How to Design System Grounding in Low Voltage Electrical Systems

An Online Continuing Education Course for Engineers

Course Number: E-2097

Credit: 2 Hours / 2 PDH / 2 CPD

How to Design System Grounding in Low Voltage Electrical Systems

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Evolution of System Requirements

Commonly used system grounding types are:

- Exposed-conductive parts connected to neutral –TN
- Grounded neutral –TT
- Ungrounded (or impedance-grounded) neutral –IT

The objective of these three grounding systems is identical regarding the protection of people and equipment; it is for mastery of insulation fault effects. They are the same with respect to the safety of people against indirect contact. Nevertheless, the same is not necessarily correct for the dependability of the low-voltage electrical installation with respect to:

- System availability
- Maintenance requirements

Quantities that can be calculated are subjected to increasingly exacting requirements in factories and buildings. Also, building control and monitoring equipment (electrical power distribution management systems) has an increasingly crucial role in management and dependability. These developments in dependability requirements impact the selection and design of system grounding. It needs to be kept in mind that the issue with service continuity (keeping a sound network in public distribution by disconnecting consumers with insulation faults) played a role when system grounding first emerged.

Insulation Fault Causes

In order to provide staff protection and service continuity, conductors and live elements of electrical installations are "insulated" from the frames connected to the ground. Insulation is accomplished by:

- Application of insulating materials

- Distancing, which calls for clearances in gases (air, SF6) and creepage distances (concerning switchgear, for example, an insulator flashover path)

Insulation is described by set voltages which, in line with standards, are applied to new products and devices:

- Lightning impulse withstand voltage (1.2; 50ms wave)
- Insulating voltage (highest network voltage)

- Power frequency withstand voltage (2 U + 1,000 V/1mn)

Example of an LV-type switchboard:

- Insulating voltage: 1,000 V
- Impulse voltage: 12 kV

When new equipment is manufactured as per adequate practices with products as specified in standards, the risk of insulation faults is extremely low. Nevertheless, as the installation ages, this risk increases. The installation is exposed to different aggressions which increases insulation faults. For instance:

During installation:

- Mechanical damage to an underground cable insulator

During service:

- Conductive dust

Insulator thermal aging due to excessive temperature caused by too many cables in a cable duct, a poorly ventilated cubicle, climate, current or voltage harmonics, overcurrents, etc.

The electro-dynamic forces created during a short circuit may damage a cable or decrease a clearance.

- The operating and lightning overvoltage
- The 60 Hz return overvoltage, created by an insulation fault in MV

Typically, it is a mix of these primary causes which creates the insulation fault. The latter is:

- Either of the differential mode (between energized conductors) becomes a short-circuit
- Or of common mode (between exposed conductors and frame or ground), a fault current then flows in the protective conductor (PE).

LV system grounding is mainly concerned with common mode faults which mainly occur in loads and cables.

Accidents Linked To Insulation Faults

An insulation fault, regardless of its cause, presents a danger for:

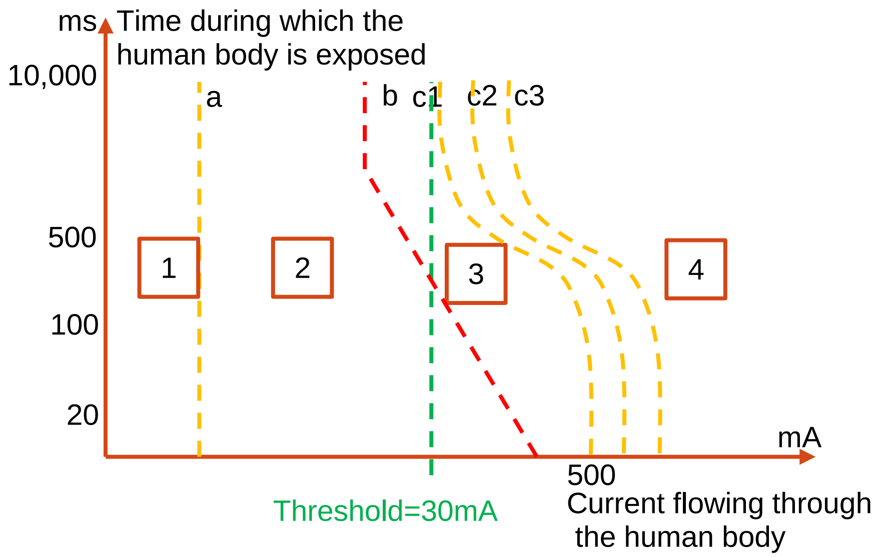
- Preservation of property
- Electrical power availability
- Personnel

