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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Interfacing of renewable energy or distributed power sources to up to 400 VDC power feeding systems

Recommendation ITU-T L.1205

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ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.1205

Interfacing of renewable energy or distributed power sources to up to 400 VDC power feeding systems

Summary

The up to 400 volt DC (VDC) power solutions feeding the power interface of ICT/telecom equipment as defined by the ITU-T L.1200 series, are well adapted to the straightforward use of renewable energy or distributed power sources through new simple direct current (DC) nano or micro grids. Recommendation ITU-T L.1205 defines the coupling of local or remote renewable energy into an up to 400 VDC power system without reducing DC performances defined in Recommendation ITU-T L.1202 mainly for efficiency and reliability. The main advantages are saving of fossil fuel (as a source of primary energy consumption), reduction of greenhouse gas (GHG) emissions and increased resilience. Additional site interconnection by a DC grid can even bring more optimization. One other big benefit is that compared to alternating current (AC), with 400 VDC there is no synchronization required between the various inputs, which keeps the architecture simple.

History

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Introduction

The up to 400 VDC power feeding solution for ICT/telecom sites (data centres, telecommunication centres) and other building using the up to 400 VDC power interface defined in [ITU-T L.1200], are well adapted to straightforward use of renewable energy or distributed power sources through the new DC nano or micro grids, most of them being more complex in alternating current (AC) than in direct current (DC). The DC allows greater simplification by avoiding frequency and phase synchronisation of AC generators or inverters.

This Recommendation aims at defining the interface and architecture for injecting renewable energy into an up to 400 VDC power system charged with providing power to telecom/ICT and facilities equipment with an interface compliant to that defined in [ITU-T L.1200] and with a DC power architecture as defined in [b-ITU-T L.1204], without reducing DC performances defined in [ITU-T L.1202] mainly for efficiency and reliability.

The addition of local renewable energy will reduce energy consumption from the public utility and possibly fossil fuel primary energy consumption as well as the corresponding high greenhouse gas (GHG) emissions.

Local renewable energy can also provide more resilience in case of public electric grid interruption.

In addition, energy exchange is simple with distributed green power sources such as photovoltaic (PV), wind power, fuel cells or engine generators using green fuel, through DC nano or micro grids at the level of a multi-building site or between different sites. These sites can be any type of information and communication technology (ICT) sites such as network access or nodes, data centres, customer premises including IoT devices, etc.). Such an inter-buildings or sites power interconnection is called a 'site grid' as opposed to a public electric utility.

These DC energy exchanges through site grids can provide a higher level of optimisation through:

– exploiting green-energy sources more efficiently by the optimal location of renewable energy generators (e.g., at windy sites or sites with low levels of sunlight)
– complementing local back-up power systems e.g., battery power
– sharing local renewable energy excesses of one site with other sites
– ensuring remote powering of distributed ICT sites in the neighbourhood (e.g., by dedicated remote DC power cables or hybrid optical and DC power cables)

Injection of renewable energy into a legacy AC public utility irrespective of the use will lead to a greener use of electricity for ICT services, by avoiding undetermined use in the neighbourhood that may be inefficient. This could be precisely accounted for in key indicators on renewable energy use in one site or inter sites through a nano grid.

Many of the documents listed in the bibliography elaborate on the benefits and need of coupling local renewable energy (REN) [b-greenstar], [b-Emerson DC REN] or nano grids [b-huawei] to ICT installations and the advantages of doing so in DC [b-Vicor Stephen], [b-Starline], [b-Emerson Case Study]. The life cycle assessment (LCA) approach is described in more detail in [b-ecodesigned DC].

This Recommendation was developed jointly by the European Telecommunications Standards Institute (ETSI) and ITU-T Study Group 5 and published respectively by ITU-T and ETSI as Recommendation ITU-T L.1205 and ETSI Standard ETSI ES 203 474, which are technically equivalent.

Recommendation ITU-T L.1205

Interfacing of renewable energy or distributed power sources to up to 400 VDC power feeding systems

1 Scope

This Recommendation defines the interconnection of the site power installation feeding an up to 400 VDC interface, to site renewable energy or to distributed DC power sources. The aspects covered include:

- general power architectures for:
  - connection of a site renewable energy source (PV, wind generator, fuel cells, etc.) to a site power plant and especially to a DC power system, (the site sources being on the buildings or around)
  - exchange of power to and from a DC nano or micro grid for use and production outside of the site (this includes dedicated remote powering networks built for telecom/ICT access equipment but also more general purpose DC electric grids)
- conditions required to maintain the specified performance for the up to 400V power system:
  - electrical stability
  - reliability and maintainability
  - proper battery charge and management
  - lightning protection coordination
  - electromagnetic compatibility (EMC) and transient limits
- specification of proper power sizing (requirements for control-monitoring and power metering)
- assessment of performances (AC grid energy saving, reliability, flexibility, environmental impact, etc.)

The current Recommendation does not cover:

- renewable energy dimensioning
- power injection into the legacy AC utilities which is already covered by many Standards (e.g., IEC Standards),
- some of the smart power management possibilities through exchanges with DC nano or micro grids

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.

[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 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.*
[ETSI EN 301 605]	ETSI EN 301 605 V1.1.1 (2013), *Environmental Engineering (EE); Earthing and bonding of 400 VDC data and telecom (ICT) equipment.*
[ETSI ES 202 336-X]	ETSI ES 202 336 series (in force), *Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks).*
[IEC 60364-1]	IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions.*
[IEC 62368-1]	IEC 62368-1:2014, *Audio/video, information and communication technology equipment – Part 1: Safety requirements.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 interface P [ITU-T L.1200]: Interface, physical point, at which a power feeding system is connected to operate ICT equipment.

