Data Center-Design Guide
Power feeding architecture with Direct Current up to 400VDC

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Summary

This document is a specification for power feeding systems architecture of up to 400 VDC for ICT equipment in data or telecommunication centres, and customer premises useful for datacentre design guide.

The proposed configuration, redundancy, power distribution and monitoring, are aiming safe, reliable and manageable power feeding systems. Only generic reference architectures are presented, many alternatives being possible. This specification is mainly based on ITU-T Recommendation L.1204 on up to 400VDC power feeding architectures and ETSI EE EN 300 132-3-1 and ITU-T L.1201 power feeding interface to ICT equipment.

Contents

1 Scope

This specification defines power systems in telecommunications centres, datacentres and customer premises feeding ICT equipment in the range 260-400VDC [ITU-T L.1200] or [EN 300 132-3-1] with high reliability, safety and manageability that covers the following items:

- power feeding architectures with different level of redundancy from AC main LVAC distribution board outputs to equipment DC input (cf figure1)
- main basic power elements: power distribution units and lines, rectifiers, power distribution units (PDUs), batteries and;
- control and monitoring functions.

This specification ensures cohabitation of power interface of up to 400 VDC with AC and -48 VDC [EN 300 132-2] to cabinets or ICT equipment in sites or rooms.

AC and 48V power architecture and systems are out of the scope except power converters 400/48 and 400/AC for transition period to full 400VDC use.

Renewable AC or DC energy sources are out of the scope

The full description of a battery, grid AC supply, backup generator and power supply units (PSU) in ICT equipment and renewable or distributed energy sources are out of the scope of this recommendation, but indications are given on their influence on the architecture of power feeding systems of up to 400 VDC. For example in chapter 6.4 an architecture with a DC switch rather than an AC switch between the LVAC building mains and an AC back-up generator is described.

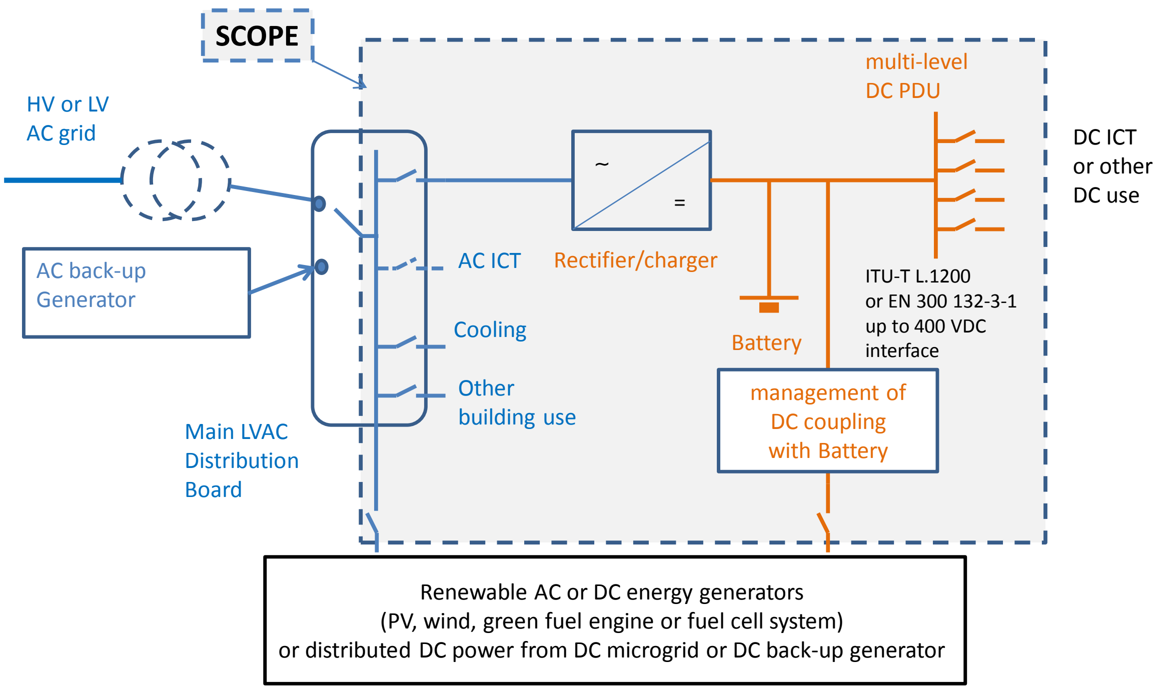

Figure 1: scope boundaries

2 References

At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this specification are therefore encouraged to investigate the possibility of applying the most recent edition of the standards.

