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Method for determining the impedance to earth of earthing systems

Recommendation ITU-T K.107

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Method for determining the impedance to earth of earthing systems

Summary

Telecommunication systems are vulnerable to the earth potential rise (EPR) that can occur in power systems, and they are also vulnerable to the transfer of EPR outside the zone of influence (ZOI), which should also be considered. A quick estimate of the earth potential rise is obtained from the product ($I_e \times R_e$) of the current I_e flowing through an earth electrode and the resistance R_e to earth of that earth electrode.

Recommendation ITU-T K.107 provides methods of varying complexity for measuring the resistance to earth of earth electrodes or even complex earthing systems. The methods provide describe both simple and more sophisticated measurements through the use of computer-based earthing multimeters. Guidance is given on the relevance of each of the different methods for various purposes.

Techniques are also given for the elimination of interference and disturbance voltages for earthing measurements.

In practice it may be necessary to determine or at least estimate the impedance to earth of a power system installation already in the design phase. For these purposes, techniques of calculating the resistance/impedance to earth of isolated, as well as interconnected earthing systems are also included.

History

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Method for determining the impedance to earth of earthing systems

1 Scope

The earth potential rise (EPR) that can occur in power systems and that can be transferred to telecommunication systems is potentially dangerous to the people working in the telecommunication plant; damage to the plant itself can also occur. The impedance to earth of earthing systems of a power installation is one of the key parameters affecting the magnitude of the EPR. This Recommendation aims to provide methods of different complexities for measuring the resistance to earth of earth electrodes or complex earthing systems. Techniques for calculating the resistance/impedance to earth of isolated, as well as interconnected earthing systems are also included.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

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|---------------|---|
| [ITU-T K.26] | Recommendation ITU-T K.26 (2008), <i>Protection of telecommunication lines against harmful effects from electric power and electrified railway lines.</i> |
| [ITU-T K.104] | Recommendation ITU-T K.104 (2015), <i>Method for identifying the transfer potential of the earth potential rise from high or medium voltage networks to the earthing system or neutral of low voltage networks.</i> |
| [IEEE Std 81] | IEEE Std 81 (2012), <i>IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System.</i> |
| [EN 50522] | Cenelec EN 50522 (2010), <i>Earthing of power installations exceeding 1 kV a.c.</i> |

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 cable with earth electrode effect [EN 50522]: (definition 3.4.33) Cable whose sheaths, screens or armourings have the same effect as a strip earth electrode.

3.1.2 circulating transformer neutral current [EN 50522]: (definition 3.4.31) Portion of fault current which flows back to the transformer neutral point via the metallic parts and/or the earthing system without ever discharging into soil.

3.1.3 (local) earth [b-IEC IEV]: (definition 195-01-03, modified) Part of the Earth which is in electric contact with an earth electrode and the electric potential of which is not necessarily equal to zero.

NOTE – The conductive mass of the earth, whose electric potential at any point is conventionally taken as equal to zero.

3.1.4 earth electrode [EN 50522]: (definition 3.4.3) Earth electrode conductive part, which may be embedded in a specific conductive medium, e.g., in concrete or coke, in electric contact with the earth.

3.1.5 earth fault [b-IEC IEV]: (definition 151-03-40) Fault caused by a conductor being connected to earth or by the insulation resistance to earth becoming less than a specified value.

3.1.6 earth fault current, I_F [EN 50522]: (definition 3.4.28) Current which flows from the main circuit to earth or earthed parts at the fault location.

NOTE 1 – For single earth faults, this is:

- in systems with isolated neutral, the capacitive earth fault current,
- in systems with high resistive earthing, the RC composed earth fault current,
- in systems with resonant earthing, the earth fault residual current,
- in systems with solid or low impedance neutral earthing, the line-to-earth short-circuit current.

NOTE 2 – Further earth fault current may result from double earth fault and line to line to earth.

3.1.7 earth potential rise, EPR U_E [EN 50522]: (definition 3.4.12) Voltage between an earthing system and reference earth.