Electric Shock Affecting People

A person exposed to an electrical voltage is electrified. This person may suffer from:

- A muscular contraction
- Discomfort
- A burn
- Cardiac arrest (this is electrocution)

All the above effects are presented in Figure 1.



Zone 1: Perception

Zone 2: Considerable discomfort

Zone 3: Muscular contractions

Zone 4: Risk of cardiac arrest

C2: Likelihood <5%

C3: Likelihood ≥50%

Figure 1. Time/current area of AC impact (15 Hz to 100 Hz) on people (defined as per IEC 60449-1)

Since the protection of people against lethal electric current effects takes priority, electric shock is the first and most important hazard that needs to be assessed.

The current strength (expressed in amperes), flowing through the human body (especially the heart) is dangerous and can be fatal. In LV systems, body impedance value (skin resistance is one of the most important aspects of overall body impedance) changes according to the environment (dry and wet premises and damp premises). In any case, a safety voltage (which is defined as the maximum acceptable contact voltage for at least 5 s) has been set at 50 V. In the case there is a risk of contact voltage Uc surpassing 50 V voltage, the application time of the fault voltage needs to be limited and shortened by applying different protection elements as presented in Table 1.

Table 1. Maximum safe contact voltage times

Dry or humid places: $U_L \leq 50$ V											
Presumed contact voltage (V)		<50	50	75	90	120	150	220	280	350	500
Protection devices' maximum breaking time	AC	5	5	0.6	0.45	0.34	0.27	0.17	0.12	0.08	0.04
	DC	5	5	5	5	5	1	0.4	0.3	0.2	0.1
Wet places $U_L \leq 25$V											
Presumed contact voltage (V)		25	50	75	90	110	150	220	280		
Protection devices' maximum breaking time	AC	5	0.48	0.3	0.25	0.18	0.1	0.02	0.02		
	DC	5	5	2	0.8	0.5	0.25	0.06	0.02		

Fire

Once it happens, fire can have serious consequences for both personnel and property. A considerable number of fires are caused by localized temperature rises or an electric arc created by an insulation fault. The danger increases as the fault current rises. It also depends on the risk of fire or explosion that may happen on the premises.

Electrical Power Unavailability

It is increasingly important to master this issue. In the case the faulty element is automatically disconnected to clear the fault, the results may be:

- Sudden absence of lighting
- Switching off equipment needed for safety purposes
- A risk for staff
- Financial effect due to production loss.

This risk must be mastered in process industries, which are lengthy and costly to restart.

Also, if the fault current is high:

- Damage can be significant and increase repair costs and times

- Circulation of high fault currents in the common mode (between network and ground) may also create problems for sensitive equipment, especially if these are part of a "low current" system geographically distributed with galvanic links.

Lastly, during de-energizing, the occurrence of over-voltages and/or electromagnetic radiation processes may lead to the malfunctioning of sensitive devices.

Direct and Indirect Contacts

Before studying the system grounding arranger … ontacts need to be provided.