2.1 Normative reference

[ITU-T L.1200]	Recommendation ITU-T L.1200 (2012), *Direct current power feeding interface up to 400 V at the input to telecommunication and ICT equipment.*
[ITU-T L.1202]	Recommendation ITU-T L.1202(2015), *Methodologies for evaluating the performance of an up to 400 VDC power feeding system and its environmental impact*[ITU-T L.1203] Recommendation ITU-T L.1203(2016), *Colour and marking identification of up to 400 VDC power distribution for information and communication technology systems*
[IEC 60038]	IEC 60038 (ed 7 2009 06) IEC standard Voltage
[ETSI EN 300 132-3-1]	ETSI EN 300 132-3-1 V2.4.6 (2011-12), *Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 3: Operated by rectified current source, alternating current source or direct current source up to 400 V; Sub-part 1: Direct current source up to 400 V*
[ETSI EN 300 132-2]	ETSI EN 300 132-2 V2.4.6 (2011-12), *Environmental Engineering (EE); Power supply interface at the input to telecommunications equipment; Part 2: Operated by -48 V direct current (dc).*
[ETSI EN 300 132-3-2]	draft ETSI EN 300 132-3-2 (2016),*Environmental Engineering (EE);Power supply interface at the input to telecommunications and datacom (ICT) equipment;Part 3: Operated by rectified current source, alternating current source or direct current source up to 400 V;Sub-part 2: Alternating current source*
[ETSI EN 301 605]	ETSI EN 301 605 V1.1.1 (2013-10), *Environmental Engineering (EE); Earthing and bonding of 400 VDC data and telecom (ICT) equipment.*
[ETSI ES 202 336-1]	ETSI ES 202 336-1 V1.2.1 (2011-07), *Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks) Part 1: Generic Interface.*
[ETSI ES 202 336–x]	ETSI ES 202 336-x (in force), *Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment; Parts 2 to 10 information model series.*

[IEC 60364-1]	IEC60364-1 (2005), *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions.*
[IEC60364-4-41]	IEC60364-4-41 (2005), *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock.*
[ATIS 0600315.01.2015]	Voltage Levels for 380V DC-Powered Equipment Used in the Telecommunications Environment
[IEC 61984]	"Connectors – safety requirements and tests"
[IEC 60950]	"Information technology equipment –safety"
[IEC 60664]	"Insulation coordination for equipment within low voltage systems"

2.2 Other reference and document

[Open Compute Project] Data Center Design Guide – Direct Current v0.3

3 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC Alternating Current

AMEA Asia Middle East Africa

DC Direct Current

FC Fuel Cell

HVAC High Voltage AC

ICT Information and Communication Technology

IMD Insulation Monitoring Device

IPR Intellectual property Rights

IT earthing configuration see NOTE

LV Low voltage

LVAC Low voltage AC

LVDC Low Voltage DC

MTTR Mean Time To Repair

MV Medium voltage

PDU Power Distribution Unit

PSU Power Supply Unit

PV	Photovoltaic
TN	earthing configuration see NOTE
TT	earthing configuration see NOTE
VDC	Volts DC
VRLA	Valve-regulated lead acid
UPS	Uninterruptible Power Supply

4 Overview

One of the main advantages of 'up to 400 VDC' power feeding is that it reduces intermediate power conversion stages (e.g., the inverter and power factor compensator can be eliminated) and gives lower current usage than –48 VDC feeding, for the same power requirement. In addition to energy savings and Greenhouse Gas (GHS) emissions reduction, the 380 VDC voltage brings also power architecture simplification improving reliability, operation and maintenance, costs, …

Many advantages and savings assessments have been presented with details and references to papers in ITU-T Recommendation series [L.1200,1,2].The major ones are listed in section 6.1.

