Technical information No. 03

Installation Monitoring with Residual Current Monitors (RCMs)
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With regard to the electrical systems, the primary aim of all the responsible persons in industry, hospitals and building management is to provide a high electrical safety for persons, systems and service. In spite of correct planning by the consultants, modern appliances and electrical equipment may cause disturbances in electrical systems, which lead to unwanted down times, damages to property and hence to high costs.

Power supply problems

Unwanted power-interruptions and disturbances always cause high costs.

No matter if it’s a fault of a simple room lighting or if there are disturbances in computer systems. Reasons for that are insulation faults, stray currents, overloads on the neutral conductor caused by harmonics, interruptions of PE- and N-conductors and as well EMC-influences. On the other hand there are effects like unwanted power-interruptions, damage caused by fire, impacts on protection systems, inexplicable malfunctions and damage to telecommunication-, fire alarm and computer systems, corrosion on pipes and lightning-protection systems. Depending on the location of the damage, costs that can easily reach several thousands or even hundreds of thousands of dollars can be caused.

In this report the specific risks and reasons for damage will be explained and measures to avoid damages in modern electrical systems with Residual Current Monitors (RCMs) are stipulated.

Insulation faults

Insulation faults occur e.g. as a result of mechanical, thermal or chemical damage in electric insulations. But also pollution, moisture or damage caused by the environment (animals and plants) can damage the insulation so that an unwanted leakage current is flowing via the fault location. The magnitude of the current is defined by the system voltage, the earthing resistance and the insulation fault $R_f$.

This fault current $I_f$ can flow between the active conductors via the insulation fault $R_f$ and/or via conductive parts to earth. If the current is high enough (short-circuit or earth fault) the connected protective device trips and the faulty equipment or part of the system is disconnected from the system. If the fault current $I_f$ is not sufficient to trip the protection system (incomplete short-circuit or earth fault), there’s an immediate fire risk, when the fault energy exceeds a value of about 60 W at the fault location (about 260 mA/230 V). For safe and reliable protection purposes, a residual current protective device (RCD) can be used that provides a reliable disconnection in dangerous situations e.g. with a rated residual current below 300 mA.

Especially in computer systems an interruption causes severe consequences. Therefore RCDs are usually not used in this area. Further: Frequently UPS-systems are used, which can only withstand a limited short-circuit current; so they cannot trip fuses or MCBs, because the conditions for disconnection cannot be met. As a result high fault currents with critical values concerning the protection of people and fire risk can be observed.

In addition to common protective devices it’s recommended to use RCMs (Residual Current Monitors) acc. IEC 62020: 1998-08. These devices can provide selective monitoring of single devices or monitoring of parts of the system and optionally pre-alarm information before the response value of the protective device is reached. In combination with a circuit-breaker disconnection can be carried out under defined conditions.
Stray currents

Although the TN-S system has been promoted (because of EMC-reasons) for some time now (IEC 60364-5-548: 1996-02, Electrical installations of buildings – Part 5: Selection and erection of electrical equipment – Section 548: Earthing arrangements and equipotential bonding for information technology installations; IEC 60364-4-444: 1996-4, Electrical installations of buildings – Part 4: Protection for safety – Chapter 44: Protection against electromagnetic interferences (EMI) in installations of buildings), practice is frequently different. The systems are mainly designed with regard to the protection of people and optimised costs, so that the N-conductor – from a special cross section (10 mm² copper) – is allowed to be joined together with the PE to a PEN-conductor. That’s why the current in the return path (N-conductor) can split via all the earth connections and equipotential bonding conductors, because the N-conductor in every floor distribution is connected to the PE system. As a result of that there are high balancing currents flowing through the entire building via all conductive (metal) parts (e.g. water pipes, heating pipes, conduits), which can partly lead to high electro-magnetic fields, cause indefinite faults which are difficult to locate in electronic circuits. Further, corrosions on water pipes of the fire fighting systems can develop. This effect is worsened by harmonics in the N/PEN conductor.

Therefore the TN-S system should always be given preference when electronic data processing systems are used. Return currents from many individual electrical devices can be carefully directed towards the power supply source and stray currents cannot creep back to the transformer neutral via earth connections. The N-conductor is only allowed to have one connection with the earthing system (preferably in the low-voltage main distribution). This connection should be equipped with a current transformer and an RCM, which permanently monitors the connection and gives an alarm in case a preset threshold is exceeded. Additionally the PE system should be monitored by a RCM in order to check the load situation of the system.

The requirements for the TN-S system can be found in IEC 60364-5-548: 1996-02 – Section 548: Earthing arrangements and equipotential bonding for information technology installations” and IEC 60364-4-444: 1996-04 – Chapter 44: Protection against electromagnetic interferences (EMI) in installations of buildings), a properly installed TN-S system is required for a building where the use of information-technology is expected.
Harmonics

One tends to assume that a voltage has a pure sine-wave. In three-phase systems the individual phase-to-phase voltages are shifted in phase by 120°. In a case a system supplies linear loads (resistances, capacitances), a linear current is flowing that has any phase angle to the supply voltage. The vector sum of the three currents in every point is zero, so that in case of a symmetrical load condition the current in the N or PEN conductor is nearly 0 A.

