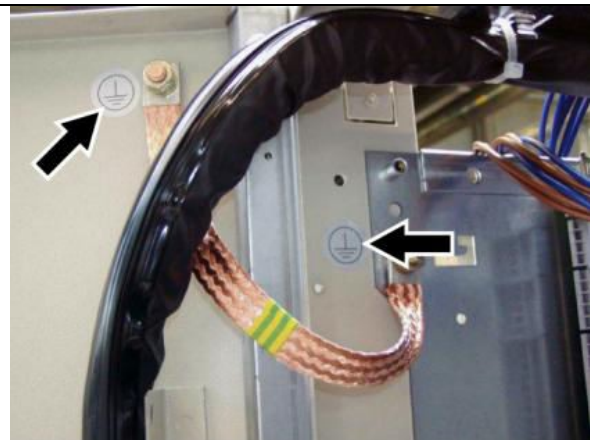


Fig. 19: Grounding bolts on powder coated sheets must be marked with grounding stickers.

2.5. Device designations (BMK)

To uniquely identify the individual components in the switch cabinet, all devices must have a device designation (BMK for German: "Betriemittelkennzeichen"). The device designation is made with yellow stickers (ensure sufficient contrast), to be put on the device and below it on the door or rear wall. It must be ensured that the surfaces to be glued on are dust-free, grease-free and dry, and that any impurities present have been removed without any residue.

The device designations must not be attached to removable covers. Exceptions are only permitted where individual parts do not fit on the device or only covers are available. Technical labels must not be covered.

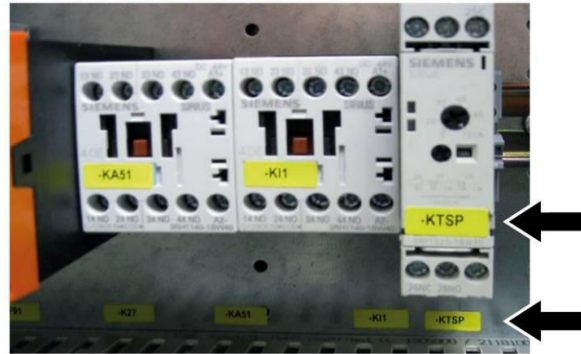



Fig. 20: Sticker positions for device designations (BMK) on device and rear wall

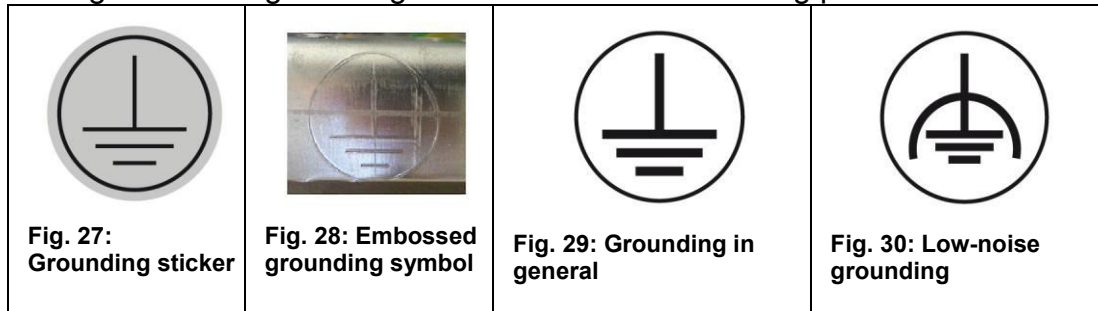
Device designations must not be glued over display windows of devices. Exceptions for the placing of device designations are devices that are expected to become hot during operation (example: radiator).

Futher examples for device designations:

<p>Fig. 21: For relays and similar BMK must leave window free</p>	<p>Fig. 22: BMK on circuit breaker</p>	<p>Fig. 23: Device vertically labelled</p>
<p>Fig. 24: Radiator with BMK (exception)</p>	<p>Fig. 25: BMK on standard circuit breakers</p>	<p>Fig. 26: BMK on door, push buttons or lamps</p>

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Device designations for groundings are shown on the following pictures:



2.6. IP Code

With regard to their suitability for different environments, protected systems are divided into corresponding protection types, so-called IP codes.

The abbreviation IP stands for "International Protection". In English-speaking countries, the abbreviation is sometimes translated as "Ingress Protection".