5 License on 400VDC

For all related ITU Recommendation and ETSI Standards referenced in this specification, the used technologies should be free of any licenses, which each member can verify by contacting the Intellectual property Rights policy (IPR) office of each Organism.

6 Electrical Design

6.1 Power interface and benefits

The electrical system uses a standard 400/230VAC distribution system to DC voltage in the 260-400 VDC range. The power supply is typically a 380VDC direct current UPS systems (DC UPS) that provide the standards power input interface of ICT equipment compliant to ETSI EN 300 132-3-1 or ITU-T L.1200.

The major benefits of this relatively high voltage direct current distribution compared to electronic or Telecom 48VDC voltages system are:

- absence of heavy batteries from ICT rooms that may have constrains because of raised floors,
- separate thermal management for batteries and servers. This allows higher temperature for servers (improving cost) and lower temperature for battery (improving lifetime),
- no very high short circuit currents at row level, as current is much more limited on smaller wire in 400VDC compared to 48V bigger wire distribution
- no need for active phase balancing of the Open Rack power supplies,

- space saving compared to 48VAC with much less copper. ,
  Note: In theory copper could be reduced by a factor 49 at same power and Joule losses (calculated at typical VRLA battery nominal voltage: $336^2/48^2$). In practice, a factor 10 is usually applied as it reduces losses and it allows reuse of AC distribution in existing datacenter powered in AC.

Compared to UPS, other gains are:

- strong reduction of total cost ownership due to long lifetime and higher reliability of DC systems up to 10 times better,
- end to end higher efficiency up to some % , when compared to on-line UPS or directly powered input by 230VAC 50 Hz transformer or external AC filters and considering saving due to higher voltage in the distribution,
- space saving especially compared to modular UPS,
- no phase balancing, harmonics, etc… specific to AC,

Use of 400VDC in ICT sector is not common, but use of LVDC domain (< 1500VDC) is massively used in other professional and public sectors such as solar energy (millions of solar roofs installed on houses and buildings), in hybrid and electric cars and recharge posts (> one million hybrid vehicles). Many components are massively produced (wires common to AC and DC, interconnections, DC breakers, battery blocks, industrial power supplies, …), and inside UPS and rectifiers first stage, so there is no specificities and safety is ensured as simply as use of 230VAC in LVAC domain (<1000VAC) by International Electrotechnical Commission (IEC).

6.2 Earthing and bounding

The voltage is preferably connected to ground through High Resistance Middle point Grounding for safety reason in compliance to Earthing and Bonding standard ETSI EN 301 605. The grounding solution ensures compliance with AC and DC 48V building and room distribution according to figure 2.