3.1.2 ICT equipment [ITU-T L.1200]: Information and communication equipment (e.g., switch, transmitter, router, server and peripheral devices) used in telecommunication centres, data-centres and customer premises.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 back-up power system: Power system providing energy to equipment of an ICT/telecom site in case of downstream electrical power unavailability.

3.2.2 distributed power source: A local electrical power source where energy is produced close to the user and distributed by a nano or micro grid as opposed to a centralized power plant with a long distance electricity transport grid. This local power source can be an individual user power system or a small collective energy power plant for a group of customers. It can include energy sources or storage or cogeneration of heat and electricity using any primary energy, renewable or not.

3.2.3 distributed power system: A system of distributed power sources and possibly other functions such as energy conversion, interconnection, safety systems, energy storage and corresponding management.

3.2.4 renewable energy: This is mainly non-fossil fuel converted into electricity (e.g., solar energy, wind, water flow, biomass) which can be obtained from natural resources that can be constantly replenished. (Based on the definitions provided in [b-ITU-T L.1204] and [b-Arena])

3.2.5 renewable energy source: Source producing electrical energy from renewable energy.

3.2.6 nano grid, micro grid: A local area grid connecting some buildings together at relatively short distances. It can be in AC or DC. In general a nano grid is lower than 100 kW and a micro grid can be of higher power.

3.2.7 site grid: DC nano or micro grid between telecom/ICT sites as opposed to a public electricity utility.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC Alternating Current

BMS Battery Management System

CHP Combined Heat and Power

CT Current Transducer

CU Control Unit

DC Direct Current

EE Environmental Engineering

EMC Electromagnetic Compatibility

FC Fuel Cell

HVAC High Voltage AC

ICT Information and Communication Technology

IoT Internet of Things

KPI Key Performance Indicator

LCA Life Cycle Assessment

LVAC Low Voltage AC

LVDC Low Voltage DC

PDF Power Distribution Frame

Ppeak Peak power

PSU Power Supply Unit

Pu Used power

PV Photovoltaic

PWM Pulse Width Modulation

REN Renewable Energy

RF Rectifier Function

TCO Total Cost Ownership

UPS Uninterruptable Power Supply

VAC Volt AC

VDC Volt DC

5 Conventions

None.

6 Architecture of up to 400 VDC power with REN coupling

6.1 Overview

In existing buildings, AC grid and AC distributions power telecom/ICT equipment, cooling systems, back-up power systems, control/monitoring, lighting, office computers, Ethernet switches and routers and many other building facilities such as ventilation, heating and lifts, etc. Some of the equipment is DC powered by DC power feeding systems and this is progressively increasing with 400 VDC rather than –48VDC preferred because of the higher power density of the equipment that reduces cable cross-section area and distribution losses.

The ICT sectors are work on the reduction of non- renewable primary energy use by reducing direct electricity consumption and producing more renewable energy (REN).

The REN generators are generally in DC and so power arrangements of up to 400 VDC power systems are far more convenient for injecting REN.

NOTE – REN generators that are in AC are generally producing variable frequency and voltage requiring precise synchronization for connection to an AC grid.

DC REN generators allow easier consumption of locally generated energy or energy generated by a group of nearby sites through DC nano or micro grids compared to solutions with local AC generators synchronized with an AC grid.

Due to the wide use of AC in ICT buildings, the REN coupling solutions should consider a progressive swap from AC injection to DC. Figure 1 shows the general principle of energy flows of renewable energy or distributed DC power to the existing power system of a building integrating an up to 400 VDC system.

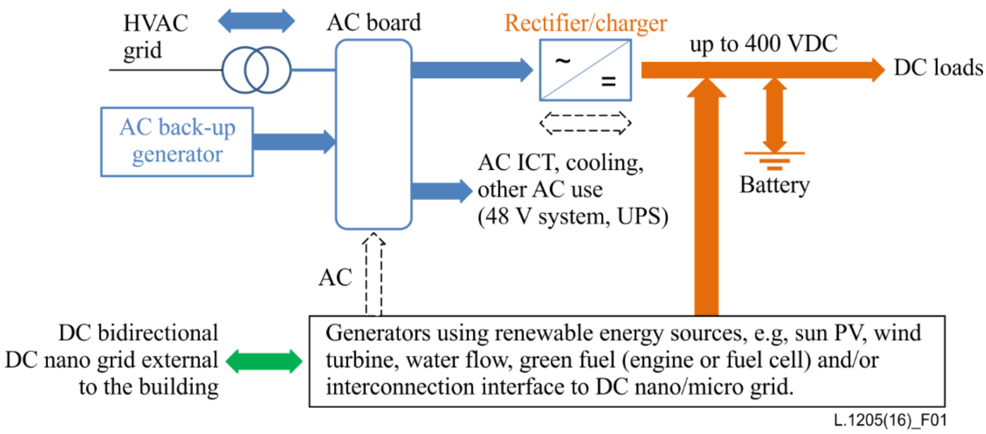

Figure 1 – General energy flow principle for coupling a renewable or distributed DC site grid to an up to 400 VDC power system in a building

The flow direction is indicated by the arrow and the reverse direction from REN to the grid depends on the excess of power not used by the sites for powering telecom/ICT equipment, cooling and air conditioning equipment and for building use can be sent to the AC or DC grids. This is to avoid loss of productivity and to contribute to the local, regional or national electric and CO_2 reduction effort and to obtain a better total cost ownership (TCO) for the user.

Combined heat and power (CHP) generation and storage can also be alternatives, but they are not covered in this Recommendation that focuses on injection of electricity in DC and to a lesser extent in AC.