The standard IEC 60529 (VDE 0470-1) „Degrees of protection provided by enclosures (IP Code)“ applies.

2.7. Protection against injuries through mechanical forces

The following illustrations show examples of means of protection against injuries caused by mechanical forces:



Fig. 31: Protective cap for a nut



Fig. 32: Protective cap for a nut



Fig. 33: Protective cap on device protects against injuries on protruding screws.



Fig. 34: Protective caps for devices



Fig. 35: Mounting rail with protective cap



Fig. 36: Cable tie tool for cutting plastic cable ties avoids sharp edges. Cable ties must not be shortened with a wire cutter.

3. Wire identification resp. labeling of conductors


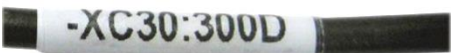


The wire identification must always correspond to the documentation (circuit diagrams, terminal lists, etc.). All types of labeling must ensure identifiability over 30 years. In

general, all cables in the switch cabinet must be labeled with the termination points of both ends of the cable.

Exceptions:

- Short wire jumpers that do not lead through a cable duct.
- Device cable, e.g. for switch cabinet lights or switch cabinet heating
- Grounding lines of sheet metal parts and devices that are led to a PE terminal block or a grounding point.

Examples for wire identification:

 <p>Fig. 37: Cable directly printed</p>	 <p>Fig. 38: Glued on label (standard)</p>
 <p>Fig. 39: Wire identification according to UL requirements</p>	 <p>Fig. 40: Shrinking tube, not shrunk „geschrumpft“ (Only allowed if affixed undetachable.)</p>

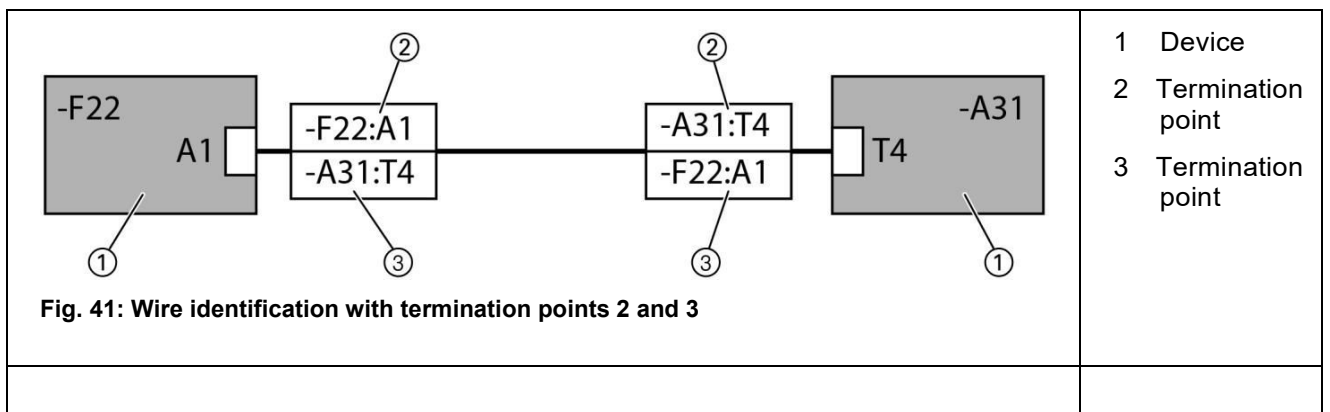




Fig. 42: Wire identifications must all be affixed at the same height with an even distance from the clamps.



Fig. 43: Wire identifications must all be affixed with the same text alignment.

- Glue all markings with the writing facing forward so that they can be read easily - otherwise "turn" the cable accordingly.
- The labeling of the wire identification must be readable from bottom to top or from left to right.



Fig. 44: The wire identification is readable from bottom to top.

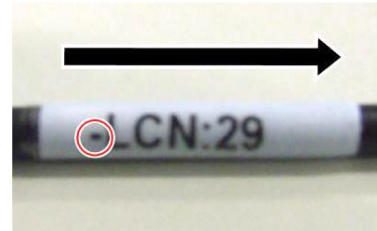


Fig. 45: The wire identification is readable from left to right.


3.1. Wire identification

Wires have an undetachable indelible identification in the switch cabinet

- at the point at which they leave the switch cabinet and
- in the immediate proximity of the terminal point of the wires or the connector.

