Safety and Interoperability of DC Power Grid Systems

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1 Introduction

Low voltage DC supply voltages of 100 V - 1500 V within the definition of the European Directive 2006/95/EC offer benefits compared with AC supply voltages and thus are used internally in many modern electrical appliances [1]. Electricity from a direct current (DC) supply can be controlled more flexible, with higher performance and efficiency, at lower cost than from AC electricity sources.

The safe and reliable operation of DC or combined AC & DC power systems is supported by specifications and performance parameters in technical standards. The knowledge on technical standards is important to realize safe and reliable technical systems with components, modules and sub-systems from different manufacturers. National, regional and global standards are offering these specifications. Many technical specifications in standards are applicable for both AC and DC low voltage power systems. These general specifications are not covered in this document in detail in this document.

This document focuses on technical specifications
that are of special importance for low voltage DC power grids
or
that are different for low voltage DC power grids
in comparison with low voltage AC power grids.

The document focuses in its current version on 380 V DC single-phase and ±380 V DC two-phase DC power grids.

Lower DC voltages of up to 60 V are addressed in the literature as save extra low voltages (SELV) are not addressed by this document.

2 Low Voltage DC Power Grid System Design

2.1 Low Voltage Electrical Installations

The design and installations of low voltage DC power grid systems shall consider specifications of the

- IEC 60364 series [2-28],
- IEC 61577 series [29-40].

Most technical specifications in these standards are applicable for both AC and DC power systems. These general specifications are not covered in this document in detail. This document focuses on technical specifications that are of special importance or that are different for low voltage DC power grids in comparison with low voltage AC power grids.

General requirements of power systems with dedicated supplies are addressed in IEC 60364-1, chapter 313 such as AC/DC power converters that supply and control the operation of DC power grids with electric energy from the AC utility grid. One important general requirement is the availability of a DC power grid to generate short-circuit currents of dedicated amplitude that trip automatic circuit breakers or fuses within specified time intervals but also without damaging the installation. Larger installations shall be divided into sub-circuits, to avoid danger and minimize inconvenience in the event of a fault according to IEC 60364-1, chapter 314.

More highlights of this series of standards are addressing details of the following subchapters.

2.1.1 Conductor arrangement and system earthing

IEC 60364-1 defines in chapter 312 conductor arrangements and system earthing for both AC and DC grids. The following DC system earthing are known.

- TN-S-system type “a” without mid-point
- TN-S-system type “b” with mid-point
- TN-C-system type “a” without mid-point
- TN-C-system type “b” with mid-point
- TN-C-S-system type “a” without mid-point
- TN-C-S-system type “b” with mid-point
- TT-system type “a” without mid-point
- TT-system type “b” with mid-point
- IT-system type “a” without mid-point
- IT-system type “b” with mid-point

It is proposed to use

1. The same system earthing principle for a DC system that is also used for an AC system if both systems are present at one location to avoid mix-up.
2. If no AC earthing reference system is available, the TN-S-system type “b” with mid-point in Figure 1 is the preferred DC earthing system because of maximum safety.

Future work on DC grid standardisation shall specify how to connect 1-phase DC loads to 2-phase DC grids.

- 1-phase DC loads shall be connected only to L+ and M,
- 1-phase DC loads shall be connected only to L- and M,
- 1-phase DC loads can be connected between L+ and M or L- and M.

