TUV SUD Product Service Training

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Safety of Machinery
Electrical Equipment of Machines

Part 1: General Requirements
So Why Do We Use Standards?

- Standards ensure minimum desirable characteristics of products and services such as quality, environmental friendliness, safety, reliability, efficiency and interchangeability - and at an economical cost.

- Standards are formal documents containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose.

- EN 60204-1 is a harmonised standard to the machinery directive, and the use of it in designing your machine will give you a presumption of conformity to the corresponding EHSR’ of the machinery directive 2006/42/EC.
Types of Standards?

There are Three Types of Standard:

• “A” type apply to all machines.

• “B” type are designed to promote safety and split in to B1 and B2.

• “C” type apply to a specific type of machine.
Some of the Relevant Standards to Consider with Machinery:

- EN 60204-1: Safety of Machinery, Electrical equipment on Industrial Machines.
- EN 953: General requirements for design and construction of Guards.
- EN 1088: Interlock devices associated with Guards.
- EN 349: Minimum gaps to avoid crushing parts of the human body.
- EN 13857: Safety Distances to Prevent Hazard Zones Being Reached by Upper and Lower Limbs.
- EN 13855 (previously EN 999) Safety of machinery. Positioning of safeguards with respect to the approach speeds of parts of the human body.
Some of the Relevant Standards to Consider with Machinery (cont’d):


- EN 13849-1: Safety of Machinery - Safety Related Parts of Control Systems.

EN 60204-1 provides requirements and recommendations relating to the electrical equipment of machines so as to promote:

- Safety of persons and property.
- Consistency of control response.
- Ease of maintenance.

- EN 60204-1 applies to the application of electrical, electronic and programmable electronic equipment and systems to machines not portable by hand while working, including a group of machines working together in a co-ordinated manner.

- The standard applies from the point of connection of the supply to the electrical equipment of the machine.

- EN 60204-1 is applicable to the electrical equipment or parts of the electrical equipment that operate with nominal supply voltages not exceeding 1000v for alternating current (ac) and not exceeding 500v for direct current (dc), and with nominal supply frequencies not exceeding 200 Hz.
General Requirements:

- Risk due to electrical equipment is part of the risk assessment of machine:
  
  - Equipment failure leading to electrical shock.
  - Control circuit failure leading to malfunction of the machine.
  - Disturbance / interruption of the power source leading to malfunction of the machine.
  - Safety related control circuit failure leading to failure of safety functions.
  - EMC problems leading to malfunction of the machine.
  - Release of stored energy leading to unexpected movements / electrical shock.
  - Excessive noise leading to damaged hearing.
  - High surface temperatures leading to burns.
General Requirements:

• Correct selection of electrical components and devices based upon the:
  
  ▪ Intended use.
  ▪ Conformity to applicable standards.
  ▪ Applied according to manufacturers instructions.
  ▪ Suitability for purpose.
  ▪ Ability to withstand the expected influence.
  ▪ Appropriate for the intended use.
  ▪ Suitably placed / positioned.
  ▪ Readily identifiable with physical durable marking of the component or device.

• Low voltage switchgear / control gear assemblies must comply with IEC 60439.
Some Definitions:

Barrier

- A part providing protection against direct contact from any usual direction of access.

Control Circuit (of a machine)

- A circuit used for the control, including monitoring, of a machine and the electrical hardware / equipment.

Control Device

- A device connected into the control circuit and used for controlling the operation of the machine (for example position sensor, manual control switch, relay, contactor, magnetically operated valve).
Some Definitions:

Control gear

- Switching devices and their combination with associated control, measuring, protective, and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures, and supporting structures, intended in principle for the control of electrical energy consuming equipment.

Equipment

- Material, fittings, devices, components, appliances, fixtures, apparatus, and the like used as part of, or in connection with, the electrical equipment of machines.

