REFLECTIONS ON GLOBAL EARTHING SYSTEMS

Thomas MALLITS, Ernst SCHMAUTZER, Lothar FICKERT

ABSTRACT

On the basis of measurements it can be shown that only a portion of the phase to ground fault current enters the physical soil. Therefore the earth potential rise (EPR) is considerably decreased and the contact voltages become much lower than those determined by the usual approaches. A risk assessment method used in the UK and Australia is presented by which the corrective actions in the case of dangerous contact voltage can be determined.

1. GLOBAL EARTHING SYSTEMS

1.1 Fundamentals

Regarding to the safety of human life in connection with an earth fault, in Austria the standard OVE / ÖNORM E 8383: 2000-03-01 ("Power Installations with Nominal Voltages above 1 kV a.c.") have to be considered. In the future the Austrian standard OVE / ÖNORM E 8383: 2000-03-01 will be replaced by the European standard OVE / Austrian Standard EN 50522 2011-12-01, ("Earthing of power installations exceeding 1 kV a.c."). This standard contains the determination of requirements for the design and construction of grounding systems for power installations, in systems with nominal voltages above 1 kV and a nominal frequency up to and including 60 Hz, to ensure a safe and trouble-free operation during normal operation of high voltage equipment. The protection objective is described in accordance to the state of the art and science by the permissible touch voltage $U_{Tp}(t)$ [2][7].

So in the above referenced standards, the design of grounding systems that are not part of a global earthing system, is described in terms of the permissible touch voltage U_{Tp}. This value has to be verified by checking the earth potential rise U_E or the touch voltage U_T (figure 1).

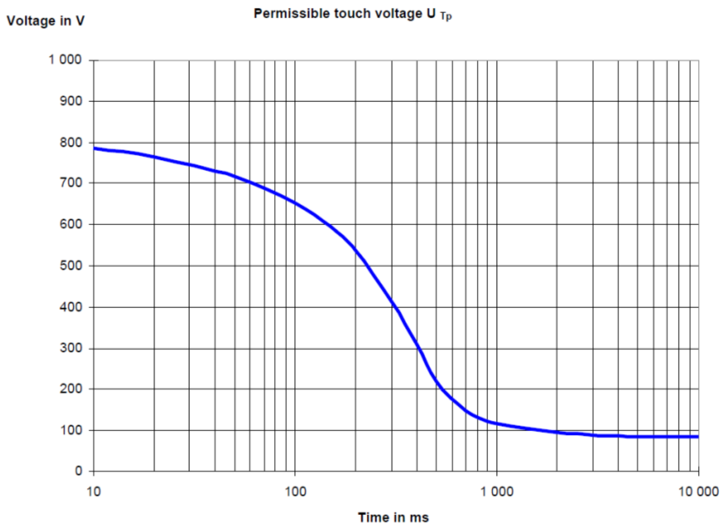

Figure 1: Permissible touch voltage (OVE / ÖNORM EN 50522, Figure 5, [3])

A critical analysis of the standard text shows that if a global earthing system exists, any further proof of the safety of human life are not necessary. This possibility is only mentioned in the text, but not explicitly shown in the flow chart. If one inserts this fact into the flow chart, one gets figure 2.