In modern electrical systems more frequently non-linear electrical consumers are used (PC with power supply units, lamps with control gear, printers, photocopy machines), that are connected additionally between a phase conductor and the N- or PEN-conductor and that superimpose additional currents of the 3rd harmonic, even under symmetric load conditions. Independently from the remaining load distribution, the sum of all 150 Hz-currents will flow in the N- or PEN-conductor. The major part of currents of the 3rd harmonic can lead to an overload of the N-conductor and to a fire risk. Screw and clamp connections are subject to thermodynamic changes, they can loosen and so lead to interruptions in the N conductor. These interruptions can lead to indefinite star point shifts and temporary overvoltage that can destroy devices and other parts of the system.

Acc. to IEC 60364-4-430 „Erection of power installations with nominal voltage up to 1000 V – Protective uses – protection of cable and cords against over current“, in neutral conductors there’s no need to have an overcurrent detection or a disconnecting device, if the cross section of the neutral conductor is at least equal to the cross section of the phase conductor. If the cross section of the neutral conductor is smaller than the phase conductor, it is necessary to have a protective system that avoids overload.

But it’s also possible to relinquish this protection, if the neutral conductor is protected by the protective system of the phase conductor in case of a short-circuit and if the maximum current in the neutral conductor doesn’t exceed the value of the load capacity (during normal operation).

But in practise this standard is insufficient. In general one should try to reduce the use of harmonic producing equipment, but that’s not possible. That’s why the cross section of N and PE shouldn’t be reduced but be designed to carry harmonics. The use of EMC filters should also be taken into consideration. Most important is a permanent (current-) monitoring of the N-conductor. So a violation of critical limits is immediately realised and indicated. If that happens in several parts of the system, the reason can be easily found. For current monitoring it is recommended to use monitoring devices that work with a current transformer, in order to avoid an additional connection point.
Interruption of the PE-conductor

The function of additional protective measures for class I equipment depends on a reliable protective conductor connection within the whole installation. In case the protective earth conductor is interrupted, there’s an increased risk to persons because of touch voltages. Further, leakage currents can flow back to the star point through parts of the building and communication wires instead of using the PE and can therefore damage or destroy interfaces. So it is advisable to monitor the PE conductor.

What are RCMs?

Residual current monitors (RCMs) are able to detect residual currents in and above the mA-range. The residual current that is detected via a measuring current transformer is evaluated in an electronic circuit. If the response value and the response time are exceeded, optical or acoustic alarm is activated. Built-in relay contacts can be used either for indication or for switching. The possibility to indicate an alarm offers the advantage that there’s no unexpected disconnection if the availability of the system has absolute priority. In addition, even minor changes can easily be recognized because of the LED bar graph indicator in RCMs. RCMs have to correspond to the IEC 62020: 1998-08 and they are applicable for AC and for pulsating DC currents. Even for pure DC currents suitable devices are available. By means of external current transformers they can easily be installed into existing installations by means of so called split-core current transformers.

For complex building installations the so-called residual current location systems (RCMS systems) are available. These RCMS systems which operate on the principle of residual current measurement are capable of monitoring up to 12 measuring current transformers resp. subcircuits per device. These current transformers are scanned in turn in a certain time pattern and an alarm is issued for each channel where the pre-alarm or main alarm has been exceeded or the value has dropped below the set response value. It is also possible to connect up to 59 residual current monitors to a central control and indication panel (PRC1470) via an RS485 interface. In this way, it is possible to monitor buildings or parts of the system from one central point e.g. from a switchboard or a control room. Fault detection can be carried out during operation, disconnection of the system is not necessary.

System features:

• Connection of 59 RCMS evaluators (max. 708 measuring points)
• Adjustable response value of 1 mA – 2250 A per measuring point
• Overcurrent or undercurrent function, window function
• Wide frequency range: harmonics are detected
• Connection of closed, split-core or flexible residual current transformers
• Central control and indication panel (PRC1470) for all RCMS evaluators with parameterization and testing function, programmable clear text display, memory with date and time stamp, parameterizable input and output relay and EIB interface.
• Connection to central instrumentation and control with gateways
Figure 6: Overview of an EMC-friendly electrical installation with different possibilities for installation monitoring with RCMS scanning systems and a central PRC1470 control and indication panel.

- \( I_N \) = Monitoring of the N conductor (interruption/overcurrent)
- \( I_{PE} \) = Monitoring PE conductor (interruption/overcurrent)
- \( I_{PEN-N} \) = Monitoring the bridge PEN/PE
- \( I_{PAS} \) = Monitoring PE/PA system
- \( I_{\Delta n} \) = Monitoring of residual resp. fault currents

Central earthing point

Equipotential bonding rail

System earth

RCMS 470-12

Sub-distribution board

Data line

TCP/IP

= Building services management / central instrumentation and control
Requirements for safe electrical installations

Modern information technology in buildings requires electrical installations adapted to the individual conditions of the system. Fundamental aspects are:

- Creation and maintenance of a low-impedance earthing system with sufficient current-carrying capacity
- No load currents on the PE equipotential bonding system
- No multiple earthing of the N when supplied from multiple sources
- No reduced cable cross-sections for N and PE
- No single conductors from the transformer to the LV main distribution (twisted cables)
- No PEN conductor in the entire building
- To control reactive-power compensation equipment at zero crossing
- Overvoltage protection for reactive-power compensation equipment
- Use of residual current monitors (RCMs)
- Permanent load monitoring of all parameters
- Documentation and marking of cables/systems
- Permanent learning and maintenance
- Converting of TN-C or TN-C-S systems to TN-S systems starting from the supply point

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