6.2 Local and distant renewable energy coupling architecture to sites with up to 400 VDC power systems

There are different architectures for interconnections of local REN, distributed power systems or DC nano and micro grids of up to 400 VDC power systems in buildings and sites. It includes local renewable power sources:

- connected to AC and/or DC distribution in the building
  - for local REN consumption
  - for local injection of excess REN production into an external grid
- connected to an external DC nano or micro grid
  - for injection of excess of DC REN production towards other buildings or sites
  - for remote interconnection to the AC grid, i.e., mutualized injection of DC REN excess from several sites on one single point of interconnection to the AC grid
  - for islanding the group of sites when running on its own distributed power production capacity (e.g., a pure or hybrid renewable energy source with energy storage).

NOTE – the connection to a DC nano or micro grid for different services is not fully covered in this Recommendation as R&D is still on-going in various directions such as swapping part of the AC grid power systems to more energy coming from local renewable energy or from external DC nano or micro grids, extending resilience of the site to overcome grid power interruption, taking advantage of smart grid services at the level of the interconnection to an AC grid e.g., renewable energy injection or storage to support the grid and on demand peak shedding, etc.

Figure 2 illustrates the general principles of electrical coupling interconnection of the local REN or from DC from a nano/micro grid to the existing power systems of a building integrating up to 400 VDC systems. The power injection can be:

- in DC only
- in AC only
- both in AC and DC

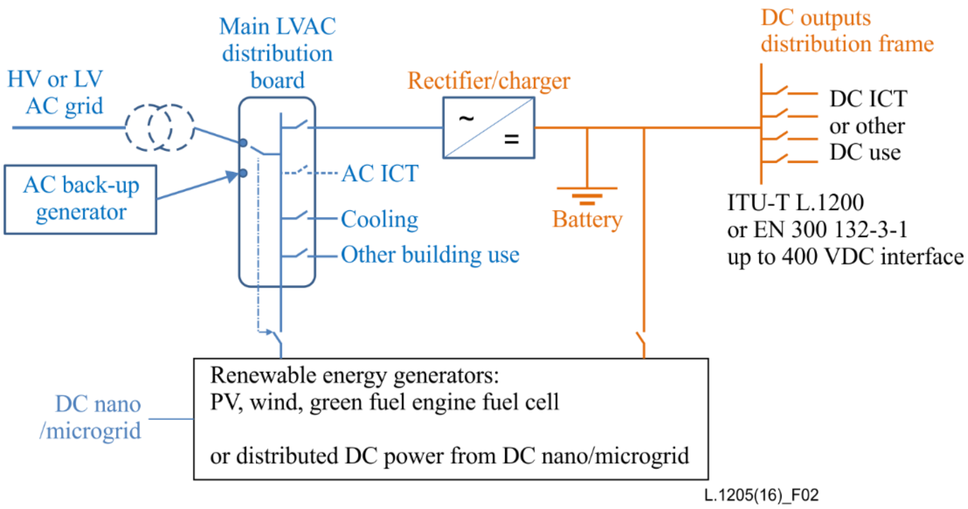

Figure 2 – Coupling a local REN or DC nano/micro grid to the AC and DC power systems of a site

Annex A describes different preferred recommended configurations, but others are possible and will require further studies.

In a redundant system, interconnection and coupling can be done on several power chains and with different shares between AC and DC injection.

The coupling architectures should be implemented with as few power conversion stages as possible between:

– the local renewable energy sources
– the site DC power system for local use of up to 400 VDC compliant with [ITU-T L.1200]
– the remote power supply to user equipment on remote DC powering lines compliant with [b-ETSI EN 302 099]
– other DC sites and REN sources interconnected to an inter-sites DC micro and nano grid.

More details will be provided in the remainder of this Recommendation for checking the considered architectures for critical conditions:

– safety shall be ensured whatever the increase of maximum combined source impedance and short-circuit current on the DC bus
– the interface shall comply whatever the case in voltage range and other characteristics of the up to 400 VDC powering interface [ITU-T L.1200]
– the proper operation, reliability and safety of the battery connected to the DC bus shall be ensured by avoiding any contradiction with the up to 400 VDC system existing charge control in current, voltage and timing characteristics

7 Conditions required to maintain specified performance for an up to 400 VDC power system

7.1 General introduction

The conditions for interconnection of renewable energy generators for up to 400 VDC power systems in a building, considered from AC input to DC output cover:

– electrical stability
– reliability, maintainability and safety
– proper battery charge and management
– lightning and protection coordination and distribution for EMC, transient limitation

7.2 Electrical stability

7.2.1 General considerations on REN power injection

Different rates of REN self-consumption on site are observed ranging from a few percent of yearly consumption to approximately 100%. Details are provided in Appendix III.

In general, with an intermittent source the higher the self-consumption ratio, the higher the peak power ratio Ppeak/Pu.

For example:

– on a vertical building with a relatively small roof, a PV power generator will be very small compared to the used power e.g., 50 kW for a 400 kVA AC grid contract and 100 kW DC use. The risk of instability is low as all parameters will remain below the limit of the AC source
– on a small country data centre with a PV field, it can be the opposite e.g., 1 MW of PV and 100 kW consumption. In this case, the peak power can reach 10 times the used power.

Power injection limitations are necessary between the PV system and the AC or the up to 400 VDC system. It is also highly recommended to study the possibility of directly injecting energy to the AC grid that acts as an huge consumer, or of adding a local energy storage; which will be able to filter the power peaks for providing a permanent means of power.

Considering orders of magnitude, the following classification can be applied:

A – Local power generation lower than local power consumption

Local power generation is at all times lower than power consumed at the site, in general, no power will flow to the grid. Local power generation might be used as backup-up power for poor grid sites or to reduce power consumption from the grid. Storage capacity for electricity might be available at the site to cover short term overproduction.

