Defects on electrical systems, electrical devices and equipment are still a major cause of fire. The insulation around cables and electrical equipment represents potentially a high fire load.

General.

According to common insurance industry statistics, approximately 30% of all fires are caused by defects on electrical systems, devices or equipment. The main ignition source in this regard is defective, incorrectly installed or insufficiently dimensioned equipment, which results in a thermal overload due to the electric current.

In the event of a fire, the fire might spread via cable trays. Toxic and corrosive gases are generated during these electrical fire events. As a result, authorities often define restrictions with regard to reinstallations. Delays are unavoidable due to the need for decontamination and repair. However, as no company can operate without electrical energy, electrical and electronic systems and equipment must fulfil the highest requirements in terms of availability, to reduce a larger business interruption at this risk.

Fire protection in electrical equipment rooms is therefore of particular importance. The measures prescribed in national standards (for instance DIN VDE) or international standards alone are normally not sufficient to cover and safely maintain fire protection for electrical equipment and service rooms.
1 Loss examples.

1.1 Chemical plant

At a chemical plant where thermoplastic polymers are produced, a short circuit and an arc occurred in the low-voltage switchgear, which ignited the insulation of the cables. Despite immediate fire fighting, two control cabinets were completely destroyed and adjoining distributors were damaged. Strong smoke caused damage to the entire low-voltage switchgear and adjoining rooms. Due to the power failure, almost all areas of the plant experienced extended malfunctions and failures. Even when the shutdown of the polymerisation units was initiated immediately after the incident occurred, it was not possible to empty and rinse large parts of the production facilities. These areas required an extensive and time-consuming cleaning as the product in the units had solidified.

Consequence: The production was interrupted for several months.

1.2 Waste incineration plant

A short circuit with subsequent arc caused a fire in a control cabinet of the 20 kV hazardous waste incineration plant. Starting from the control cabinet, the fire was able to spread to other control cabinets in the plant. The smoke detectors arranged in the high-voltage distributor board triggered an alarm. However, several fire brigades and huge quantities of CO₂ had to be employed to extinguish the fire.

The fire caused a power failure on the entire premises. Even though the emergency diesel generator at the plant started correctly, it shut down very shortly afterwards, probably due to a short circuit in the switchgear because of the fire.

The entire 20 kV plant was destroyed. The low voltage system and the compensation systems could be cleaned. The uncontrolled shutdown of the plant caused additional damage to the incineration plant.

As is often the case, the business interruption loss was significantly higher than the property damage.

1.3 Power plant

An explosion that occurred in a temporary installed transformer located in the cable basement of a block-unit power station led to a fire with far-reaching consequences. Burning transformer oil dispersed over large areas and ignited the cables. The fire was able to spread to all areas of the switchgear building via non partitioned breaks, channels and ducts.

The air conditioning system, which was only equipped with thermally triggering flap controls in the ducts, contributed significantly to the spreading of the smoke.

The fire alarm system notified the plant fire brigade, but even with a short response time they could not prevent the need for the central control room to be evacuated due to dense smoke. The automatic protection functions caused the shut-down of both block-unit power stations and the external electricity supply.

The entire loss (property damage, business interruption due to interruption to operations and damage to electronic systems) amounted to approximately € 45 million.

These examples of losses clearly show the far-reaching consequences that a fire in an electrical equipment room might have. Even minor damage of electrical and electronic systems may have disastrous consequences for a company.

2 Terms.

Electrical equipment rooms according to this Risk Engineering Guideline comprise:

- High voltage systems (e.g. according to IEC 61936-1).
- Low voltage systems (e.g. according to IEC 60364).
- Any rooms that are exclusively or mainly used for operating electrical systems.
3 Hazard sources/loss causes.

As the evaluation of loss incidents has shown, the following loss causes are the main causes of fires in electrical equipment rooms:

- Generation of arcing faults. Causes for this may include:
  - contact faults at the screw-type or clamp connections of contactors, switches and other components (e.g. due to material fatigue, metal flow at pressure points, faulty or soiled clamp connections),
  - creeping current due to humidity, dust, oil and coalification (creeping distances, arcing spots),
  - mechanical damage due to shocks, vibration stress and rodent attack,
  - insulation faults due to ageing (brittleness), introduction of foreign matter, weather and other external influences.
- Heat build-up due to
  - insufficient discharge of heat,
  - too densely arranged connections in control cabinets or of cable trays or
  - dirt deposits on electrical equipment.
- Fire risk due to impermissibly high ambient temperatures.
- Improper installation of cables and lines, e.g. by impermissibly small bending radii.
- Impermissibly high forces at clamps or strain relief (deformation).
- Insufficient safety distances.

