NEW WAYS TO INTEGRATE GROUNDING, EQUIPOTENTIAL BONDING, SHIELDING AND LIGHTNING PROTECTION

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ABSTRACT

The safe and reliable operation of electronic equipment in modern low-voltage electrical, suitable for bidirectional energy and information flows, requires - starting from the transformer stations via the mains connection to the location of the equipment in the buildings - special attention with regard to the integration of grounding, equipotential bonding, shielding and lightning protection. As these themes so far in the planning, implementation and verification are considered mostly separately, in practice a variety of electro technical problems such as with stray currents, unwanted interference fields and inductive interference caused by low-frequency and transient currents result. In the following article new and old methods for a functional, comprehensive approach to planning and construction of electrical installations are combined, which takes into account the needs of various grid-bound supply systems such as electricity, gas, water and telecommunications.

1. INTRODUCTION

To meet the requirements of ensuring protection measures against electric shock and the safe and reliable operation of electronic equipment in modern low-voltage grids intended to be suitable for bidirectional energy and information flows, special attention has to be focused on the integration of earthing, equipotential bonding, shielding and lightning protection - starting from the transformer stations via the interconnection point to the location where the equipment used for the electrical and information technology is located.

As these themes so far in the planning, implementation and examination are considered mostly separately, in practice there are a multitude of problems caused on the one hand by stray-currents, unwanted interfering electromagnetic fields and inductive influences by low-frequency and transient currents and on the other hand by effects due to switching operations in the network or as a result of atmospheric discharges.

In the following new ways for a functional, comprehensive approach to planning, installation and refurbishment of grounding, equipotential bonding, shielding and lightning protection systems are presented, taking into account, both the operational frequency as well as transient frequency processes to assure the basic requirements of different electrical grid-bound supply systems such as electricity, gas, water and telecommunications and the shielding of energy- and information-and-communication-technology (ICT)-cables.

2. SITUATION

In order to ensure safe function of both, the protection against electric shock as well as protection measures against resistive, inductive and capacitive influences of electrical equipment in electrical installations grounding, equipotential bonding and shielding measures and lightning protection systems have to be suitable coordinated already at the planning stage. As in single buildings, building complexes (Smart Buildings) and spacious electrical systems (Smart Grids), the function of the infrastructure for information technology management systems is of great importance and a functional disruption can cause serious consequences, disturbances have to be avoided as good as possible.

Other than in the most European countries, where the observation of standards is voluntary, in Austria, based on the Electro technical Law 1992 ETG and in the Electrical Engineering Regulation ETV 2002 (2006) certain safety standards have to be obeyed mandatorily by the planners, builders and operators of electrical installations by law. One problem of this regulated approach is, that most of the planners, builders and operators consider only the legally obligatory safety standards (representing only the minimal safety requirements) and the state of art (technology), the state of science and other relevant standards, rules and knowledge originated from the practice, going beyond the requirements of obligatory standards, are not sufficiently taken into account and applied. In the other European countries the situation is not much better. Everywhere planners and owners submit to the cost pressure and attempt to follow a minimalist approach where a minimum of technological standard is pursued.

3. METHODOLOGY

Already in the planning stage and depending on the risk of damage, the type and the arrangement as well as the integration of the earthing system, the equipotential bonding system, the shielding method and the lightning system has to by obeyed, because the necessary requirements (safety of people and property, protection measures for objects, areas, space, electronic equipment, external and internal lightning protection, EMC) as well as physical safety measures (grounding, equipotential bonding system, utilization of existing or planned on-site metallic components and structures such as metal façades, concrete reinforcing steel, metal cases, …) overlap.

From the well-timed cooperation of all involved professionals significant benefits for the entire structural system can be realized as the design, the construction and refurbishment of an integrated installation, technical and functional issues can be considered easier and better, and the effectiveness of the earthing, equipotential bonding and lightning protection system can be improved significantly optimizing economic burdens. In Figure 1, the integrated process of holistic planning, state of the art construction and operation phases of single buildings and building complexes is presented and expanded to current scientific knowledge.