B – Local power generation equivalent to local power consumption

The local power generation might exceed local power consumption for extended periods of time. The site shall be either able to feed the excessive energy back into the grid or otherwise sufficient storage capacity shall be installed to utilise all locally generated energy.

In that case, the REN system may not produce all the energy required by the site.

C – Local power generation higher than local energy consumption

A telecom/ICT site might be combined with a large power generator (solar farm, large wind generator, etc.) producing more power than needed for most of the time. A grid connection is required to utilise the full amount of produced energy. The REN generator can also be connected remotely through this grid. The grid can be a utility grid or a DC nano/micro grid.

Prior to the installation of local energy generation, a life cycle assessment (LCA) should be carried out to analyse the total life time effect of local energy generation and the most efficient amount of REN production.

7.2.2 DC injection of locally generated REN power

For local electrical distribution design reasons the DC power interface of REN energy to the up to 400 VDC system shall be limited by the protection devices to the maximum power rating of the fully equipped DC power system defined at the level of the DC power bus that is able to accept the maximum rectifier or battery current.

It is required to manage the power flow to give preference to REN usage.

The REN DC power injection limit should be reduced for different reasons including:

– limiting the risk of over-charge current in the battery to avoid thermal run-away. This should cover multiple faults in the charge control at the level of the rectifier, battery management system or REN output stage control
– dynamically limiting REN power to the momentary DC system load to avoid risk of voltage overshoot

NOTE – When the local DC site provides remote powering in DC 400 V to several neighbourhood ICT sites, additional precautions should be taken to avoid dynamic instability through remote line and distant systems. Appropriate decoupling should be defined e.g., by limiting the power rising slope of a distant system, line inrush current, etc.). This can be obtained through proper automation, local energy storage, etc. A remote powering interface in 400 VDC as described in [b-ETSI EN 302 099] should be used to limit these risks.

7.2.3 AC injection of REN power

The injected AC power from a REN system in the AC distribution of the site shall be done in coordination with the AC power distribution and back-up source of the site.

For the protection of the line to the REN output, an AC inverter system shall keep a correct fault discrimination in case of short circuits, in order not to affect the AC power feeding from the grid or from the back-up generator. In particular, when the installation is running on the AC back-up generator, generally the short-circuit current is much lower than on the AC grid or transformer.

7.3 Reliability, maintainability and safety

The reliability of up to 400 VDC systems can be affected by REN AC or DC coupling by:

– equipment failures

– possible current or voltage surges

– intervention errors for electrical maintenance or electrical work (extension, modification).

The manual decoupling of a device (e.g., disconnection switch) of a REN system shall be possible before any operation on the REN system. This is useful to avoid propagation of failure, e.g., a short circuit creating high current stresses and voltage transient.

Automatic disconnection of the REN system should be provided in case of failure in the REN system, to avoid propagation of faults to the up to 400 VDC systems considering that the REN power is not used as main source of the considered on-grid site.

NOTE – Further studies are required to determine the rules of disconnection and reconnection.

The rules could be very different compared to a standalone off-grid site without an AC grid input where there is in general no automatic disconnection of the generator but only regulation and battery charge management with the appropriate redundancy.

When REN power is injected in the electrical system either in AC or DC, manual disconnection with proper safety rules defined by IEC and national standards and regulations shall be applied.

This is critical for safe out of voltage operation on up to 400 VDC systems.

Particularly in the case of DC with multiple source inputs (rectifiers, batteries, REN input), the presence of voltage should be very clearly signalled.

Any ICT equipment used in the up to 400 VDC REN coupling system shall comply with [IEC 62368-1].

7.4 Proper battery charge and management

7.4.1 DC injection of REN power

The DC power of the REN generators when connected directly to the battery shall be injected according to the battery charge/discharge requirements. This shall be done in line with the management achieved by the existing control unit (CU) of the DC power system i.e. rectifiers, or by the controller of an advanced battery e.g., a lithium battery equipped with battery management system (BMS).

In general the important conditions to comply with are:

– avoiding any over-voltage or over current compared to the limit imposed by the rectifiers under their controller or by the battery controller if any (e.g., in Lithium-ion battery systems),

– avoiding any change of the charging characteristics of the battery.

The maximum values and the charging modes are set according to the installed battery type, its capacity and the battery manufacturer datasheet.

In normal operation, there are charging modes and steps with parameters of voltage, current, time, charge quantity, temperature and many thresholds to pass from one step to another. Deviation from these values can have immediate effects and long term impacts on:

– operation (e.g., disconnection of the battery in the case of over-voltage or over-current, loss of autonomy in the case of confusion inside the existing control on the charge management)
– safety (risk of fire due to overcharge)
– life-time (by changing charge conditions e.g., more cycling for a battery not designed for this type of operation).

In practice, several solutions for REN coupling on the DC bus are possible:

– Voltage follower REN solution: In this case the REN generator voltage follows the up to 400 VDC system voltage
– DC/DC converter coupling solution: In this case a converter e.g., DC/DC separates the REN generator from the up to 400 VDC system voltage which adapts to the up to 400 VDC system
– Upstream solution: The up to 400 VDC system has a dedicated input for a REN energy system in addition to an AC input.

Detailed information on these solutions is provided in Appendices I and III. Other solutions may also be possible.

In general, the common DC power feeding systems are designed with the assumption of connecting a single power source type at a time e.g., a set of rectifiers of the same type with the same controls. This raises new issues when connecting renewable energies to such a DC power feeding system. Solutions are described here and more details can be found in Appendix II.

7.4.2 AC injection of REN power

AC needs an AC/DC conversion system in order to be connected to a battery able to follow the battery management requirements as in clause 7.4.1.