4 Protective measures.

4.1 Structural fire protection measures

The following principles are applicable:

- High and low voltage switchgear, compensators, batteries and oil insulated equipment must be installed in separate rooms with separate fire protection. The same applies to distribution systems, transfer stations of the public power supply, as well as process control rooms.
- Switchgear must be provided with an outward pressure relief for deflecting the shock wave in the event of an arcing fault.
- The walls and the ceiling of the rooms should be built according to fire resistance class REI 90. (ASTM 3-hours).
- Only non-combustible materials shall be used as building materials.
- Access doors should at least comply with fire resistance class EI₂₃₀-CS (T₃₀-RS).
- Wall and ceiling penetrations for cable trays must be fire sealed by approved material. The fire seal must have the same fire resistance rating as the corresponding walls or ceilings. The same applies to ventilation ducts that must be closed with approved fire dampers. Activation of the fire dampers must be triggered by smoke detectors.
- Where separate electrical service rooms share one air conditioning/ventilation system, it must be ensured by the activation of the fire dampers and the automatic shutdown of the ventilation system that smoke and flue gases cannot spread via the ventilation ducts (prevention of "cold smoke"). However, separate ventilation systems would be required for an actual redundancy.
- The routing of third-party systems, such as pipelines, conveyor systems or similar through electrical equipment rooms should be avoided.

4.2 Plant technology

4.2.1 Arcing fault protection

Arcing faults may occur in low and high voltage switchgear and may endanger both people and property. They may be caused by overvoltage, insulation or handling faults, e.g. by bypassing electrical conductors, overloads due to defective plant components, failure to observe safety rules etc.

In the event of a fault, an arc burns between the faulty phases or at grounded plant components of the switchgear. Within 20 ms (a 50 Hz AC cycle), temperatures of up to several 10,000 °C and pressures of up to several bars are generated. The pressure and the heat, which causes the evaporation of metal parts, among others, may result in personal injury and also destroy the entire switchgear or the entire service room. This results in immediate business interruption, normally for an extended period.
Despite the closed type of modern switchgears, major losses and extended downtimes usually cannot be avoided. Here, major losses and extended downtimes are accepted. The divisions in between the individual switchgear sections are not always effective particularly during assembly and maintenance work, as doors and shutters are open. Switchgear for distributing electrical energy should therefore additionally be equipped with active protective systems.

Neither normal fire alarms nor conventional protective relays can detect an arc quickly enough to switch off the respective plant component. Detection and disconnection via an earthing relay is not reliable either as the neutral connector/ground wire does not necessarily have to be affected by the arcing fault. Besides, arcing faults are resistive incidents. The current in this regard is not necessarily higher than the rated tripping current of the protective device, and will not result in tripping or extended switch-off times of the protective devices.

Arcing fault protection systems detect the arc, extinguish the arc within a few milliseconds, and disconnect the defective plant from the mains. If an arcing fault occurs, a metallic short circuit is generated in parallel to the fault location, and the arc is extinguished before the shock wave and the temperature have reached their maximums. The resulting short circuit current causes the respective power switch to disconnect the fault location from the mains power supply.

Arcing fault detection systems comprise light and current sensors and electronic evaluation units. The light sensors, fibre optic cables or point sensors allow monitoring of the entire lengths of contact rails and connections systems. The arc current is measured with current transformers installed upstream of each mains power switch.

### 4.2.2 Plant fire protection

#### 4.2.2.1 Fire alarm system

Electrical equipment rooms should be monitored by a fire alarm system with smoke detectors and alarm transmission to a permanently staffed office.

Important criteria for the selection of a suitable fire alarm system include:
- Monitoring scope:
  - room monitoring (incl. raised floors and suspended ceilings),
  - installation monitoring (e. g. in control cabinets) required to ensure early detection,
  - monitoring of the fresh air supply (to ensure that, in the event of a fire close by, smoke will not enter this sensitive area).
- What ambient conditions (e. g. ventilation system in the monitoring area) must be considered?
- What measures must be initiated in the event of an alarm (e. g. alarming of the fire brigade, de-energising of the affected plant components, closing of air conditioning flaps)?
- How secure is the system in the event of false alarms?

The following detectors could be used:
- Spot detectors
  To safeguard against false alarms, these detectors could be installed in groups of two or in two-detector dependence.
Smoke aspiration system
In these systems, air samples are taken continuously via a pipe system from the area to be monitored. Extraction can be done directly at the location where a fire is likely to start. These detectors feature very reliable and extremely sensitive response characteristics and are capable of detecting pyrolysis products that are generated before an actual fire breaks out. Nevertheless, their sensitivity to false alarms is still very low. Furthermore, different alarm thresholds can be defined for these systems.

Fire alarm systems should be designed according to internationally recognised rules and standards (e.g. NFPA 72 National fire alarm and signaling code). Only approved systems should be used.