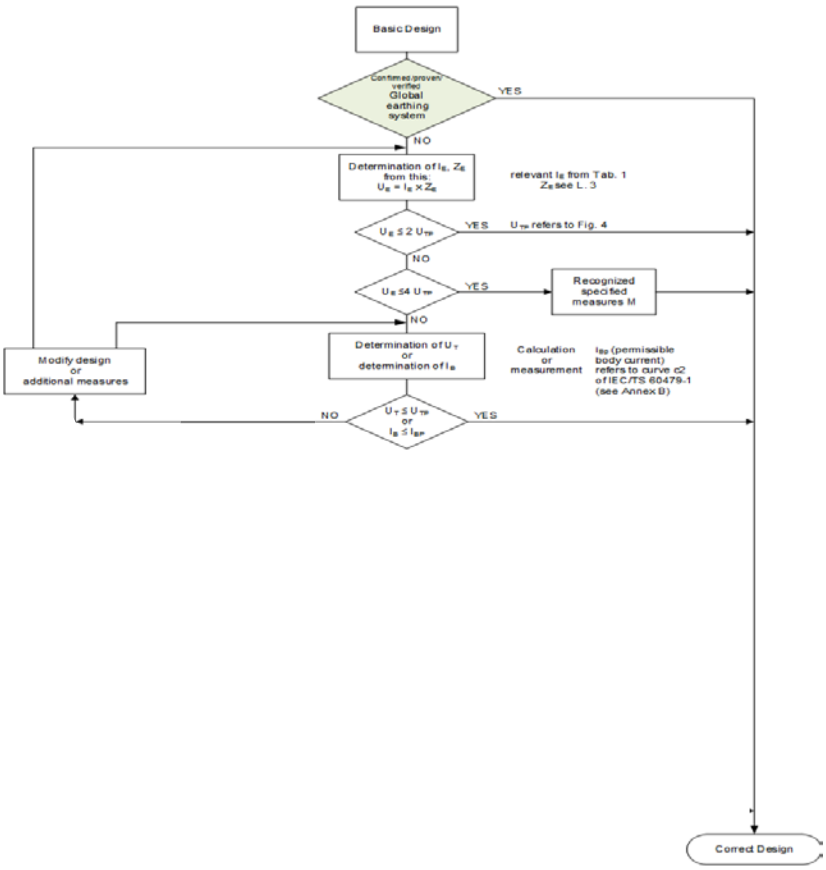

Figure 2: Extended flowchart for the determining of the human safety

1.2 Definition of a global earthing system

The difficulty of proving the existence of a global earthing system lies in the lack of operationability of the term. Here is the essential message that the prevention of dangerous touch voltages in case of an earth fault can be improved by connecting the local grounding systems to one or more other grounding systems.

According to DIN EN 61936-1 (VDE 0101-1): 2011-11 / EN 61936-1: 2010, the existence of a global earth system can be proven by measurements or calculations for typical configurations.

Remark: Due to time dependence of the permissible touch voltage, the function of any security-related earth fault protection device has a significant influence on the evaluation of the safety situation. That in turn is determined solely by the system design, including the grounding system.

The main idea of a global earthing system is to distribute the fault current in as many paths as possible and the creation of an equipotential surface. Therefore the existence of a global earthing system has the following indicators:

- A low total grounding resistance is useful, but does not provide safety under all circumstances.
- In systems with high soil resistivity and total grounding resistance the safety requirements can be met by adding potential control measures.
- Cable shields which are grounded on both sides are useful for enhancing the current distribution and for reducing of the local earth potential rise.
- A short error duration (≤ 1 s) is also useful in global earthing systems.

Typical cases when an electrical installation is considered to be part of a global earthing system are described as follows:

- the electrical installation is surrounded by buildings with foundation earthing and interconnected ground systems, e.g. through cable shields of MV cables and / or PEN conductors and / or gradient control conductors / earth electrodes
- the electrical installation supplies city centers or densely built up areas with a high concentration of metallic fittings in the ground
- the electrical installation has a particular number and length of outgoing earth electrodes
- the electrical installation is supplying extensive industrial areas

As typical possible cases that a plant is not part of a Global Earth system, the following situations have to be considered:

- cable riser poles in network spurs
- sparsely populated areas
- free-standing installations (e.g. pumping stations)
- transformer stations with only overhead line connections

1.3 Measurements of the distribution of ground fault currents

As many measurements of the Institute of Electrical Power Systems of Graz University of Technology in different network areas and at various error conditions have shown, the fault current due to inductive couplings between the active conductor and the return conductor, tends to flow back in the immediate vicinity of the active conductor. The current distribution through cable shields and earth-trace electrodes are shown in figure 3. It is typical for global earthing systems that only a small fraction (3%) of the earth fault current passes the local grounding system, while the essential part of the fault current stays in the cable shields and the earth-trace electrodes. So only a small part of the earth fault current generates the local surface potential. As a result, the touch voltages are significantly lower than is generally believed [5][6].