3.2. Plug identification

Connectors have an undetachable indelible identification. If there is an unchangeable assignment, plugs and sockets can have the same designation. However, the labeling is done on both parts.

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3.3. Labeling of conductors

Basically, only cables are permitted that are clearly marked by colour or numbering. If the wire marking and cable identification are clearly visible and readable at the connection point, no further identification is required.

3.4. Single conductors

Individual wires must be provided with a wire identification at both ends, which describes the component, terminal point and terminal number in accordance with the reference labeling applicable to the product group (Example: =KF01-KF12-X01:12).

Only the part of the reference that is necessary for uniqueness within the switch cabinet is shown on the labels.

3.5. Types of labels

- All types of labels must ensure identifiability over 30 years.
- Printed labels must be UV-stable and require a protective film over the print side. Glued labels must be wrapped around the conductor several times.
- The label on shrinking tube markers must not be water or oil soluble. If it is ensured that the labels are undetachable, shrinking can be avoided.
- Closed ring grommets can also be used. They should be chosen to suit the size of the conductor. Otherwise the same requirements apply.
- The same requirements apply to printed cables.

3.6. Application of labels

- Associated labels must be attached at the same height and in the same orientation.
- Font size and type should be the same for similar conductors.
- Wire labels should be at a distance of 5-10 mm from the stop.

4. Wiring

4.1. Wiring in general

The following wire colours are recommended in the DIN EN 60204-1:

"Where colour coding is used to identify conductors, it is recommended that they be colour coded as follows:

- BLACK: Main circuits for AC and DC;
 - RED: Control circuits for AC;
 - BLUE: Control circuits for DC;
 - ORANGE: Excepted circuits according to 5.3.5."
- acc. DIN EN 60204-1

The following colour codes also apply:



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Colour	Use
black	230/400 V, AC
light blue	Neutral conductor N
green-yellow	Protective earth PE
red	230 V, AC (Control voltage after a control transformer)
dark blue	DC control voltage
grey	Measuring and control lines DC
purple	Transformer circuits
orange	External voltage

4.2. Terminals

Unless otherwise agreed, spring-type terminals are to be used. If certain types of terminal clamps are to be used, this may have to be agreed.

CORRECT	WRONG
 <p data-bbox="485 719 836 748">Fig. 46: Terminal block jumper</p>	 <p data-bbox="1034 719 1378 748">Fig. 47: Incorrectly cut jumper</p>
 <p data-bbox="485 1043 847 1104">Fig. 48: Terminal block jumper (comb)</p>	 <p data-bbox="1034 1043 1378 1072">Fig. 49: Incorrectly cut jumper</p>

Terminal block jumpers must be cut cleanly and correctly with an adequate pair of pliers. Incorrectly cut terminal block jumpers cause a short circuit when touched, which can lead to an arc fault.

To maintain protection against accidental contact:

- Do not cut off the edges of terminal block jumpers.
- Only cut on one side.
- Only let the cut surfaces point to the right or upwards.
- Two cut surfaces next to each other are not permitted.



Fig. 50: 1 Front cutter

2 Jumper notching tool

4.3. Wires, cable routing, connections

The greatest possible spatial separation (at least 30 cm) must be ensured between the signal or data and power lines. Signal and power lines should possibly only cross each other, but never run parallel to each other. Signal lines must not pass strong magnetic fields (e.g. motors and transformers). Cables and lines must not be routed through cable trays (dismountability). In hazardous areas, cables must be provided with mechanical protection. Only UV resistant types shall be used for cables and lines in outdoor areas. Only types of screw connections that are specified in the parts list are to be used. Installation boxes are also to be foreseen with the corresponding screw connections. For single-conductor cables, the cable clamps must be made of non-magnetically conductive material. The same applies to the cabinet bushings (heating of iron by magnetic short circuit). Fire alarm cable must be installed uncut. Necessary equipotential bonding cabling must be carried out (heating, water circuits, etc.).

see also Rittal "EMC-compatible enclosure assembly, Practical assembly tips"

Subsequent cable installations must be possible at all points. The accessibility of the components of the finalised switch cabinet must be ensured for maintenance.

Please note when laying cables:

- As far as is technically possible and sensible, cables and wires must be halogen-free. PVC should be avoided.