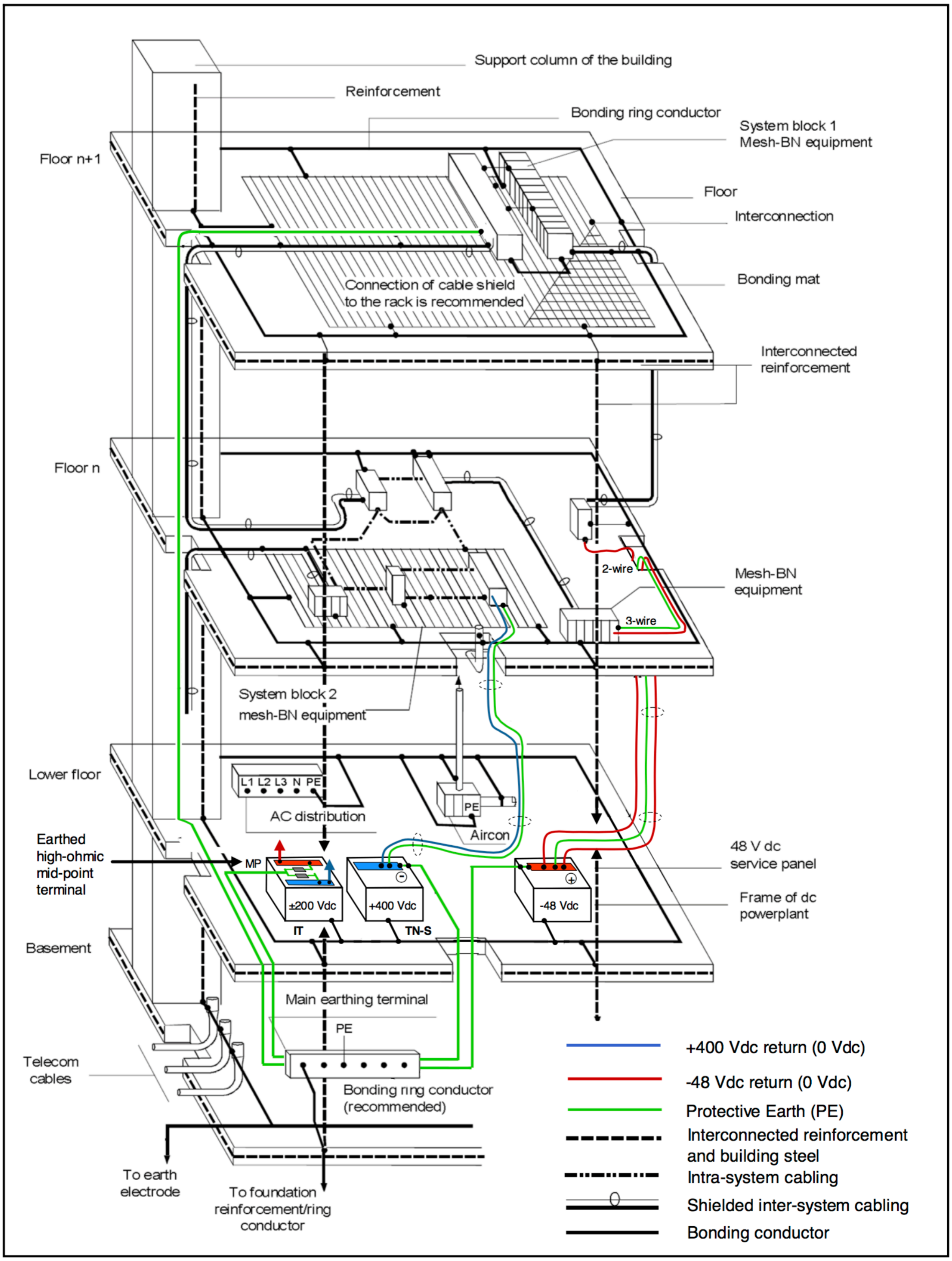

Figure 2: DC distribution at building level from DC source to ICT/telecom systems [ETSI EN 301 605]

6.3 Architecture, performance and reliability for 400VDC distribution

6.3.1 Target architecture

As defined in ITU-T L.1202 about architecture performance in efficiency and reliability five classes of redundancies are defined in reference of The Green Grid and Emerge Alliance from no redundancy to full 1 + 1 end to end chain redundancy from AC source to DC ICT equipment input.

Among the redundancies classes of [ITU-T L.1201], this document particularly focused on

- Class#3: single DC UPS with rectifier modules and battery string redundancy, and double DC distribution and DC equipment input (figure 3)
- Class#5: end to end full redundancy (figure 4) that typically applies to medium to big size small installation provided to a limited number of customers services.