4.2.2.2 Fire extinguishing systems
Depending on the availability requirements of individual electrical equipment rooms, an automatic extinguishing system might be required in addition to the monitoring. Generally, gas extinguishing systems are preferable even though water extinguishing systems also provide adequate protection (with minor restrictions).

The extinguishing system should be designed according to internationally recognised rules and standards (e.g. NFPA 2001 Standard on carbon dioxide extinguishing systems). Only approved systems should be used.

4.3 Organisational fire protection measures
- A general smoking ban must be implemented in electrical equipment rooms and must be clearly marked by the corresponding signs.
- Electrical equipment rooms may not be misused as storage rooms, and must be kept free from any fire loads, such as e.g. transport pallets, packaging material, cables, spare parts or office supplies.
- Electrical equipment rooms may not be misused as electrical workshop or by other workplaces.
- Documentation, manuals and circuit diagrams should not be kept close to electrical equipment. They must be stored in separate steel cabinets.
- In view of the associated ignition hazard, the installation of private electrical appliances (e.g. coffee machines, radios, refrigerators) should be strictly prohibited.
- Fire and hot work must be avoided in principle. Where these are absolutely required, provision must be made for a written permit procedure that must include a form on that the necessary protective measures are defined as well as documentation of the corresponding checks during and after completion of the work. (see Risk Engineering Guideline "Hot Works").
- These rooms must be inspected at regular intervals, e.g. in terms of housekeeping, closure of cable bulk-heads etc.

No unauthorised people may be allowed entry to the electrical equipment rooms, which must be prevented by suitable measures (locking of these areas).

4.3.1 Fire extinguishers
A sufficient number of CO₂ fire extinguishers must be installed, easily visible and accessible at a central location for use by staff for fighting incipient fires. Dry powder extinguishers are principally suitable for controlling a fire in electrical systems. However, they cause considerable secondary damage due to the release of very fine and highly corrosive dry powder.

CO₂ allows for extinguishing fires in electrical and electronic systems without residues.

Staff should be trained in the operation of hand-held fire extinguishers to ensure that these are used quickly and effectively in an emergency.

5 Checks.

5.1 Initial acceptance
Also in view of the validity of warranty claims, new systems should be checked and accepted by an independent expert. A thermographic inspection of the system should always form part of the acceptance (refer to 5.3). It should be done after an operating time of approx. 4 to 6 weeks (real operation).
5.2 Repeated inspection

In accordance with regulations, the proper state of an electrical system must be maintained. Regular inspections of the entire system are indispensable in this regard. Normally, such inspections are prescribed by the insurance contract and must be performed routinely by approved experts, as they

- are always neutral and independent during the inspection,
- are familiar with the latest standards and the special concerns of fire protection as defined in electrical system guidelines,
- offer advice to the clients in accordance with the requirements of the property insurance if changes, repair and new constructions are necessary,
- are familiar with particularities of the inspection of electrical systems in terms of material asset protection, as normal inspections (e.g. the inspection according to the accident prevention regulations of the professional associations) are normally aimed at the protection of people, and
- are supervised by an independent third party.

The certification of the inspection should be stored at a safe place so that they are available if they have to be submitted to authorities or to the insurance company.

5.3 Thermography

The use of a thermographic camera (infrared camera) allows for inspecting electrical systems, such as distributors, control cabinets, etc. for any abnormal heating when these are energised, i.e. during the production and under nominal load conditions. Such overheating may be caused by incorrectly performed work, ageing components, loose clamps (increased transition resistances) or networks that have grown over time (incomplete circuit diagrams) and the associated gradual overload. Impermissibly high temperatures may represent a direct ignition source, or a permanent temperature overload may damage the electrical insulation and thus result in a conductor-to-conductor or short circuit (with arc).

To ensure qualified inspection and assessment of the plant components, this should be done by an approved thermographer.

6 References.

Local standards should be complied with.

Internationally recognised standards:

- IEC 603664 Low voltage electrical installations
- IEC 61936-1 Power installations exceeding 1 kV a. c.
- IEE Wiring regulations Inspection and testing, guidance note 3
- NFPA 70 NATIONAL ELECTRICAL CODE
- NFPA 70 B Recommended practice for electrical equipment maintenance
- NFPA 72 National fire alarm and signaling code
- NFPA 2001 Standard on clean agent fire extinguishing systems
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HDI Risk Consulting GmbH supports major corporations, industrial and mid-size companies with loss prevention and in establishing risk management systems.

HDI Risk Consulting offers its’ customers access to some 180 engineers and experts from a wide range of technical disciplines. We aim to support companies with the management of risks and the development of individual risk-based concepts for insurance cover.

HDI Risk Consulting operates globally in the Property, Motor, Engineering and Marine markets, with particular focus on the identification and assessment of risks and the development of appropriate, individual protection concepts.

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