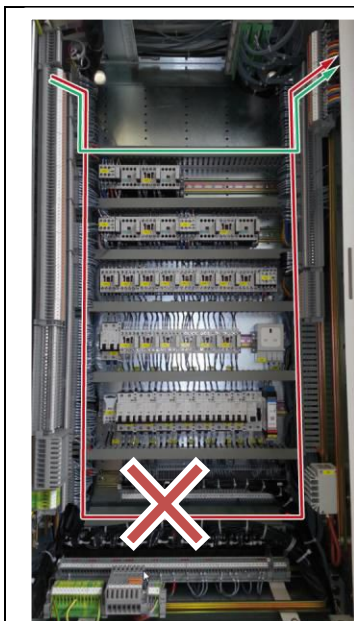


Fig. 51: Wiring

Correct: green line: short and few other cables

Wrong: red line: long and unfavourable due to overfilling the channel on the floor support

1. Cables on sheet metal parts are to be laid in horizontal cable ducts as standard. If an installation of a cable duct is not possible due to specifications or due to



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space constraints, the cables must be bundled horizontally and routed sensibly into the next cable duct.

2. Cables running from side wall to side wall have to be distributed sensibly over the horizontal cable ducts.
3. Cables near sharp edges must be protected against damage by applying an edge protection profile.
4. Cables are to be laid, bundled and fastened in such a way that they do not vibrate and the insulation does not wear, particularly when the cabinet is transported.
5. Cables must not be squeezed or otherwise damaged by moving parts.
6. Cables must not touch any heat-generating components (transformers, heat sinks, etc.).
7. The bending radius of the cables must not cause deformation of its insulation so that the cable does not damage itself on other components nor other devices.
8. Cables must not be exposed to mechanical tension.
9. Cables must not cover device terminals.
10. Overfilling the cable ducts has to be avoided; cables must be evenly distributed within the switch cabinet.
 - a. Cable ducts in which cables are routed from the primary part of the switchgear must not be filled completely. The next larger in size of the cable ducts should be installed (if this is spatially possible).
 - b. Cable ducts must be closed with covers.
11. Cables for devices with metallic strain reliefs and distributor housings must be provided with a fabric hose.
12. Cables are to be installed with slings (wire-end sleeves etc.). Connections with bare strands are not allowed.
13. Cables and cable harnesses shall always be laid cleanly and in straight lines so that a good appearance is created.
14. Special attention is to be paid to the wiring on the door because of the flexible connection to the cabinet.
15. If several identical switch cabinets are manufactured, it must be ensured that they are wired 100% identically.

This can be ensured by the following measures:

- a. Close coordination of all employees involved in the order

- b. Taking photos as samples of the first wired cabinets
 - c. Clear demands due to pre-assembled cables
16. When the control or display device is fully wired, the cables shall be tied with cable ties parallel to each other and at the same distance. The control and display devices must be wired uniformly for the whole series.
17. Use a cable tie tool to shorten the cable ties cleanly. (see figure below)
18. Handling of additional conductors (reserve wires): [...] "It should be considered to provide additional conductors for maintenance or repair. If reserve conductors are provided, these must be connected to replacement terminals or insulated so that they do not come into contact with active parts." - acc. to DIN EN 60204-1

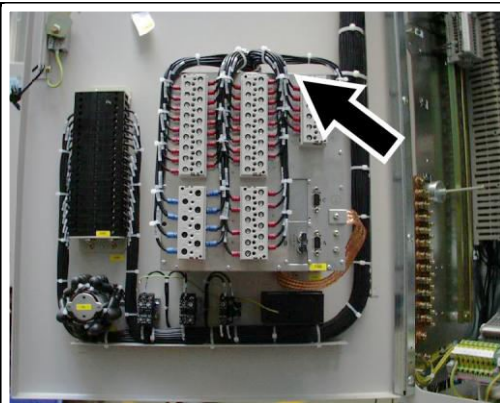


Fig. 52: Properly wired cables

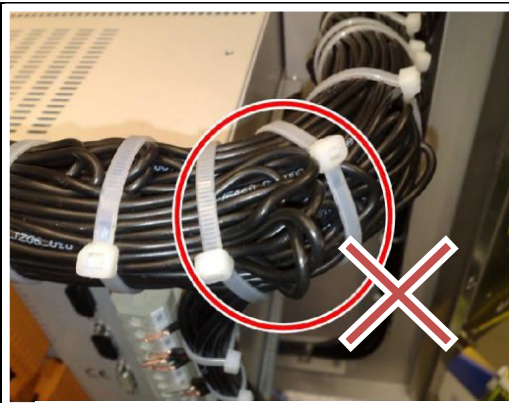


Fig. 53: Avoid squeezed cables!