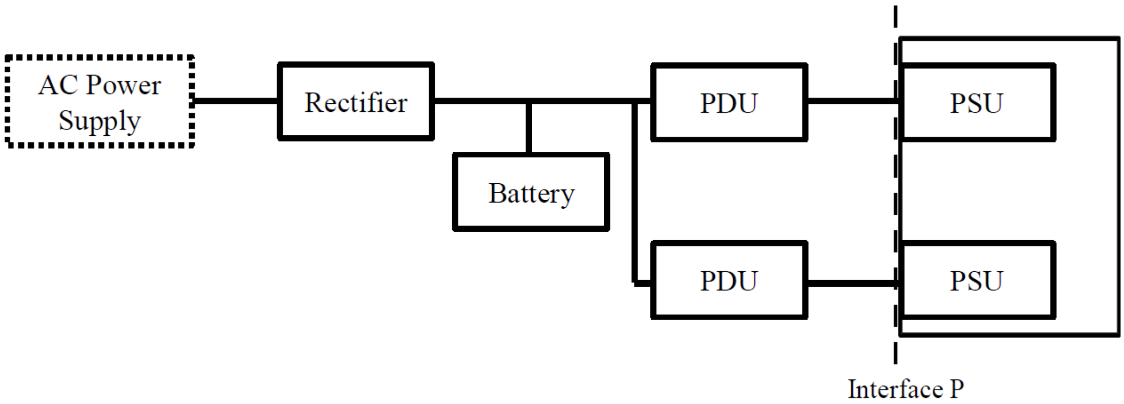

Figure 3: System configuration with redundant DC distribution and ICT equipment input [ITU-T L.1201]

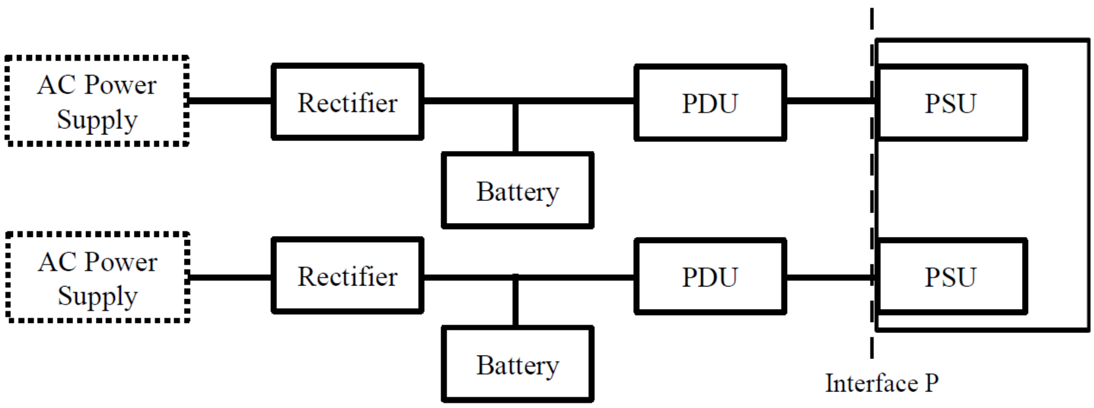

Figure 4: System configuration with end-to-end redundancies of power feeding systems to redundant inputs ICT equipment [ITU-T L.1201]

Class#3 typically applies to small to medium size installation of some kVA to 10's of kVA providing broadband multimedia services to a limited number of customers.

Class#5 typically applies to medium to big size installation of 10's of kVA to MVA's providing critical services or centralized services to a huge number of customers.

In addition to standard data center electrical design elements of the AC power supply (grounding, MV/LV transformer, AC Main/backup generator), this design features the electrical and DC related systems:

· DC UPS (rectifiers and batteries) including distribution units

· DC Power bus duct system

6.3.2 Migration period to full 400VDC

This is very likely that we will have a transition period of progressive migration from multi interfaces (48V, AC, 400VDC) in the buildings to full 400VDC distribution, which is easy to make with some converters 400/48 and/or 400/AC (see fig 5) with limited end to end losses of about 2% considering available industrial converters efficiencies.

