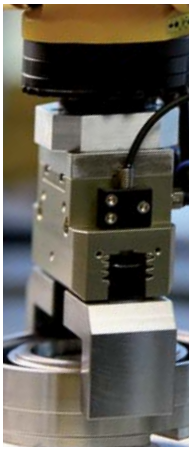
Electrical safety
in control and auxiliary circuits



The increasing health and safety requirements on machines and installations require comprehensive measures to protect man and machine against possible hazards. For instance, insulation faults in a controller must not result in hazardous movements of a machine. If there is a high availability requirement, it is also appropriate to consider this aspect correspondingly on the selection of the type of system and the protective measures. Both the related normative and practical requirements are explained in the following article.

Safety objectives

An insulation fault can, independent of the cause, represent a life-threatening hazard for personnel and a hazard for the integrity of assets and the availability of electrical power. For this reason the following aspects in particular should be taken into account on the selection of the type of system (TN, TT and IT systems) and the related protective measures:

- Probability of insulation faults
- Necessary basic protection and fault protection
- Continuity of the supply of electrical power
- Technical and commercial aspects
- Experience available on secondary effects (fire, downtime costs etc.)

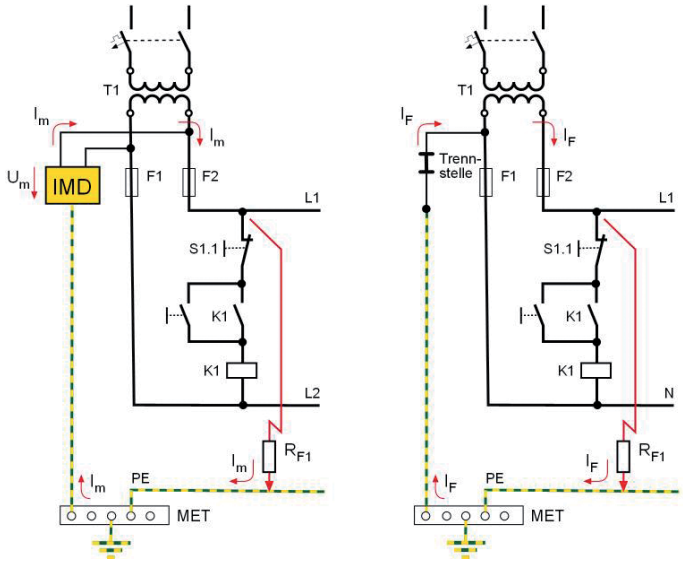
On electrical machines these aspects relate to the control and auxiliary circuits, as well as the main circuits. While in the main circuits the issue is more the protection against electric shock, the protection of personnel as well as the prevention of fire, reliability plays a significant role on control and auxiliary circuits, in particular those with voltages below the permissible touch voltage of AC 50 V/DC 120 V.

Auxiliary and control circuits

In DIN VDE 0100-557 (VDE 0100-557) a differentiation is made between control circuits and auxiliary circuits. Accordingly, this standard is always to be applied if there is no other independent standard. As such DIN VDE 0100-557 (VDE 0100-557) is not to be applied, for example, to

- Electrical equipment of machines: DIN EN 60204 (VDE 0113) series of standards;
- Installations and equipment for the transmission and processing of information for the public electricity supply: DIN VDE 0800-1 (VDE 0800-1) and DIN VDE 0804 (VDE 0804);
- Electrical equipment for furnaces: DIN EN 50156-1 (VDE 0116-1);
- Auxiliary equipment and control systems in high power installations exceeding rated AC voltages of 1 kV: DIN VDE 0101 (VDE 0101);
- Alarm systems for fire, intrusion and hold-up: DIN VDE 0833 (VDE 0833) series of standards.

FIG. 1:
Unearthed control circuit (IT system) and earthed control circuit (TN system) (I_m << I_F!)
(Note: Disconnection point for insulation test)



In DIN VDE 0100-557 (VDE 0100-557):2007-06 and DIN EN 60204-1 (VDE 0113-1):2007-06 both earthed and unearthed control circuits are addressed. Therefore the key differences are given in the following.

Earthed or unearthed control circuits?

On the occurrence of an insulation fault R_F a fault current I_F, flows in the earthed system (TN system); in the event of a very low-resistance insulation fault this current corresponds to the short circuit current I_K. This situation then triggers the overcurrent protective device and the supply of power is interrupted. Residual current devices (RCD) also shut down.

By contrast, in the IT system the active conductors are not connected to earth and such a small fault current flows on the first insulation fault that disconnection is not necessary (DIN VDE 0100-410 paragraph 411.6). To prevent the triggering of the overcurrent protective device on a second fault on one of the other conductors, the first fault is detected and signalled by the insulation monitoring device (IMD). The system operator is therefore informed and can undertake the maintenance measures at a suitable time. The other key advantage: the supply of power is maintained and operation is not interrupted. Particularly in industrial installations that require a high level of continuity (e.g. automotive, glass production etc.), this is a significant advantage and avoids high costs associated with failures.