The (mandatory) minimum level in most European countries as well as in Austria is preferably the establishment of a concrete footing-type grounding electrode system in the foundation area (eg. base plate, granular sub-grade course, blinding concrete) wherein in buildings with specific EMC requirements of information technology equipment for EMC reasons (especially for the reduction of magnetic interference fields, inductive and resistive influences by transient currents) the construction of an additional equipotential bonding system for each floor is essential (see Figure 2).

Many synergies can be utilized if the earthing, equipotential bonding, shielding and lightning protection system is planned and implemented in compliance with the requirements of the generic ICT cabling system and the definition of the EMC and lightning protection zones and in compliance with the dimensioning of the cross-sectional area of the cables, lengths, location, distances. If the worst-case scenario is the basis of dimensioning (dimensions based on operation, short circuit, equipotential bonding, PEN and lightning protection conductor currents) the coordinated entire system can fulfil several functions and multiple implementations of components for reasons of grounding, of equipotential bonding and of lightning protection and shielding can be avoided. The result is an efficient overall system, that - and only that - can meet the modern requirements of a single building or a building complex.

As can be shown easily, considering only low-frequency effects, a close-meshed structure of the concrete footing-type grounding electrode system or earthing system is not necessary to achieve a low resistance of the ground grid (a mesh distance of 10 m or less affects the reduction of the resistance of the grounding grid only very little).

<table>
<tr><th rowspan="6">
• Planning
• Implementation
• Operating
and
• Coordination
of
grounding, equipotential bonding, shielding and lightning protection systems in single buildings, building complexes and electrical distribution</th><th>State of the Art</th><th>State of Science</th></tr>
<tr><td>Planning phase</td><td></td></tr>
<tr><td>• Concept, planning and requirements for concrete-footing grounding systems, protection against electric shock, TT-, TNS-, IT-system, equipotential bonding, lightning protection, EMF, EMC, IEC 60364, ÖVE E8001-1, ÖVE E8383, ÖVE E8014, ÖVE E8049, EN 62305, EN 50310, EN 50341, EN 61347-1, EN 50164, EN 50172, EN 50173, EN 50174,...</td><td>• Coordination with the protection system against electric shock
• Coordination of grounding systems, concrete-footing grounding system, vertical and horizontal grounding systems, isolated base plates, equipotential bonding systems and measures
• Combined use of grounding, equipotential bonding, shielding and lightning protection equipment under consideration of operational and transient frequencies (grounding resistance / impedance), narrow meshed-grid grounding systems to distribute the currents and to realise a low impedant grounding impedance
• Consideration of resistive and inductive interference
• Inclusion of concrete (building) armouring
• Utilization of synergy effects, avoidance of redundancy
• Planning of verifiability and check-intervals</td></tr>
<tr><td>• Guidelines for grounding, equipotential bonding and ICT, EN 50174</td><td></td></tr>
<tr><td>• Multiple connections, meshed (or radiating) grounding and bonding system, HD 60364-4-444, ÖVE E8001-1/A4, star-point-connection SVL</td><td>• Star-point-connection scheme or
• narrow meshed grounding and equipotential system</td></tr>
</table>