7.4.3 EMC, transient voltage and current surge limitation

It is highly important to check the compliance of the lightning protection, EMC and voltage transient limits of the REN system output as the PV system, wind generator or DC micro grid can cover a wider area and may be of much higher peak power than the ICT site where the DC power system is installed and could cause more electrical disturbances.

The full system shall be in accordance with [ETSI EN 301 605]. It may be necessary to add protection inside the REN energy system or filters in the power distribution interface between the REN system output and the DC and AC site power systems.

When distributed power sources such as PV are installed outside and connected to the power feeding system, there is a high probability of it being affected by a lightning surge. In order not to cause degradation of reliability of the power feeding system, it may be necessary to implement some countermeasures. Insulating points and dielectric strength voltage shall be specified in order to protect ICT equipment from destruction and malfunctions.

Clause 7.4.4 provides complementary information on cabling and risk limitation on and from the REN generator itself.

7.4.4 Protection of distribution cables and protection coordination

The system configuration (connection points of distributed power sources and locations of circuit breakers) shall be very clearly studied, documented and clear marking applied to the different circuits to discriminate the installation from ICT high reliability systems and local or distributed REN energy circuits. The up to 400 VDC wires, cables and distribution equipment colour and marking shall comply with [ITU-T L.1203]. The distribution used in the up to 400 VDC REN coupling shall comply with [IEC 60364-1].

Appropriate standards from IEC should be followed for REN system installations which are out of the scope of this Recommendation.

In general for telecom/ICT installations, it is recommended to reduce the risk of overcurrents and voltage transients as follows:

– reduce to a minimum the area of loop in the cabling to reduce the voltage induction by magnetic coupling
– minimize the earth connection length using local earthing on the REN generator itself
– when using an underground cable conduit, the conduit shall be made of metallic conductor and earthed
– use transient protective devices as necessary depending on the environment and climatic conditions and against possible induction from high power lines in the neighbourhood
– increase equipotential grounding by inter-connecting the metallic parts when there is a risk of high resistance of the earthing especially on rocky and dry ground.

When distributed power sources are connected to the power feeding system, if a short circuit failure occurs it would probably cause a larger short-circuit current. In order to avoid this serious event, it is necessary to implement some countermeasures.

When these REN local or distributed sources are under the same user responsibility, previously implemented precautions can be applied. When this is not the case, additional precautions shall be taken.

It is necessary to specify connection points of distributed power sources and locations of circuit breakers in order to implement the protection of distribution cables and protective coordination work.

On a wide area REN installation attention should be focused on cabling to avoid sources of serious trouble from high current and voltage induction from other cables and from lightning. This is a better solution than spending a lot of time and money as well as the great difficulty and uncertainty of trying to correct the consequences.

8 Control-monitoring and metering

A local and remote energy metering and management of coupling installations shall be defined and installed in compliance with [ETSI ES 202 336-X] control monitoring standards.

The requirement for control-monitoring and metering is considered in addition to those of the up to 400 VDC system to obtain a full view of the energy flows including REN inside and outside the considered architecture or site and for better management of operation and maintenance.

If REN injection is also performed by coupling REN on the AC side, the metering and management of coupling should be compliant to [ETSI ES 202 336-X].

9 Assessment of performances improvement of up to 400 VDC systems with REN power

9.1 Performance, reliability and efficiency assessment

Performance, reliability and comparative energy efficiency assessment methods defined in [ITU-T L.1202] shall be used.

At minimum, it shall be checked that the coupling of renewable energy or distributed power does not reduce the energy efficiency and reliability or availability of the power systems existing in the building which could happen for example as follows:

– change in power load of the existing rectifiers when REN is injected to DC bus

– change in reliability due to more dynamic load behaviour

The energy efficiency shall be studied and then measured on site on a yearly base to integrate ICT load variation and seasonal effects and more dynamic load variation due to intermittent REN injection.

9.2 Operational KPI of REN coupling to sites with up to 400 VDC systems

Key performance indicators (KPIs) are intended to reflect the operational benefit of injecting renewable energy at the level of the site and particularly in DC over a relevant period, typically of one year, in order to comprise profile and average including seasonal variations.

Monitoring KPIs over several years will show the evolution including load changes, equipment ageing, installation of more REN and effects of additional functions such as energy storage, setting changes, etc.

When KPI reflecting the renewable energy self-consumption and production are required, they should use standards for renewable energy use such as those defined in [b-ITU-T L.1302] and [b-ITU-T L.1350].

When KPI reflecting other environmental impact reduction measures are required, they should use the results of assessment based on [b-ITU-T L.1410] for assessing the change in life cycle impacts of goods networks and services when using more renewable energy, etc.

This would also allow assessment of AC grid energy saving and other KPIs such as reliability/maintainability, complexity, resilience, flexibility, economic and environmental sustainability, etc.

The basic data used for these KPIs should come from the control-monitoring systems defined in clause 8 and from additional meters and sensors on the REN system itself.

Annex A

Different possible coupling architectures of REN energy to AC and DC site powering systems or to a nano or micro grid

(This annex forms an integral part of this Recommendation.)

This annex gives a set of possible detailed configurations and functions of REN coupling to a site including up to 400 VDC systems.

Advantages and drawbacks are discussed.

A combination of these configurations is possible on some big sites and other configurations can be studied.

A.1 Interconnection of REN on a single AC site input

Figure A.1 shows the legacy interconnection of REN sources to an AC grid. The power source can be PV, wind generator, fuel cell or an engine-generator possibly using biofuel.

The REN output power is converted into AC and either can be sold only or can be used by all loads in the site and only the excess sold to the AC supplier.

The drawback of AC injection is that the inverter must be stopped in case of grid interruption which is a standard of grid inverters to avoid electrocuting people undertaking interventions on the AC grid.