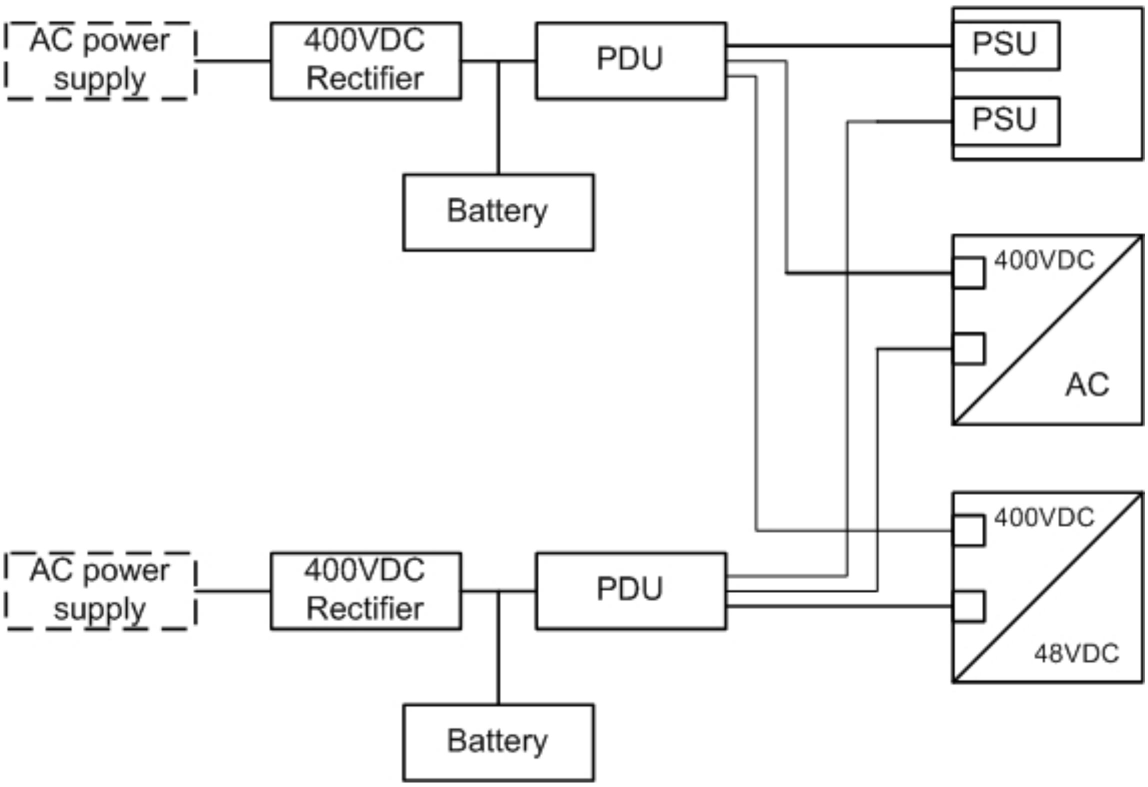

Figure 5: Migration period to unified 400VDC interface, using converters (DC/AC and DC/for adaptation to voltage

6.4 main components of the 400VDC architecture

The figure 6 describes an implementation highlighting the main components of the DC architecture from end to end. Each components is then described.