systems such as Smart Buildings and Smart Grids under consideration of operating and transient frequencies	• Planning of a combined and coordinated meshed equipotential system (CBN) in single or complex buildings, EN 50310, ÖVE E8001-1/A4, ÖVE E8001-1/A5, EN 50174-2, EN 62305, ...	• *Combination grounding and equipotential bonding system in all levels, combination with the lightning protection system, observation of the separation distance* • *Efficient (narrow) intermeshing of grounding, bonding and lightning protection system* • *Utilization of natural parts of the building (armouring and other conductive parts)* • *Equipotential bonding and PE with sufficient profile* • *Grounding points in suitable distances*
	• Generic ICT-cabling, EN 50173, EN 50174, EN 50098-1, ...	
	• Consideration of nonlinear load-flow, ÖVE E8001-1, EN 50174, EN 61800-5...	
	• TNS- or IT-system in buildings or building complexes, EN 50310, ÖVE E 8001-1, (pr)HD 60364-4-444	• *Location of equipotential bonding and PE-conductors*
	• Concept for shielding and equipotential bonding, treatment of shielding systems, by-pass conductor for screen reinforcement, EN 50173, EN 50174	• *Compensation conductors* • *Cables and metallic pipes shall enter the system at the same place (single point entry)* • *Fish-trap like equipotential bonding and armouring*
	• Protection against direct and indirect lightning effects, ÖVE E8001-1, ÖVE E8383, ÖVE E8049, EN 62305	• *Lightning protection zones* • *EMC protection zones* • *2- and 3-dimensional meshing of systems* • *Single-point-entry principle*
	• Measures against operating and transient overvoltages, protection of buildings, facilities and appliances, protection zones, ÖVE E8001-1/A3, EN 50310, EN62305, EN 61000 Series	• *Distributed complex buildings* • *Coordinated surge protection systems*
	• Dimensioning of equipotential bonding, PE- and grounding conductors, ÖVE E 8001-1/A5	• *Sufficient dimensioning of conductors based on operating and fault conditions considering lightning and transient effects*
	Implementation phase	
	• General safety requirements, use of metallic conductors or fibre optics, screen treatment, symmetrical or asymmetrical operation of ICT-systems, *EN 50173, EN 50174, EN 50098-1, -2, ...*	• *Implementation of reliable connections taking into account the expected operating and transient frequencies*
	• Compliance with the general installation guidelines, E8001-1, EN 50310, EN 50174	• *Installation guidelines for low-impedant connections for low-and high-frequency*
	• Initial verification, documentation IEC 60364-6	
	• Verification of ICT-cabling EN 50364	
	• Verification of the lightning system ÖVE regulations, EN 62305	

	Operating phase	
	• Operation of electric installations EN 50110	
	• Operation of electric, electronic and ICT-systems, • quality management, administration, repair and maintenance, EN 50173, EN 50174	
	• Periodic verification, documentation, IEC 60364-6	
	• Periodic verification of the lightning protection system, EN 62305, ÖVE directives	

Figure 1: Integrated planning and building process and the operation phases of a coordinated grounding system for equipotential bonding and lightning protection

To reduce step and touch voltages and to achieve an appropriate shielding effect (about 20 dB in the lightning-relevant frequency range) however, a further reduction of the grid dimensions to a minimum distance about 5 m grid or less, and the bonding of concrete reinforcement in the floor (distance of the connection approximately ≤ 2 m) and the concrete reinforcement in the walls in the combined earthing, equipotential bonding, shielding and lightning protection system may be necessary additionally.