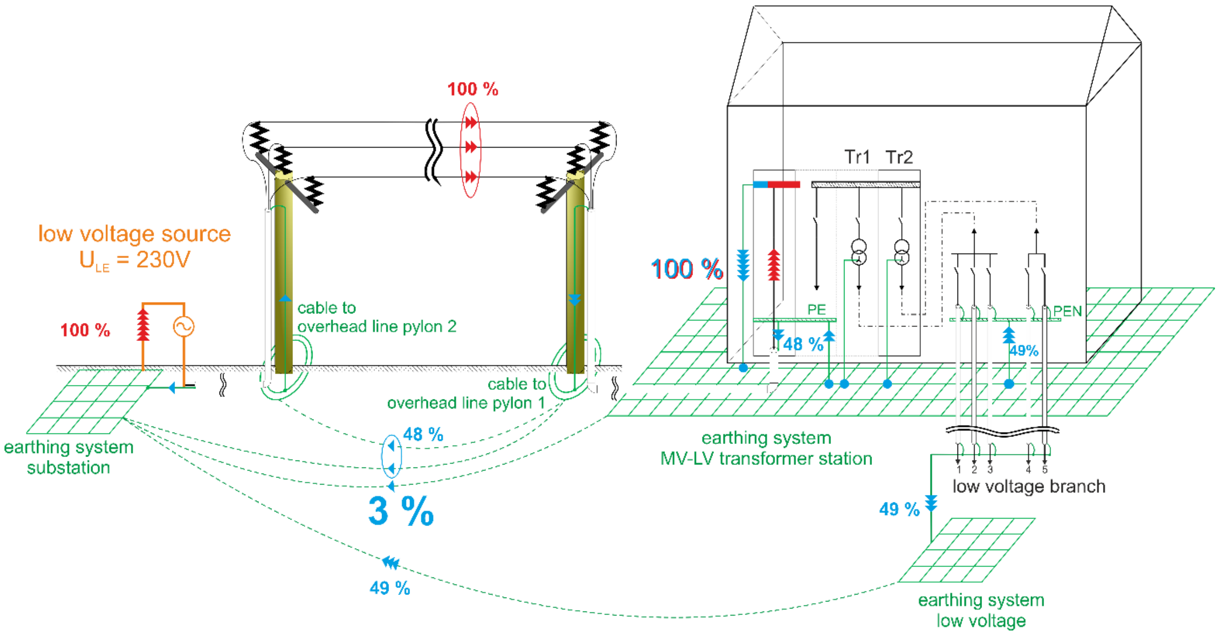

Figure 3: Real current distribution example in a resonant grounded network

1.4 Risk considerations

Another novel approach for consideration of risks arising from ground faults is brought in by the international debate concerning an Australian standard [1] and the UK National Annex to BS EN Europe 50522:2010 [2]: In this case, the risk is calculated per single individual and year for a potentially dangerous structure. The worst-case assumptions shall be taken for all concrete parameters.

$$p_{indiv} = \frac{n_{earthfault} * n_{expo} * (t_{earthfault} + t_{expo}) * p_{Fib} * CRF}{365 * 24 * 60 * 60} \quad (1)$$

p_{indiv} … risk of an individual to get in contact with a potentially hazardous structure (Earth Potential Rise, EPR) [1 / a]

$n_{earth\ fault}$ … frequency for a single-pole error affecting this structure [1 / a]

$t_{earthfault}$ … average duration of such a single pole error [s]

n_{expo} … contact frequency of the individual with the potentially hazardous structure mentioned above [1 / a]

t_{expo} … average contact duration of the individual with this structure [s]

p_{fib} … voltage and time dependent risk for ventricular fibrillation [p.u.]

CRF … reduction factor by any warning signs or barriers [p.u.]

In the event such a worst-case analysis gives a probability of less than $p_{indiv} < 10^{-6}$ any further measures may be waived away according to [1].

If the probability is higher and takes values up to $p_{indiv} < 10^{-4}$, an economic assessment (Cost Benefit Analysis, CBA) according to is permissible. Possible remedial measures will be assessed on this basis.

Inserting these considerations in the previous chart (figure 2) leads to the following flow chart (figure 4) and determines the admissibility of an earthing system.