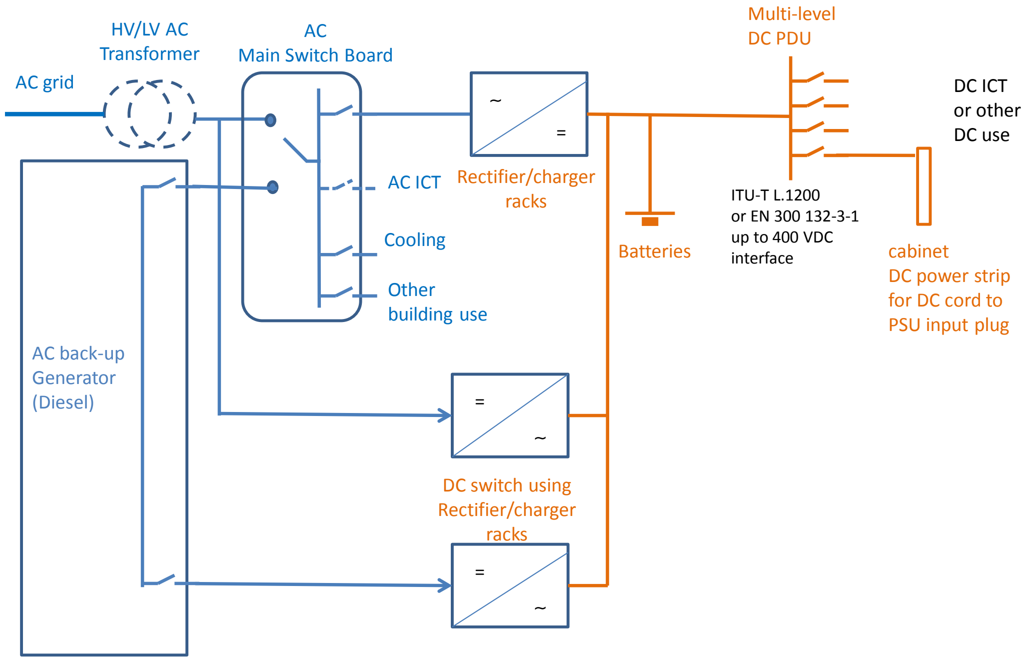

Figure 6: Example of implementation of an end to end DC system with AC and DC switching of the Diesel back-up Generator showing all the major components

6.4.1 HVAC – LVAC Transformers

This component is out of the DC power chain scope.

The role of the transformer is to lower and insulate the grid 3 phases HVAC distribution voltage to LVAC building internal distribution. There is no specific requirements for 400VDC systems compared to AC UPS or 48V system at this stage of the installation.

6.4.2 Main power switching

6.4.2.1 AC switching (MSB)

General information can be found in MSB definition in OCP Data Center V1.0 specification.

6.4.2.2 DC switching

For optimization, the AC switch could be replaced by a DC switch solution using rectifiers which is more reliable and much easier to maintain with modular rectifiers since the migration period beginning as shown on figure 7.