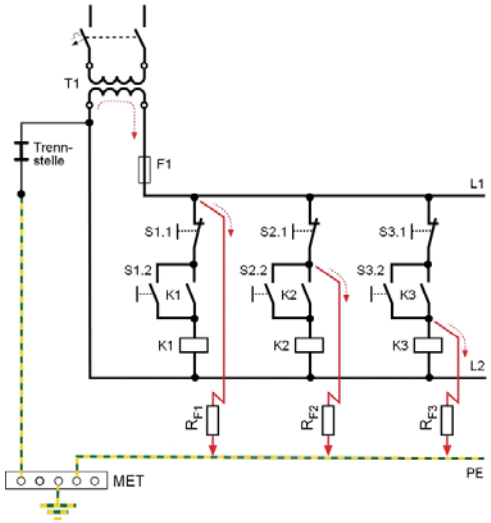
More operational safety, also on symmetrical insulation faults

According to E DIN EN 60204-1(VDE 0113-1) section 9.4.3.1 methods shall be provided to reduce the probability of an insulation fault in a control circuit that can cause maloperation – such as unintentional starting, potentially hazardous motions or prevent stopping of the machine. Here the usage of IT systems with insulation monitoring has the highest priority.

In control circuits, symmetrical insulation faults can also occur due to dirt, dust or moisture, e.g., on limit switches; these faults then prevent shutdown or cause the installation to switch on in an uncontrolled manner. Symmetrical insulation faults are defects in the insulation of an electrical installation or equipment creating a resistive path to earth having approximately the same resistance from all phase conductors to earth.

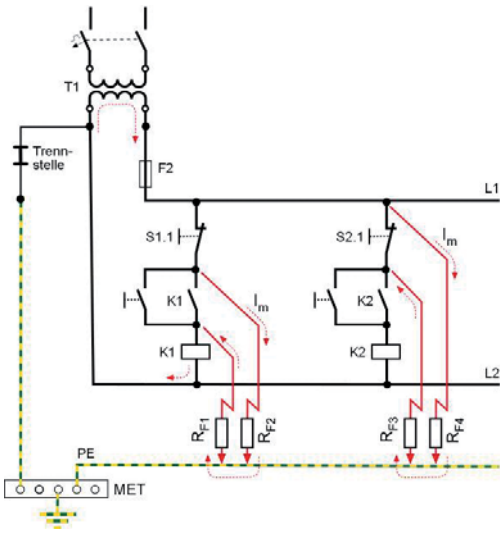
On sensitive control inputs, two high-resistance insulation faults are enough to "set" the input. These faults do not then cause the overcurrent protective device to trigger, as the fault current is significantly lower than the necessary short circuit current. Residual current devices can also not provide any help, as the outgoing and return currents are identical and there is therefore no residual current that could trigger the RCD. On the selection of the appropriate insulation monitoring device, attention is to be paid to ensuring the device detects symmetrical insulation faults. Earth fault relays that measure the displacement voltage to earth as the evaluation criterion do not meet this condition due to the measuring principle used. According to E DIN EN 60204-1(VDE 0113-1) section 9.4.3.1 and DIN VDE 0100-557 (VDE 0100-557) section 557.3.4.3, insulation monitoring devices must meet the requirements of DIN EN 61557-8 (VDE 0413-8).

FIG. 2:
First fault in an earthed control circuit (TN system)



	K1	K2	K3
Before power on	F1 trips	F1 trips	No effect
Switched on	–	–	F1 trips

FIG. 3:
Symmetrical insulation fault in an earthed control circuit (TN system)



On the occurrence of a first fault in an IT system, the two standards define different actions. While DIN VDE 0100-557 (VDE 0100-557) requires, in section 557.6.3.2, that an insulation fault must be signalled (minimum insulation resistance 100 Ω/V), section 9.4.3.1 of DIN EN 60204 (VDE 113-1) requires an automatic disconnection of the control circuit. This requirement is, however, contrary to the actual intention of an IT system, specifically to make possible continued operation despite a first fault. Section 411.6.1 of DIN VDE 0100-410 (VDE 0100-410) also states that the fault current on the occurrence of a single fault to an exposed-conductive partor to earth is low and automatic disconnection is not necessary – however it is a prerequisite that the exposed-conductive parts are earthed individually, in groups or collectively and the condition RA x Id = ≤ 50 V (for AC systems) or ≤ 120 V (for DC systems) is met. The draft standard E DIN EN 60204-1(VDE 0113-1) published in 2014, however, also states that signalling can be used in control circuits if disconnection represents a risk for the operation of the machine or the installation. As such here the planner is required to estimate this issue in a risk analysis.