Fig. 54: Cable ties, arranged evenly

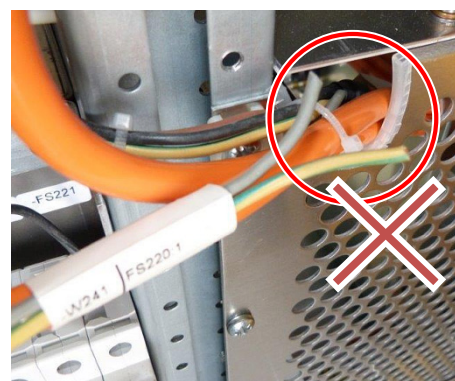


Fig. 55: Connect or insulate reserve conductors!



Fig. 56: Cable tie tool for cutting plastic cable ties



Fig. 57: The tool can be adjusted to various widths of plastic cable ties. This leads to a proper cut without frayings.

Before use the tie width is to be adjusted correctly for a proper cutting:

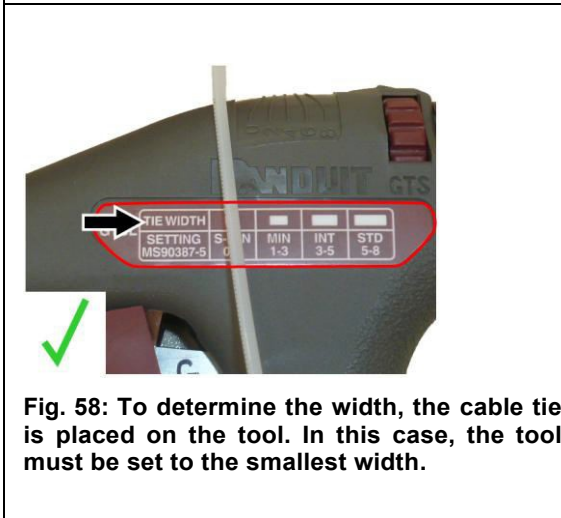


Fig. 58: To determine the width, the cable tie is placed on the tool. In this case, the tool must be set to the smallest width.

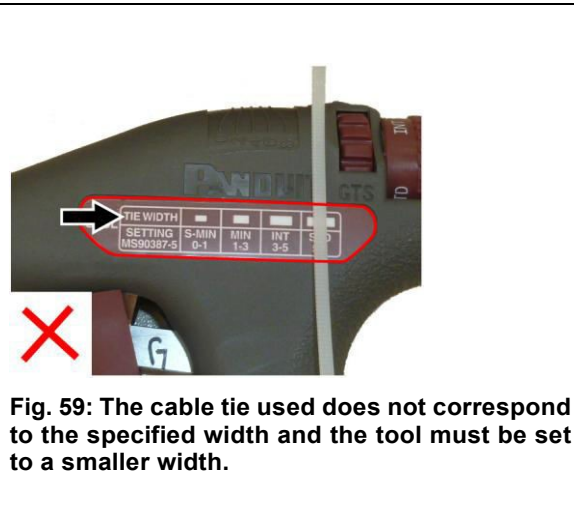


Fig. 59: The cable tie used does not correspond to the specified width and the tool must be set to a smaller width.

Adhesive sockets and adhesive brackets

Adhesive sockets and adhesive brackets are available in different designs and with different types of adhesives. If adhesive sockets or adhesive brackets are to be used, they must be selected according to their requirements with regard to environmental conditions and type of mechanical load. It is important to ensure that the surfaces to be glued are dust-free, grease-free and dry and that any existing contamination has been removed residue-free. Handling instructions from the manufacturers must be adhered.



Fig. 60: Adhesive socket (example)



Fig. 61: Adhesive bracket (example)

4.4. Cable routing from door into the switch cabinet

All conductors must be protected against damages.

Special attention must be paid to the cable harness from the door to the interior of the switch cabinet . A protective hose is generally to be used here.

When shaping the cable harness with the protective hose, it must be ensured that the door closes properly and crushing of the cable harness is avoided.