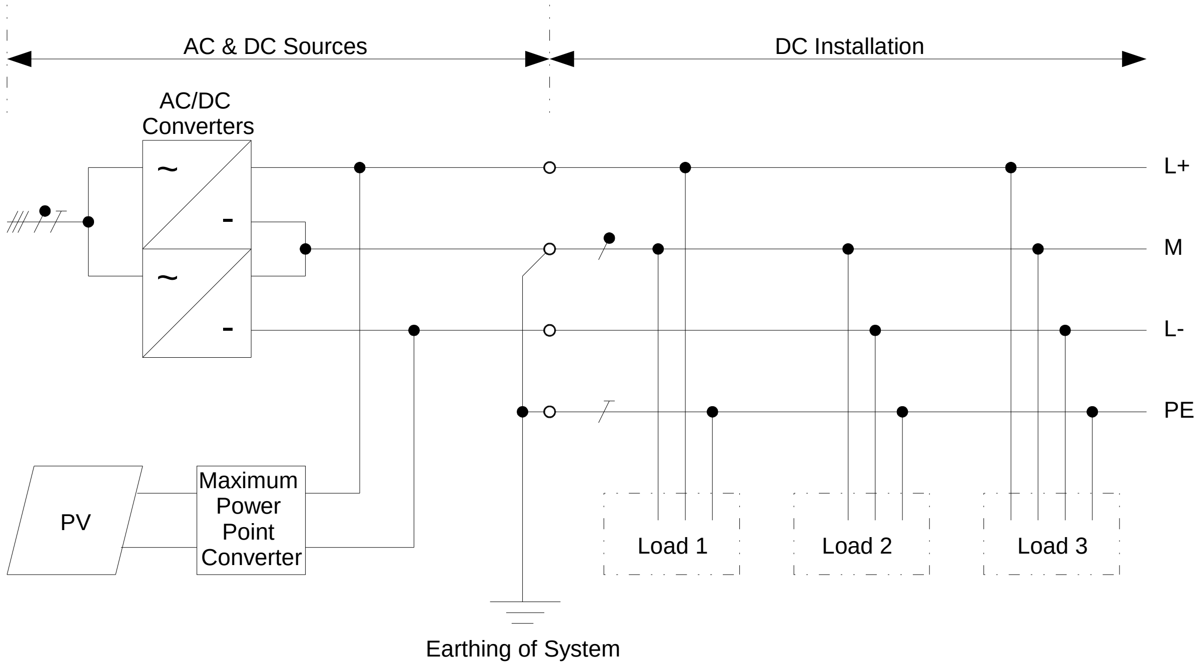

Figure 1: TN-S DC system with 1-phase loads and 2-phase loads

2.1.2 Cross-sectional area of conductors

IEC 60364-1 defines in chapter 132.6 that the cross-sectional area of conductors shall be determined for both nominal operating conditions and fault conditions according to

a) Their admissible maximum temperature;
b) The admissible voltage drop;
c) The electromechanical stress likely to occur due to earth fault and short-circuit currents;
d) Other mechanical stress to which the conductors can be subjected;
e) The maximum impedance with respect to the functioning of the protection against fault currents;
f) The method of installation.

2.1.3 Initial and periodic verification

IEC 60364-1 defines in chapter 134.2-3 that electrical installations shall be verified before being placed in service and after any important modification. Periodic verifications are recommended. Verification of DC power grid systems must be performed such that lose cables or contacts are identified to avoid damage by arcs.

3 Interoperability

3.1 Nominal Voltages and Operational Voltage Ranges

Technical standard IEC 60038 defines standard voltages for

- low, medium, high and highest AC power grids,
- nominal DC voltages below 750 V DC as well as
- DC and AC traction systems [41].

It is proposed to extend this standard on nominal DC grid voltages and operational DC voltage ranges in Table 1 below following Table 1 on AC systems in [41].

Table 1: DC systems having a nominal voltage between 100 V and 1500 V inclusive and related equipment

Single-phase three-wire systems			Two-phase four-wire systems		
Voltage			Voltage		
Lowest V	Nominal V	Highest V	Lowest V	Nominal V	Highest V
???	**350 V**	???	???	**± 350 V**	???
360 V	**380 V**	400 V	± 360 V	**± 380 V**	± 400 V

3.2 EMC Emission

Electricity grids can distribute in addition to AC or DC power also disturbance voltages from power sources and loads that interfere the interoperability of grid systems. Measurement procedures and limits for conducted disturbances voltages on AC power grids are well specified [42]. The development of DC power grids for solar power systems has generated proposals for measurement procedures of conducted disturbance voltages on DC power grids [43-45]. These proposals are currently discussed at IEC working group CISPR B WG1 MT Grid Connected Power Conditioner (GCPC) to extend test procedures defined in standard CISPR 11 [46].

As long as CISPR 11 does not define test procedure for disturbance voltages from power conditioners on DC grids it is proposed to use a DC line stabilization network (LISN) similar to [44] to measure conducted disturbance voltages on DC power grids and to consider equal radio frequency disturbance voltage limits for low voltage AC and DC power grids.

3.3 EMC Immunity

Protection against overvoltages of atmospheric origin or due to switching is specified in IEC 60364-4-44 Chapter 443 [6]. Overvoltage category classes I – IV are specified only for low voltage AC installations currently. An extension of that standard shall be developed and proposed to IEC to consider overvoltage category classes for low voltage DC power grids.

4 Safety

DC – like AC – power grids shall include protective measures to guaranty safety of power systems under normal and fault operations. IEC 60364-4-41 documents protection against electric chock that asks for the general requirements of e.g.

- Automatic disconnection of a supply (IEC 60364-4-41, chapter 411)
- Double or reinforced insulation (IEC 60364-4-41, chapter 412)

IEC61557 Parts 1 – 12 shall be considered [29-40].

4.1 Automatic disconnection of supplies

Protective devices shall disconnect loads or sub-systems in cases of faults. Standard IEC 60364-4-41 defines in table 41.1 maximum disconnection time intervals for AC and DC power systems in different voltage classes considering nominal currents not exceeding 32 A [3]. Proposed DC power grids fall in the voltage class 230 V – 400 V DC. Here protective devices shall disconnect fault currents in dependence of the earthing system within

- 0.4 s in TN systems and
- 0.2 s in TT systems.

4.2 Fuses

Fuses shall fulfill and be used according to IEC 60269 parts 1 - 6 [47-52].

5 Appendix

5.1 Abbreviations

A	ampere
AC	alternating current
CISPR	Comité International Spécial des Perturbations Radioeléctriques
DC	direct current
EMC	Electromagnetic Compatebility
IEC	International Electrotechnical Commission
IT	Isole-terre electricity grid system
LISN	Line Impedance Stabilisation Network
s	second
TN-C	Terre-Neutral-Combined electricity grid system
TN-S	Terre-Neutral-Separated electricity grid system
TT	Terre-Terre electricity grid system

5.2 References

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