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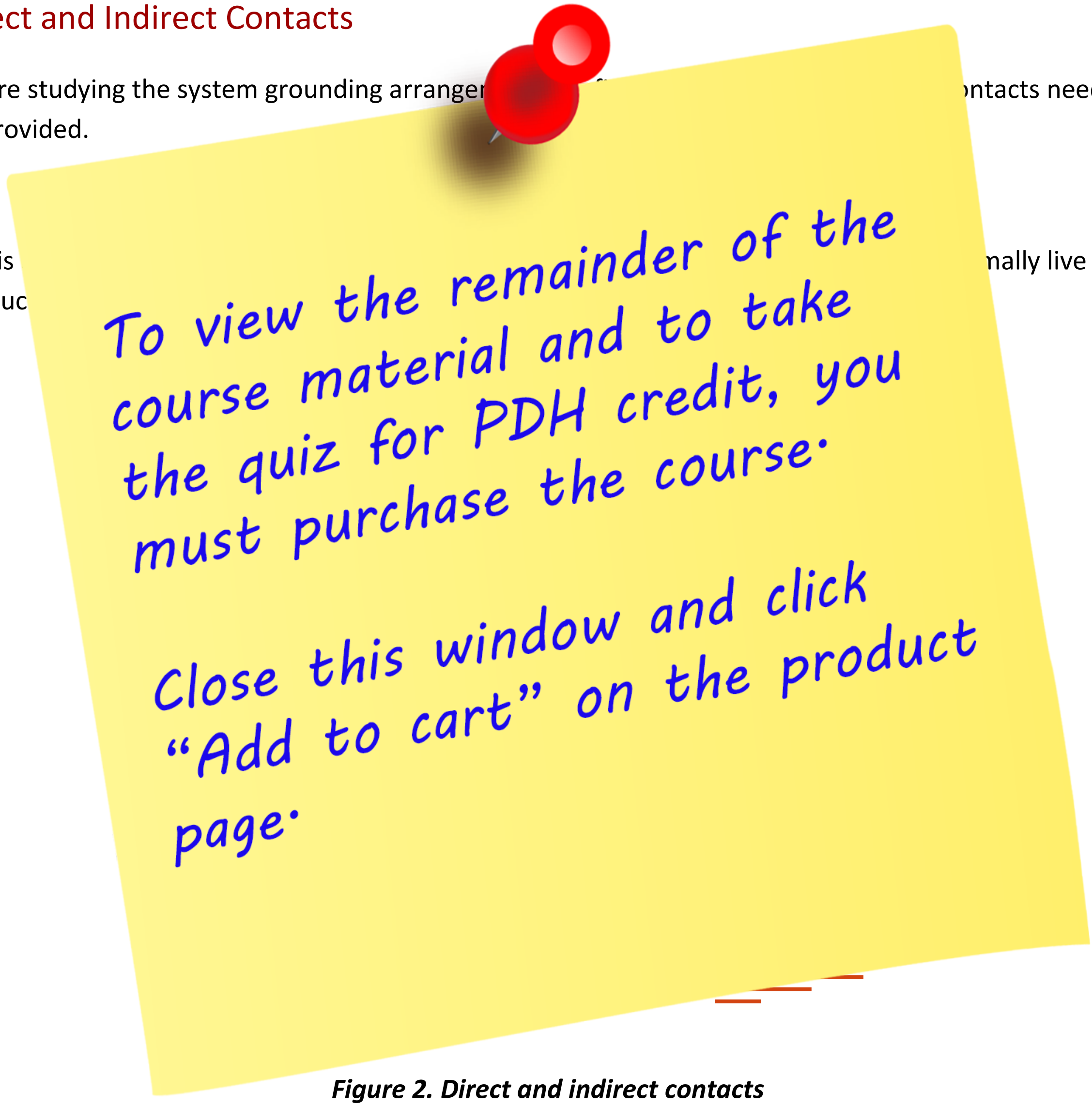

Figure 2. Direct and indirect contacts

In risky cases, the typical solution is transferring electricity using a non-dangerous voltage, i.e., less than or equal to a safe voltage. This is also known as using extra-low voltage. In LV, protection actions include placing live elements out of reach or insulating them by means of insulators, enclosures, or barriers. Additional measure against direct contact consists of using instantaneous 30 mA High Sensitivity Residual Current Devices known as HS-RCDs. Protection against direct contact is totally independent of