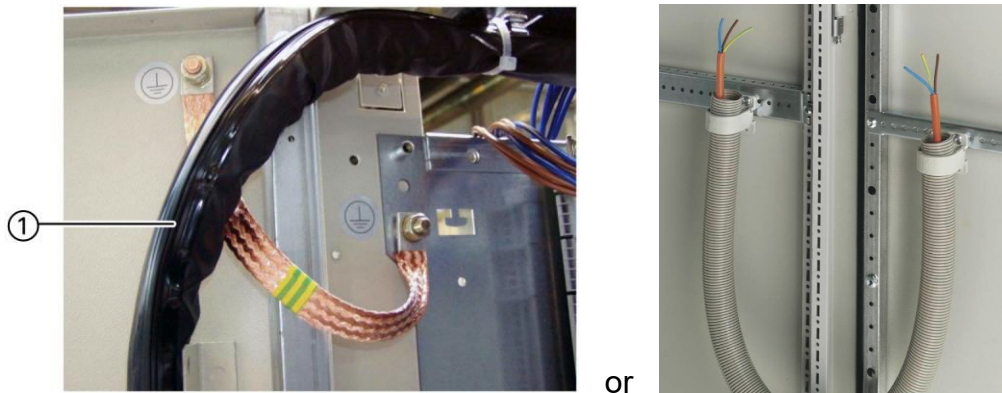


Fig. 62: Cable transition in protective hose (1) from door to switch cabinet

If the diameter of a protective hose is too small for the cable harness, two parallel hoses can be put together according to the same principle and thus result in a larger hose diameter.



Fig. 63: Tool for protective hose
e.g. of Reiku GmbH



Fig. 64: Tool for protective hose
e.g. of Reiku GmbH



Fig. 65: Cable ties and laying of the protective hose on door

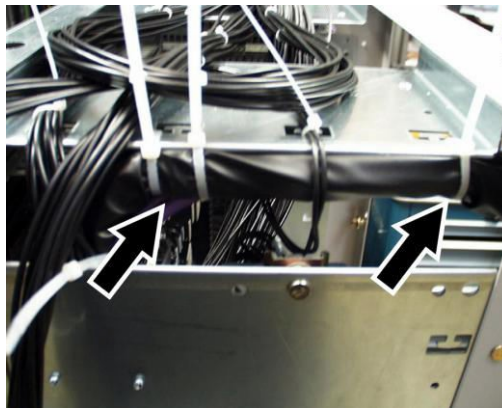


Fig. 66: The protective hose must extend into the cable duct and be fastened with cable ties.

4.5. Crimping

For crimp connections it is necessary to take into account various international standards and regulations, which are clearly bundled in the following documents:

- IPC/WHMA-A-620 Requirements and Acceptance for Cable and Wire Harness Assemblies
- Molex „Industrial Crimp Quality Handbook“

Crimping tools and their application

Tools must be checked regularly in accordance with their use (tensile tests, pull force tests, etc.). The tests must be documented. Suitable tool or press jaw inserts must be used for the corresponding crimp sleeves. The standard DIN EN 60352-2 recommends that tools and contacts should be from one manufacturer, as this is the only way to ensure a consistent high processing quality. Otherwise the manufacturer is responsible for the quality. Hand crimping pliers must have integrated full-cycle ratchet mechanism with the possibility of unlocking. Suitable tools for manual crimping are shown here as examples:

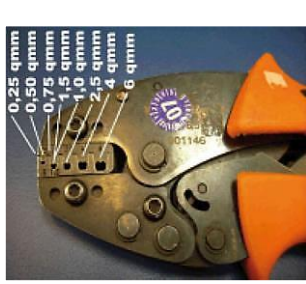


Fig. 67: Manual crimping tool



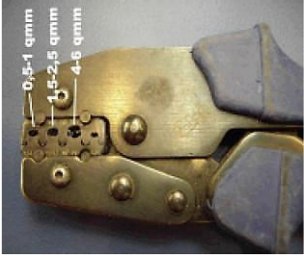






Fig. 68: Non-insulated cable end sleeve



Fig. 69: Manual crimping tool




Fig. 70: Non-insulated cable end sleeve

 <p>Fig. 71: Manual crimping tool</p>	 <p>Fig. 72: Non-insulated cable lug</p>
 <p>Fig. 73: Manual crimping tool</p>	 <p>Fig. 74: Insulated ring cable lugs</p>  <p>Fig. 75: Insulated reducing sleeves</p>
 <p>Fig. 76: Electrical crimping tool</p>	 <p>Fig. 77: Non-insulated ring cable lug</p>

5. Types of cables and their application

“Conductors, cables and wires must be selected so that they are suitable for the operating conditions (e.g. voltage, current, protection against electric shock, accumulation of cables and wires) and suitable for external influences (e.g. ambient temperature, presence of water or corrosive substances, mechanical stresses (including the stresses during installation), fire hazards).” acc. DIN EN 60204-1:2007

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If short-circuit cables or earth-fault-proof cables up to 1000 V must be used, the type "NSGAFÖU flexible rubber wire cable" must be used.