3.1.8 earthing conductor [b-IEC IEV]: (definition 195-02-03) Conductor which provides a conductive path, or part of the conductive path, between a given point in a system or in an installation or in equipment and an earth electrode.

NOTE – Where the connection between part of the installation and the earth electrode is made via a disconnecting link, disconnecting switch, surge arrester counter, surge arrester control gap etc., then only that part of the connection permanently attached to the earth electrode is an earthing conductor.

3.1.9 earthing system [b-IEC IEV]: (definition 604-04-02) Arrangement of connections and devices necessary to earth equipment or a system separately or jointly.

3.1.10 electric resistivity of soil, ρ_E [EN 50522]: (definition 3.4.9) Resistivity of a typical sample of soil.

3.1.11 foundation earth electrode [b-IEC IEV]: (definition 826-13-08, modified) Conductive structural embedded in concrete which is in conductive contact with the earth via a large surface.

3.1.12 high voltage (HV) [IEC 60050-151:2001, 151-15-05]: Voltage having a value above a conventionally adopted limit.

NOTE 1 – An example is the set of upper voltage values used in bulk power systems.

NOTE 2 – In the case of three phase system the voltage refers to the line-to-line voltage.

3.1.13 impedance to earth, Z_e [EN 50522]: (definition 3.4.11) Impedance at a given frequency between a specified point in a system or in an installation or in equipment and reference earth.

NOTE – The impedance to earth is determined by the directly connected earth electrodes and also by connected overhead earth wires and wires buried in earth of overhead lines, by connected cables with earth electrode effect and by other earthing systems which are conductively connected to the relevant earthing system by conductive cable sheaths, shields, PEN conductors or in another way.

3.1.14 low voltage (LV) [b-IEC IEV]: (definition 151-15-03) Voltage having a value below a conventionally adopted limit.

NOTE 1 – For the distribution of AC electric power, the upper limit is generally accepted to be 1000 V.

NOTE 2 – In the case of three phase system the voltage refers to the line-to-line voltage.

3.1.15 medium voltage (MV) [b-IEC IEV]: (definition 601-01-28) (not used in the UK in this sense, nor in Australia). Any set of voltage levels lying between low and high voltage.

NOTE 1 – The boundaries between medium and high voltage levels overlap and depend on local circumstances and history or common usage. Nevertheless, the band 30 kV to 100 kV frequently contains the accepted boundary.

NOTE 2 – The medium voltage is not a standardized term. It is specified as a system voltage class by IEEE [b-Terms].

NOTE 3 – The preferred medium nominal (line-to-line) voltages in North America: 4.16 kV, 12.46 kV, 13.8 kV, 34.5 kV and 69 kV [b-Terms]. Typical MV system voltages for public distribution: in Europe 10 kV (mainly underground) 20 kV and 35 kV (mainly overhead) [b-Lacroix], in Japan 6.6 kV.

3.1.16 multi-earthed HV neutral conductor [EN 50522]: (definition 3.4.20) Neutral conductor of a distribution line connected to the earthing system of the source transformer and regularly earthed.

3.1.17 PEN conductor [b-IEC IEV]: (definition 826-13-25) Conductor combining the functions of both protective earthing conductor and neutral conductor.

3.1.18 potential [EN 50522]: (definition 3.4.13) Voltage between an observation point and reference earth.

3.1.19 protective bonding conductor [EN 50522]: (definition 3.4.5) Protective conductor for ensuring equipotential bonding.

3.1.20 reduction factor, r or screening factor k_s [EN 50522]: (definition 3.4.30) Factor r of a three phase line is the ratio of the current to earth I_E over the sum of the zero sequence currents $3I_0$ in the phase conductors of the main circuit ($r = I_E / 3 I_0$) at a point remote from the short-circuit location and the earthing system of an installation, (also referred to as screening factor, k_s).

3.1.21 reference earth [b-IEC IEV]: (definition 195-01-01, modified) (remote earth) Part of the earth considered as conductive, the electric potential of which is conventionally taken as zero, being outside the zone of influence of the relevant earthing arrangement.