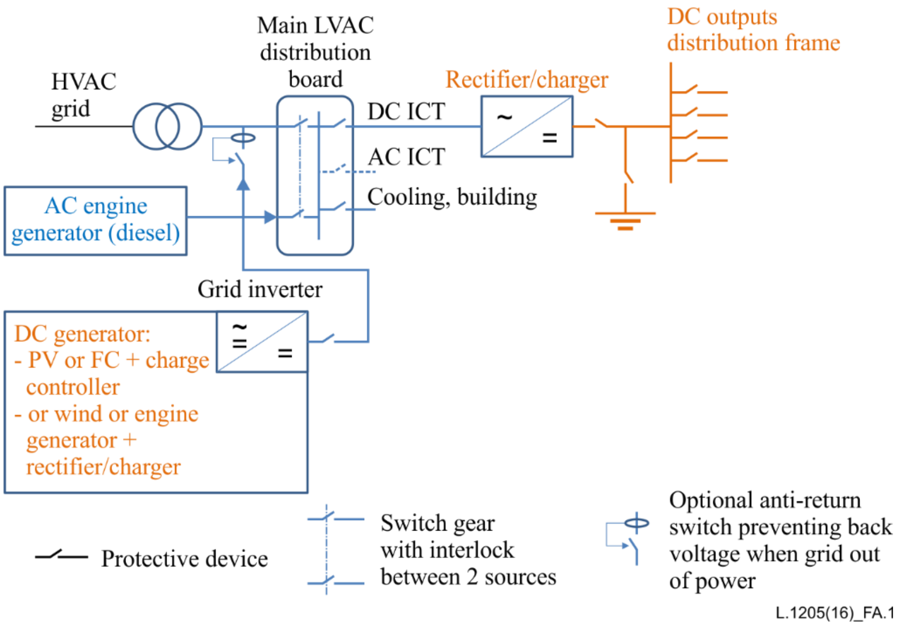

Figure A.1 – Interconnection of REN on AC site input

A.2 Interconnection of REN on single and multiple DC distribution system

Figure A.2 shows the interconnections of REN on a DC system. The source output power is converted into DC, so only DC load can use it and excess power is not sold to an AC grid. The advantages are higher efficiency of self-consumption of renewable energy and no need for interruption in the case of an AC grid interruption as there is no power injection in the AC grid.

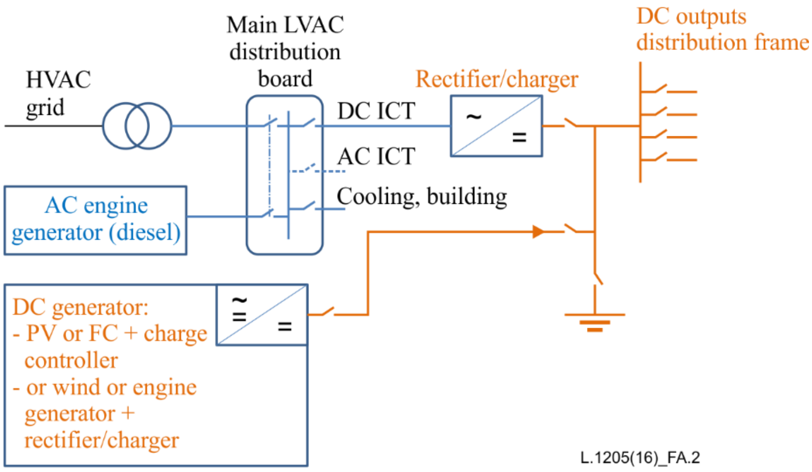

Figure A.2 – Interconnection of REN on DC system

Figure A.3 presents interconnection of a REN to multiple DC systems possibly in redundant configuration or not.

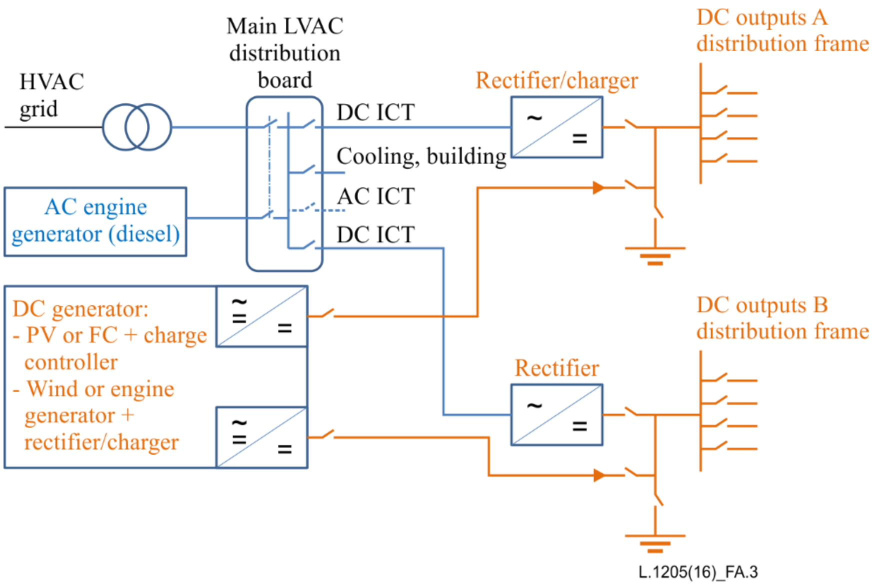

Figure A.3 – Interconnection of REN on multiple DC systems

A.3 Interconnection of REN on single or multiple AC distribution frame

Figure A.4 shows REN source output power converted into AC and injected into an AC frame, so all site loads can use it. This configuration is a simple solution for self-consumption and peak shedding to reduce the AC grid power contract and its cost. However it needs an AC synchronized inverter stop when there is intervention on the AC grid and it is less efficient than using directly REN DC as it needs two conversion stages: inverters followed by rectifiers.