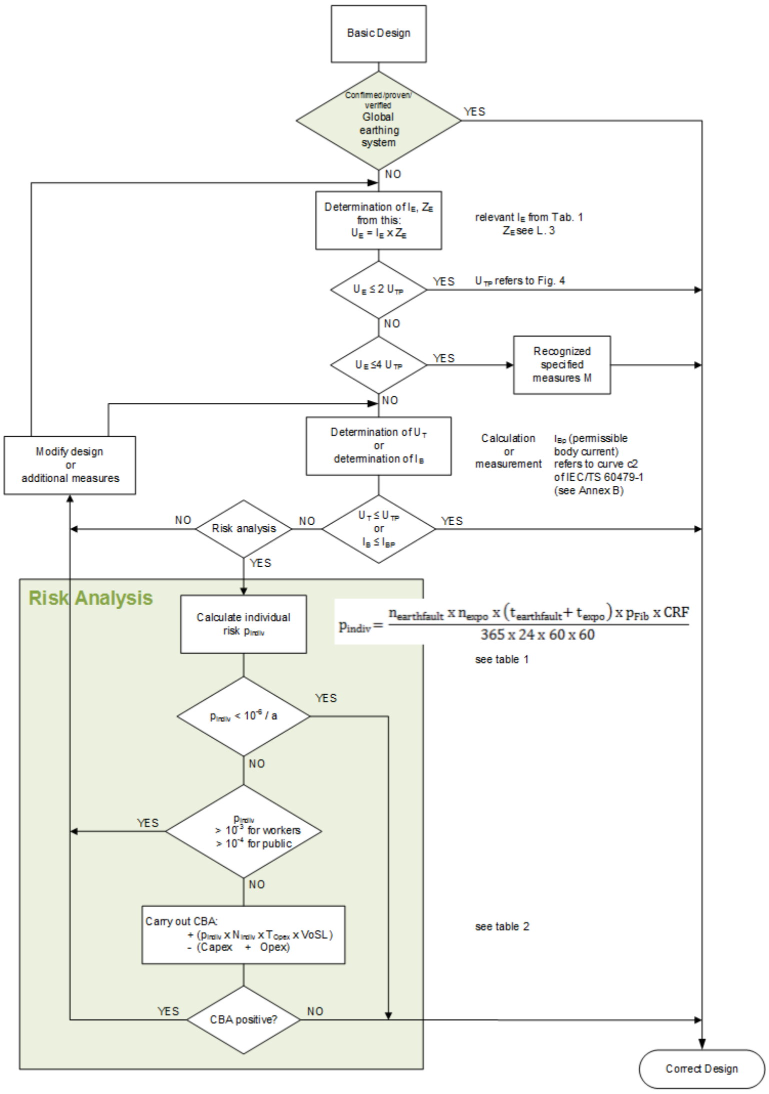

Figure 4: *Extended flow chart according to the UK National Annex to BS EN 50522: 2010 [7]*

2. OUTLOOK AND CONCLUSION

Experience with global earthing systems show that in any case it is necessary to investigate in case of a ground fault the occurring touch voltages in the surroundings of earthing systems and in particular, the fault current distribution in global earthing systems. To answer the question of how far risk considerations can be included in the assessment of earthing systems, discussions on a wide scale are still needed.

3. LITERATURE

[1] EG-0, Power System Earthing Guide, 2010, Energy Networks Association Limited

[2] BS EN 50522:2010, National Annex NA

[3] ÖVE/ÖNORM EN 50522:2011, Erdung von Starkstromanlagen mit Nennwechsel-spannungen über 1 kV

[4] ÖVE/ÖNORM E 8383: 2000-03-01, Starkstromanlagen mit Nennwechselspannung über 1 kV

[5] Bräunlich, R., „Die messtechnische Überprüfung von großen Erdungsanlagen“, Fachkommission für Hochspannungsfragen, FKH, Zürich, 1995

[6] M. Lindinger, „Nachweis Globaler Erdungssysteme durch Messung und Berechnung von verteilten Erdungsanlagen “, Dissertation TU Graz 2012

AUTHORS ADDRESS

Thomas MALLITS

Ernst SCHMAUTZER

Lothar FICKERT

Institute of Electrical Power Systems, TU Graz

Inffeldgasse 18, 8010 Graz

Phone +43(0)316/873-7064,

Email: lothar.fickert@tugraz.at , http://www.ifea.tugraz.at