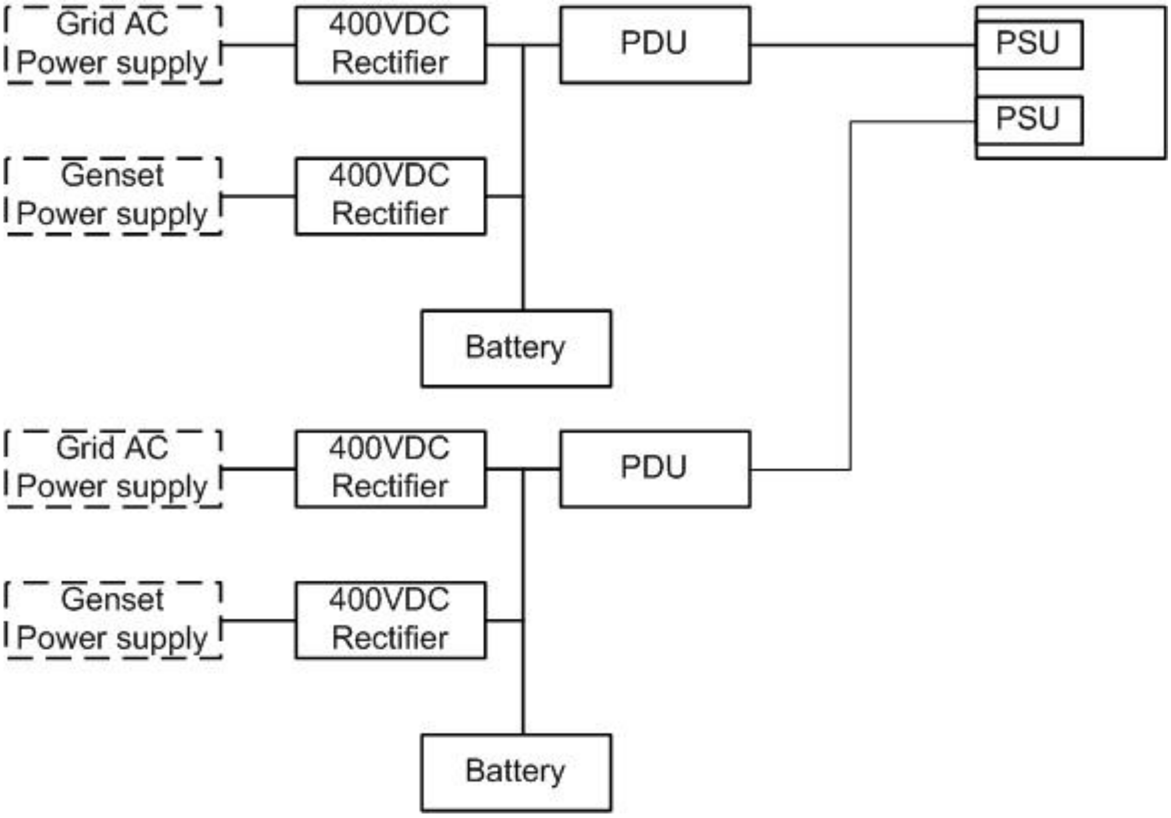

Figure 7: DC switching solution to replace AC/backup genset switch

6.4.3 Direct Current UPS

The DC UPS can be divided into three major sub elements: the AC interface, Energy Storage System and DC Output interface, for which specific requirements are defined.
Additionally the overall system electrical and environmental conditions are defined.

6.4.3.1 Overall AC – DC System

- AC – DC conversion efficiency of greater than 97%
- Power factor shall be: >0.97 at greater than 5% load rate
- Air Inlet environmental conditions of AC interface and DC power system, shall respect EN 300 019-1-3 class 3.1:
  - temperature range in °C: (normal conditions +5/+40, exceptional conditions -5 °/+45°C
  - humidity range in %: (normal conditions 5/85, exceptional conditions -5/90)
- Efficient air cooling (for example fresh air cooling)

Note: liquid cooling can be an option in further research

- Indoor rated equipment: IP21
- Sound pressure level maximum 80dBa at 1 m distance

6.4.3.2 AC Interface

The AC interface shall be:

For Europe and part of AMEA:

400/230 VAC – 3phase, 4 wires (-10% +6% voltage range) 50Hz [IEC38] nominal voltage of public mains, [ETSI EN 300 132-3-2] AC interface of Telecom/ICT equipment

- Breakers shall be compliant with IEC standards defined in EN 302 605
- IEEE 519 Compliant interface

6.4.3.3 Electrical energy Storage System

The electrical energy storage system is designed to filter AC main input interruptions for the IT loads downstream from DC UPS while the starting time of the back-up generator.
Many storage technologies can be used for this:

- Battery systems (lead-acid, Lithium ion, Nickel-based, flow battery, …),
- Direct current output high speed flywheels,
- Zero-time genset using inertia wheel,
- Supercapacitors

The great advantages of this DC architecture, compared to AC UPS, are:

- to be directly connected to batteries, which remove the risk of dips or short interruptions
- to give very high current to trip protective device in case of short-circuit in the DC distribution without very limited voltage drop.

6.4.3.4 DC Output Interface

The direct current output interface shall be defined for compliance with IT and Telecom load input Interface [ETSI EN 300 132-3-1] or [ITU-T L.1200], and for proper operation of the battery as defined by the manufacturer in its different mode e.g. for lead-acid:

- charge maximum current and end of charge voltage,
- discharge end of discharge voltage,
- floating voltage with temperature compensation
- multi-string management

For some battery technologies such as Lithium, there can be additional management (safety, thermal, etc…) but this can be included in a dedicated Battery Management System (BMS) able to interact with the 400VDC rectifier system control unit.

6.4.3.5 Other devices

Some other devices can be found in specific installation:

- DC output switchgear system
- overhead busway interface
- input DC electrical connector for cabinet or rack (Open Rack Hardware V1.0 specification)

These devices needs further investigation as many installations do not require it.

6.4.3.6 Cabinet power strip and PSU plugs

The server PSU are equipped with a plug compliant with IEC 61984: “Connectors – safety requirements and tests”, IEC 60950: “Information technology equipment –safety”, IEC 60664: “Insulation coordination for equipment within low voltage systems” such as Anderson SAF-D-Grid 400DC/AC model.