Grounding wire cross-sections are to be designed according to the currently valid DIN VDE 0100-540.

Further details can be found in the currently valid DIN EN 60204-1 "Safety of machines - Electrical equipment of machines - Part 1: General requirements".

6. Screws and torques

If specified, the manufacturer's specific information on components must be taken into account. In most cases, these can be seen on the components or in the technical manuals or data sheets. The applied tightening torques shall be noted in the manufacturing documents of the switch cabinets. The screws used must comply with a DIN / IEC / ISO standard. Calibrated torque wrenches must be used for corresponding tasks. In the final manufacturing step of each switch cabinet, it must be ensured that all screws are tightened with their corresponding tightening torques.

6.1. Cordless screwdrivers

When using cordless screwdriving tools, torque monitoring is important. (see figures below)



Fig. 78: Screwdriver handle with torque indicator (example)



Fig. 79: Cordless screwdriver with two speed levels and precise torque preselection (example)



Fig. 80: Cordless screwdriver (example)



Fig. 81: Mini cordless screwdriver, foldable with continuous adjustable torque preselection (example)

It is recommended to align the torques [Nm] of the screwing tools with the adjustable torque levels (1, 2, 3 ... or similar), to document this for use and to check it regularly. The battery charge levels should also be specified and checked.

6.2. Terminals and screw connections

It must be ensured that electrically conductive connections are firm, flat, flush and completely contacting and without tensile and compressive stress (see figure below). For connections and screw connections, tightening torques are to be carried out according to material strength classes and manufacturer's specifications. These shall not be confused with the maximum permissible torques.

Precise tightening and test torques are prescribed in particular in the data sheets for certain power semiconductors.