Failure

- Termination of the ability of an item to perform a required function.
Some Definitions:

Fault

- State of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources on or off the ability of an item to perform a required function.

Live Part

- Conductor or conductive part intended to be energized in normal use, including a neutral conductor.

Protective Bonding

- Equipotential bonding for protection against electric shock.
Electrical Supplies and Isolation:

- A single incoming supply is recommended for machines. However where a second supply for electronic equipment with different voltage is required (for example from a 24vdc PSU), this shall be derived from main machine supply.

- Isolators must be readily accessible located between 0.6 m and 1.9 m above servicing level (with an upper limit 1.7 m recommended).

- Isolators should be lockable (LOTO type) and attached to the machine i.e. on-board.

- They should disconnect all supplies!!!

- Control on / off isolators must be black and grey.

- Emergency off isolators must be coloured red and yellow.

- It must have one off (isolated) and one on position marked with "O" and "I".
Electrical Supplies and Isolation:

- The isolator must be clearly identified as to its function i.e. what it isolates.

- The isolator should ideally be interlocked to the panel door. If this is not possible then IP2X protection must be installed to all devices that remain live when the door is opened.

- The isolator must not be mounted on the door itself.

- For large complex machinery there may be a need for more than one incoming supply, therefore consideration must be given to ensuring all supplies can be appropriately isolated by the use of protective interlocks for correct operation to prevent hazardous situations arising, including damage to the machine.
Electrical Supplies and Isolation:
The Supply Disconnecting (isolating) Device(s):

- A supply disconnecting device must be provided:
  - For each incoming source of supply to a machine(s) direct connection or via a feeder system - feeder systems include conductor wires, conductor bars, slip-ring assemblies, flexible cable systems (reeled, festooned) or inductive power supply systems.
  - For each on-board power supply.

The purpose of this is to ensure it is possible to disconnect (isolate) the electrical equipment of machine from supply when required i.e., to allow work on the machine which includes it’s electrical equipment.

- Where a machine has two or more supply disconnecting devices, protective interlocks for correct operation to prevent hazardous situations arising, including damage to the machine.
Protection Against Unauthorized, Inadvertent and / or Mistaken Connection:

- Isolation / disconnection devices located outside the electrical panel shall be fitted with a means to secure them in off position (disconnected state) i.e. of the LOTO (lock out tag out) design by using padlocking, or a trapped key interlocking system.

The prevention of remote as well as local reconnection shall be prevented by the use of:

- Non-lockable disconnecting devices such as withdrawable fuse-links, or withdrawable links, these must be kept under the immediate supervision of the person carrying out the work.

- A plug and socket combination positioned in such a way so as to be kept under the immediate supervision of the person carrying out the work.
Protection Against Electric Shock - General:

- Persons must be protected from electric shock from:
  - Direct contact.
  - Indirect contact.
Protection Against Electric Shock - Direct Contact:

- Measures must be taken to prevent electric shock by the use of barriers, placing out of reach, using obstacles, using construction or installation techniques as defined in IEC 60364-4-41 such as IP protection.

- In public places provision must be made for children resulting in a minimum requirement of IP4X.
Protection by Insulation of Live Parts:

- Live parts protected by insulation shall be completely covered with insulation that can only be removed by destruction.

- Such insulation shall be capable of withstanding the mechanical, chemical, electrical, and thermal stresses to which it can be subjected under normal operating conditions.
Potential Sources of Electric Shock from Wiring:
Potential Sources of Electric Shock in Enclosures:
Protection Against Electric Shock Protection - Indirect Contact:

The risk in this case is an insulation fault between live parts and exposed conductive parts.

- Protection is afforded by prevention of the occurrence of touch voltage and automatic disconnection of supply before time of contact with touch voltage can become hazardous by fast disconnection or tripping.