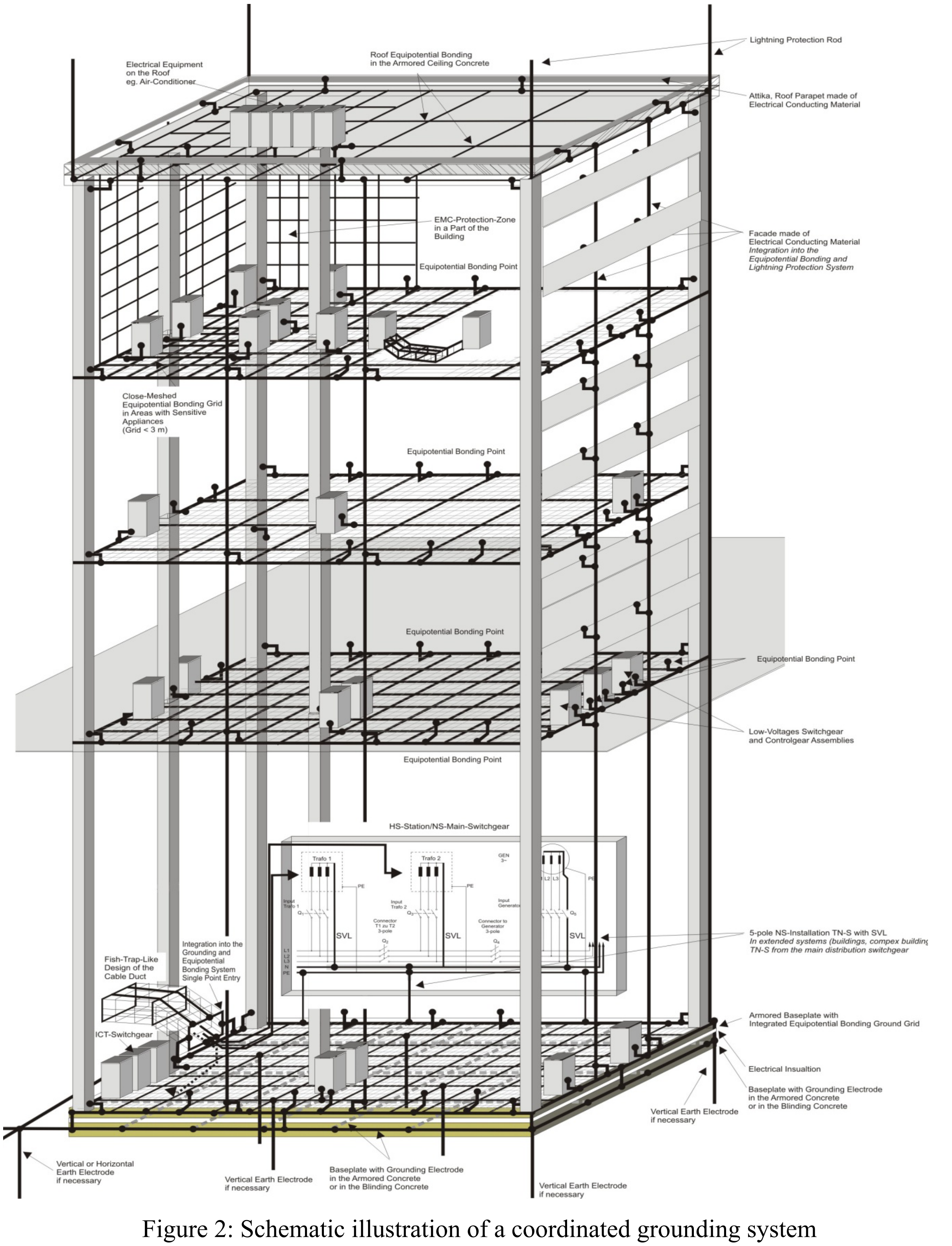

Figure 2: Schematic illustration of a coordinated grounding system
for equipotential bonding and lightning protection

Based on the requirements of electronic equipment with regard to provide possible low impedance connections for reasons of surge and lightning protection, a particularly dense grounding and equipotential bonding system with a mesh size of about 3 m … 1 m is required. If no suitable close-meshed grounding, equipotential bonding and lightning protection system in the single building or building complex can be established or it is not feasible in the case of renovation or retrofit, an equivalent internal zone concept is required consisting of interconnected fish-trap-like formed zones and connection channels.

The integration and the direct use of constructive metallic conductive parts of the building (eg. façades designs) is based on equipotential bonding and lightning protection reasons and because of the necessary close-meshed grid indispensable (see Figure 2). The effect of the close meshing is, that because of the good distribution of fault and lightning currents, the electromagnetic interference is minimised and therefore the treatment of the ends of energy and ICT cable-shields is widely free (see generic cabling standards).

4. RESULTS

Only a holistic approach and implementation of the earthing system, the equipotential bonding system and the lightning protection system as well as the implementation of EMC- and lightning protection-zones as a jointly co-ordinated system, taking into account operational frequency and transient frequency processes in modern and future-proof electrical equipment provide a flexible operation and meets the requirements for protection against electric shock, minimizes resistive, inductive and capacitive interference, reduces the occurrence of electromagnetic fields and enables the implementation of high-quality measures for the electric/electronic equipment safety, as well as a efficient lightning and surge protection.

The desired function of a grounding and equipotential bonding system with the inclusion of lightning protection and other protection concepts (eg. internal lightning protection, EMC, shielding concepts, ICT-concepts) can be integrated easily in the design concepts of an architectural structure, if early enough considered. Not only in designs with reinforced concrete or steel structures, metal roofs and metal cladding a modern grounding, equipotential bonding and lightning protection system can be integrated unobtrusively to achieve a reasonable protection goal but also in classical building concepts. Similarly, innovative details of modern architecture can be integrated into the protection system, with neither the prejudice to the architectural design and technical function nor the need to modify the architectural concept.

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