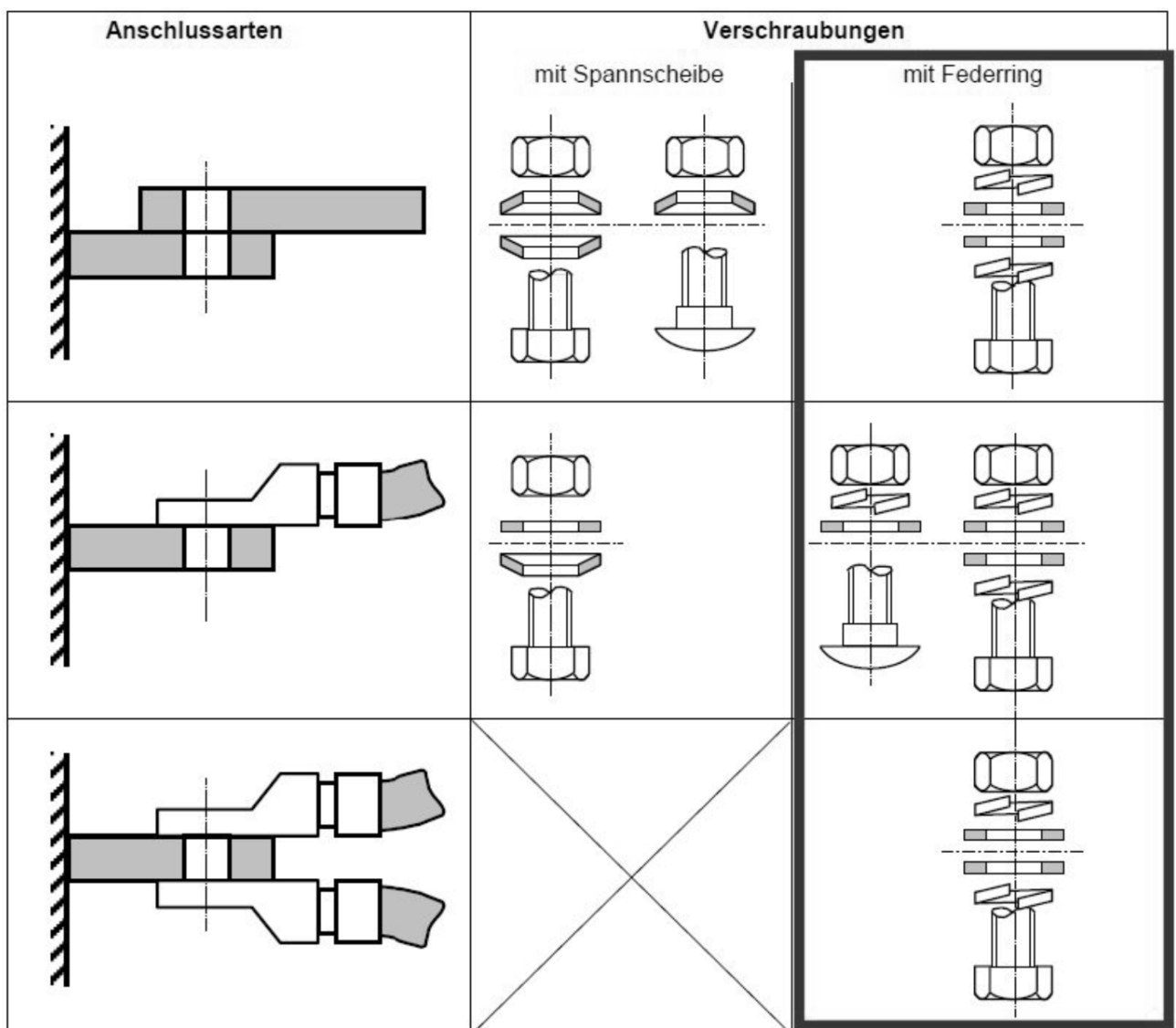


Fig. 82 Examples for technical drawings of electrical connections



Fig. 83: Torque indications on terminal clamp



Fig. 84: Torque indications on terminal clamp

7. Transport

It is necessary to determine how the transport shall take place. It is important to ensure that the manufacturer's transport regulations are observed. If there are no regulations, these must be requested.

8. Cleaning

It is important to ensure in all respects, a clean way of working conditions. Mechanical processing should, if possible, be completed before assembling the mounting plate and/or before starting the wiring.

Attention: When using compressed air, cut wires or strands can reach to places where they can cause short circuits. Therefore, appropriate countermeasures and precautions must be taken. When cleaning the control cabinet or device, make sure that there are no wiring residues or similar that remain from assembly stages.



Fig. 85: Falling shavings and residues (1) must not remain in the cabinet and have to be removed with an industrial vacuum cleaner.




Fig. 86: Example for industrial vacuum cleaner



Fig. 87: Unwanted adhesive residues



Fig. 88: All adhesive residues have to be removed with a special surface cleaner. (Example)

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9. Mechanical and visual inspections

Mechanical and optical tests must be carried out at least according to IEC 60364-6. See also the Helmholtz-Guideline „Sicherheit bei Errichtung, Betrieb und Prüfung elektrischer Anlagen im Forschungsbetrieb“ (see EDMS No. 1718499).

Additional inspection points:

- Device connections (screw, plug, crimp, solder connections) must be firmly connected.
- Complete (100%) tensile tests on all cables in the device
- No bare wires or strands must be visible.
- Check the device for internal and external damage.
- Check that there are no wiring residues in the device.
- Optically good design of the cable harnesses and a correspondingly uniformity of the wiring throughout the series.
- Compare the documented missing parts with actual missing parts.

10. Documentation

Unless other standards are listed, at least test reports based on IEC 60364-6 must be provided.

Before connecting a switch cabinet to supply voltage, at least the following documents must be available:

- technical documentation of the system to be connected and
- associated test records (with clear test instructions, responsible person, date, signature, etc.).

The Helmholtz-Guideline „Sicherheit bei Errichtung, Betrieb und Prüfung elektrischer Anlagen im Forschungsbetrieb“ (see EDMS No. 1718499) also states:

"Before the first commissioning of systems and devices, a test must be carried out. This is to ensure that the completeness, functionality of the system or equipment and functionality of the safety devices are guaranteed, and any existing defects are detected.

Warning: No switch cabinet may be put into operation without having its documentation!

For switch cabinets, safety instructions, circuit diagrams and parts lists must be kept available on the device. A final acceptance of a cabinet generally only takes place with an existing declaration of incorporation or Declaration of Conformity.