NOTE – The concept "earth" means the planet and all its physical matter.

3.1.22 resistance to earth, R_e [EN 50522]: (definition 3.4.10) Real part of the impedance to earth.

3.1.23 solidly earthed neutral system [IEC 601-02-25:1985]: System whose neutral point(s) is(are) earthed directly.

3.1.24 structural earth electrode [EN 50522]: (definition 3.4.8) Metal part, which is in conductive contact with the earth or with water directly or via concrete, whose original purpose is not earthing, but which fulfils all requirements of an earth electrode without impairment of the original purpose.

NOTE – Examples of structural earth electrodes are pipelines, sheet piling, concrete reinforcement bars in foundations and the steel structure of buildings, etc.

3.1.25 substation [b-IEC IEV]: (definition 605-01-01) Part of a power system, concentrated in a given place, including mainly the terminations of transmission or distribution lines, switchgear and housing and which may also include transformers. It generally includes facilities necessary for system security and control (e.g., the protective devices).

NOTE – According to the nature of the system within which the substation is included, a prefix may qualify it.

EXAMPLE Transmission substation (of a transmission system), distribution substation, 400 kV substation, 20 kV substation.

3.1.26 system with isolated neutral [b-IEC IEV]: (definition 601-02-24, modified) System in which the neutrals of transformers and generators are not intentionally connected to earth, except for high impedance connections for signalling, measuring or protection purposes.

3.1.27 system with resonant earthing [EN 50522]: (definition 3.4.26) System in which at least one neutral of a transformer or earthing transformer is earthed via an arc suppression coil and the combined inductance of all arc suppression coils is essentially tuned to the earth capacitance of the system for the operating frequency.

NOTE 1 – In case of no self-extinguishing arc fault there are two different operation methods used:

- automatic disconnection;
- continuous operation during fault localisation process.

In order to facilitate the fault localisation and operation there are different supporting procedures:

- short-term earthing for detection;
- short-term earthing for tripping;
- operation measures, such as disconnection of coupled bus bars;
- phase earthing.

NOTE 2 – Arc suppression coil may have high ohmic resistor in parallel to facilitate fault detection.

3.1.28 transferred potential [EN 50522]: (definition 3.4.17) Potential rise of an earthing system caused by a current to earth transferred by means of a connected conductor (for example a metallic cable sheath, PEN conductor, pipeline, rail) into areas with low or no potential rise relative to reference earth, resulting in a potential difference occurring between the conductor and its surroundings.

NOTE – The definition also applies where a conductor, which is connected to reference earth, leads into the area of the potential rise.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 effective earth current: The total zero sequence component of the fault current ($3I_{0sc}$) diminished by the circulating transformer neutral current, if present.

3.2.2 effective impedance to earth: This is composed of the resistance to earth, R_e of the earthing system (grid) and the parallel equivalent of the impedance to earth of the connected passive lines with earth electrode effect.

3.2.3 equivalent current to earth: The sum of the earth current ($I_{EM}=3I_{0EM}$) induced by the zero sequence component ($I_M=3I_{0M}$) of fault current of the in-feeding power lines. It can be expressed as a sum of the products of the screening factor k_i and the zero sequence current $3I_{0,i}$ relevant to the i -th line (see Figure 5).

3.2.4 length constant, $\tau = 1/\alpha$: The length τ measured along a line with an earth electrode effect, where at a distance of $x = \tau$, the voltage is reduced to 37% of the value at $x = 0$.

NOTE – This corresponds to the time constant associated with a time dependent phenomenon.

3.2.5 overall/equivalent impedance to earth: The parallel equivalent of the resistance to earth of the mesh earth electrode and input (earth wire/tower footing chain) impedance of the passive conductors of all (in-feeding and passive) lines which have an earth electrode effect.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

a.c.	Alternating current
CT	Current Transformer
EPD	Earth Potential Difference
EPR	Earth Potential Rise
FOP	Fall-Of-Potential
HV	High Voltage
LV	Low Voltage
MV	Medium Voltage
OHL	Overhead (power) Line
ZOI	Zone Of Influence