Note: The risk of harmful physiological effects from a touch voltage depends on the touch voltage and duration of possible exposure.
Protection of Equipment:

Equipment should be protect against the effects of:

- Over current arising from a short circuit.
- Overload and / or loss of cooling of motors.
- Abnormal temperature.
- Loss of or reduction in the supply voltage.
- Over speed of machines / machine elements.
- Earth fault / residual current.
- Incorrect phase sequence.
- Over voltage due to lightning and switching surges.
Equipotential Bonding Protective Bonding Circuit:

The protective bonding circuit consists of:

- PE terminal.
- Protective conductors including sliding contacts.
- Exposed conductive parts and conductive structural parts of electrical equipment.
- Those extraneous conductive parts which form the structure of the machine.

Where:

- Their resistance shall not exceed that of the allowable copper conductor.
- They are not less than 16 mm$^2$ in cross-sectional area.
- Flexible or rigid metal ducts and metallic cable sheaths must not be used.

Note: ‘Functional Bonding’ is for EMC protection only.
Control Circuits and Control Functions - Stop:

- Operational Stop

- Emergency Stop where the emergency stop device complies with EN ISO 13850
  - An emergency stop can only be a category 0 or 1 stop.
  - The initiation of the emergency stop must supersede all modes of operation and other functions.
  - There must be no automatic restart of the machine on reset.

- The switching of an ‘Emergency Off’ device (EMO) but only if the hazard is from electricity.
Control Gear - Location, Mounting, and Enclosures Requirements:

General Requirements:

• Accessibility and maintenance.

• Protection against external influences or conditions under which it is intended to operate.

• Operation and maintenance of machine and its associated equipment.

• The necessary special tool to adjust, maintain, or remove a device shall be supplied.

• Be located between 0.4 m and 2m above the servicing level.

• Terminals at least 0.2 m above the servicing level.

• Conductors and cables can be easily connected.
Wiring Practices - General Requirements:

- Secure against accidental loosening of terminals.
- Two or more conductors to one terminal only if terminal is designed for that purpose.
- Only one protective conductor connected to one terminal connecting point.
- Soldered connections only where terminals suitable for soldering.
- Terminal blocks plainly marked or labelled to correspond with diagrams.
- Flexible conduits and cables - liquids shall drain away from fittings.
- Retain conductor strands when terminating conductors - Do not solder.
- Identification tags labels must be legible, permanent, appropriate for physical environment.
Wiring Practices - General Requirements:

- Only one protective conductor connected to one terminal connecting point.
Wiring Practices - Identification of Conductors:

- Identification of conductors is required at each termination according to technical documentation.

- Recommended means of doing this are number, alphanumeric, colours (either solid or with one or more stripes), or a combination of these. Numbers in Arabic, letters in Roman.
Marking, Warning Signs and Reference Designations:

Where appropriate the system / machine must be marked with all mandatory signage and appropriate warning labels and signs, and identifiers for cables etc., as previously discussed.

Some examples being:

- Electrical Shock
- Hot Surface
- Caution 240 volts
- Caution 415 volts
Technical Documentation:

The system / machine must be supplied with all appropriate technical documentation including parts list or list of documents, these can include:

- A clear, comprehensive description of the equipment, installation and mounting, and connection to the electrical supply instructions.
- Electrical supply requirements.
- Information on the physical environment (if applicable).
- Overview (block) diagrams (where appropriate).
- Circuit wiring diagrams.
- Recommended spare parts list and list of tools supplied.
- Operating instructions (where applicable).

"We don’t have the manual, so just start pushing buttons and things until you know what you’re doing."
Verification and Testing:

If there is no dedicated product standard (a ‘C’ standard) for the machine the verifications shall always include the items a), b) and f) and may include one or more of c) to e), in the following order:

- a) Verification that electrical equipment complies with its technical documentation.
- b) Protection against indirect contact by automatic disconnection: Verify the conditions for protection by automatic disconnection.
- c) Insulation resistance test.
- d) Voltage test.
- e) Protection against residual voltage.
- f) Functional tests.