It could be possible but complicated to run on renewable energy without stopping the inverter, when the AC grid is interrupted, if the AC transfer switch can be safely disconnected from the AC grid. This can be done by another switch. Unless the power contract so specifies it does not allow selling the excess power.

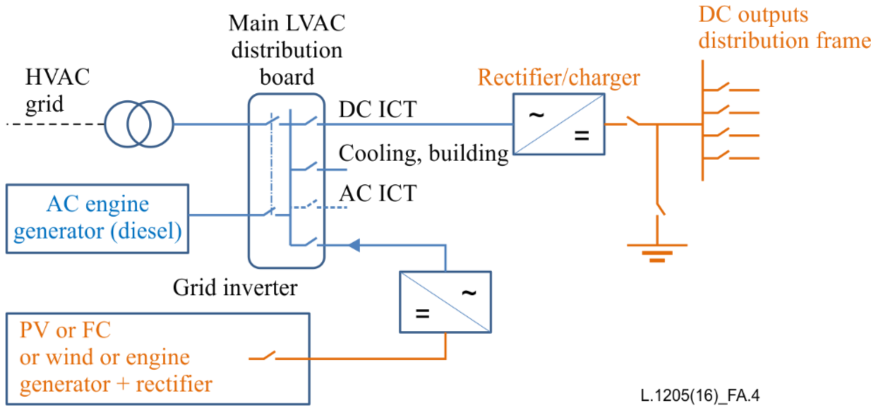

Figure A.4 – Interconnection of REN on AC distribution frame and DC system

Figure A.5 shows injection of REN energy in a redundant AC distribution in a site.

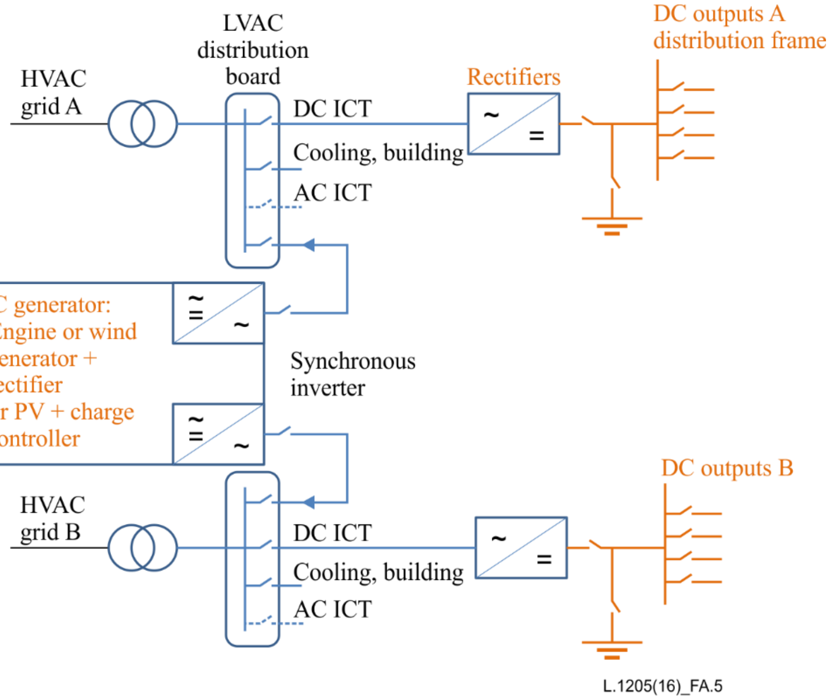

Figure A.5 – Interconnection of REN on a redundant AC distribution frame

A.4 Hybrid interconnection of REN on AC and DC distribution

Figure A.6 shows a hybrid injection of a REN source on AC and DC sides. The REN source output power is converted into DC and AC, so all site loads can use its power.

This configuration is more complex but allows maximum efficiency and reliability for DC use.

This configuration is a simple solution for self-consumption and peak shedding to reduce the AC grid power contract and its cost.

It may allow sale of the excess power under certain conditions on the AC switch gear as described in clause A.3.

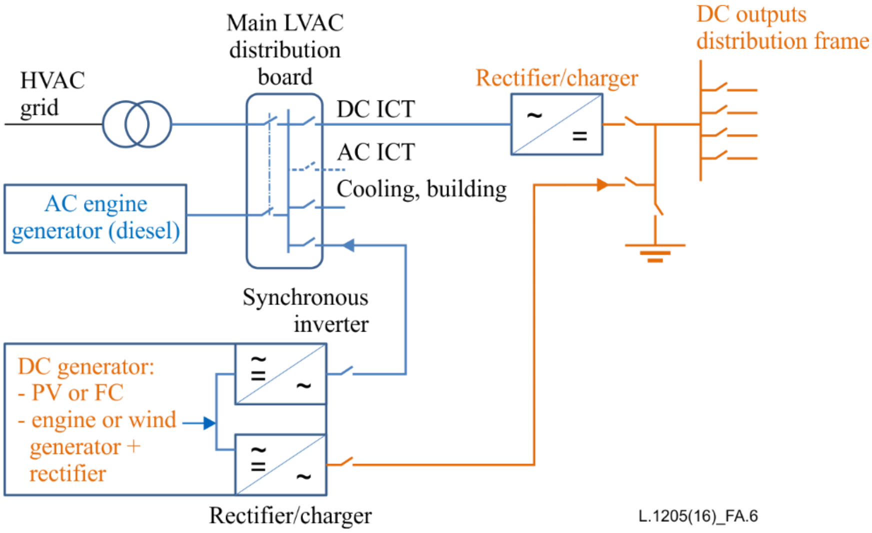

Figure A.6 – Hybrid interconnection of REN on AC and DC

Figure A.7 shows a variant of a hybrid configuration where the DC is secured by a DC biofuel engine generator, while the PV or wind energy is injected on AC distribution on all site loads and can be sold under certain conditions as described in clause A.3.