FIG. 4:
Symmetrical insulation fault on a switching element in an unearthed control circuit (IT system) with detection by the IMD

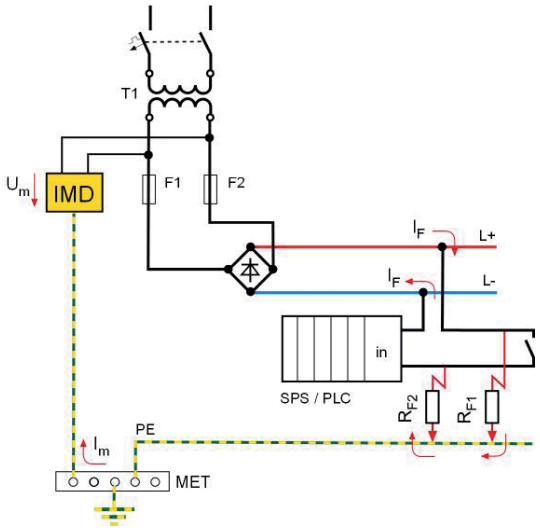
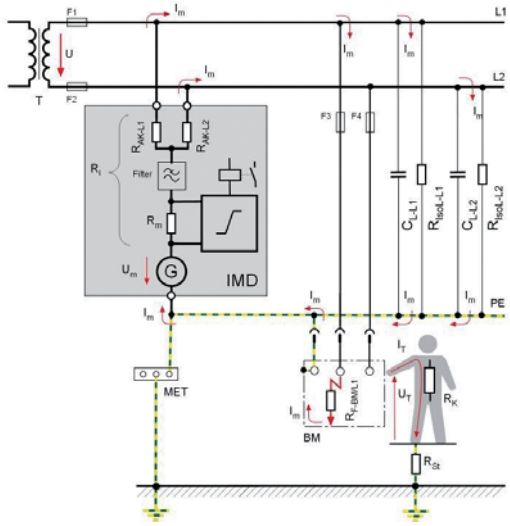


FIG. 5:
Operating principle of an insulation monitoring device with superimposed measuring voltage where R_i is correspondingly high-impedance and therefore I_m is very low (ideally < 1 mA)



Correct selection of an insulation monitoring device (IMD)

Insulation monitoring devices are described in the product standard DIN EN 61557-8 (VDE 0413-8). To detect also symmetrical insulation faults, the insulation monitoring device must employ a suitable measurement technique. Insulation monitoring devices that evaluate the displacement voltage (so-called earth fault relays) cannot detect this fault condition and for this reason are also not allowed to be used as insulation monitoring devices according to DIN EN 61557-8 (VDE 0413-8).

In principle IMDs can be equipped with various measurement techniques. During selection it is to be ensured they are also suitable for AC circuits in which there are, e.g., rectifiers that are electrically connected to the AC circuit. An insulation fault in the DC circuit can have negative effects on IMDs that operate using the measurement principle of superimposed DC and result in fault messages.

SUMMARY

The usage of earthed control circuits is not stipulated for the design of control circuits according to the standards. The usage of unearthed control circuits with insulation monitoring is often the better choice, particularly in relation to the aspects of reliability, prevention of failures and cost reduction. Systems for insulation fault location, for instance according to DIN EN 61557-9 (VDE 0413-9), can be used in addition to indicate the location of the insulation fault while the installation is in operation. Which measures are taken at the end of the day is to be determined as part of a risk analysis. ■

AUTHORS:

Dipl.-Ing. Harald Sellner
Head of standardisation
Bender GmbH & Co.KG
35305 Gruenberg
E-mail: Harald.Sellner@bender-de.com

Dipl.-Ing. Holger Potdevin
Standardisation manager
Bender GmbH & Co.KG
35305 Gruenberg
E-mail: Holger.Potdevin@bender-de.com

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DIN VDE 0100-557 (VDE 0100-557):2007-06
Low-voltage electrical installations – Part 5: Selection and erection of electrical equipment – Chapter 557: Auxiliary circuits

DIN VDE 0100-410 (VDE 0100-410):2007-06
Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock
(IEC 60364-4-41:2005, modified); German implementation HD 60364-4-41:2007

DIN EN 60204-1 (VDE 0113-1):2007-06
Safety of machinery – Electrical equipment of machinery
Part 1: General requirements (IEC 60204-1:2005, modified); German version EN 60204-1:2006

E DIN EN 60204-1 (VDE 0113-1):2014-10
Safety of machinery – Electrical equipment of machinery
Part 1: General requirements (IEC 44/709/CDV:2014); German version FprEN 60204-1:2014

DIN EN 61557-8 (VDE 0413-8):2014-10
Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 8: Insulation monitoring devices for IT systems
(IEC 61557-8:2014-12); German version EN 61557-8:2015

DIN EN 61557-9 (VDE 0413-9):2014-10
Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. Equipment for testing, measuring or monitoring of protective measures – Part 9: Equipment for insulation fault location in IT systems
(IEC 61557-9:2014); German version EN 61557-9:2015

DIN EN 62020 (VDE 0663):2005-11
Electrical accessories; Residual current monitors for household and similar uses (RCMs)
(IEC 62020:1998 + A1:2003, modified); German version EN 62020:1998 + A1:2005

Standards are available from: www.vde-verlag.de; www.beuth.de

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