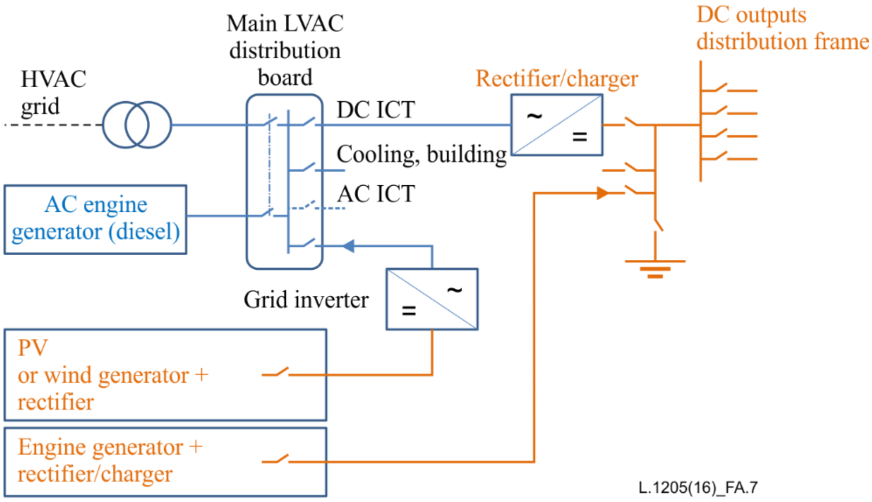

Figure A.7 – Hybrid interconnection of REN on AC and DC

A.5 Interconnection of REN to a DC nano or micro grid

Figure A.8 shows a possible interconnection of REN systems of a site to a DC micro or nano grid, the local REN source being already coupled to AC and DC systems of the site.

The energy exchange can be bidirectional between the site and the micro or nano grid by importing or exporting energy at a given voltage range e.g., at up to 400 VDC as defined for remote powering in [b-ETSI EN 302 099].

The REN energy can be imported from a REN source of another telecom/ICT site or from a REN source located outside the site (e.g., a PV array on a nearby building roof or a wind machine on a windy place far from inhabitants). This is done through an interface converter to an internal power bus of the local REN system of sources.

The imported energy is then considered as being from a virtual local REN source and can be managed as the local REN sources energy though a coupling converter to the AC or DC systems of the site.

On the other end the local REN source energy production can also be exported to the DC grid, by the interface conversion when it is made in a bidirectional arrangement.

The detailed control of power exchange on the DC micro or nano grid is out of the scope of this Recommendation.

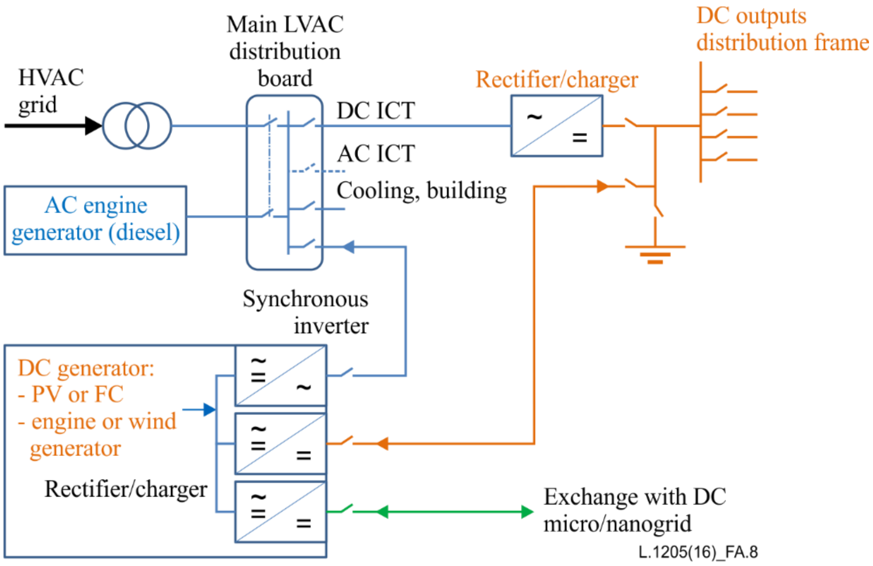

Figure A.8 – Interconnection of REN source to a DC micro or nano grid

Appendix I

Details on coupling solution of REN generator to an up to 400 VDC system

(This appendix does not form an integral part of this Recommendation.)

This appendix proposes some solutions for coupling a REN generator to an up to 400 VDC system:

1) Voltage follower REN solution:

REN energy is supplied by an output power stage controlled at a voltage a little bit higher than the rectifier charge voltage. This solution is equivalent to the so called "pulse width modulation (PWM) solar controller" following the battery voltage, to avoid any discharge and using the maximum REN possible. The voltage difference shall be very low to avoid a rectifier control fault alarm by the controller.

To maintain control of the battery charge current and voltage, a protocol between the DC system control and the REN system is required to exchange settings and also a measurement of the sum of REN and rectifier current into the battery. This solution may be difficult to adjust and can be unstable with changes of load or REN power.

2) Converter coupling solution:

This solution eliminates the difficulties of control described in solution 1). Some 400 VDC power system manufacturers are providing DC/DC converters equivalent to AC/DC rectifiers that can work coupled in parallel on the output DC bus. They are controlled by the same system control unit, so that it is easy to keep exactly the same battery management with AC and DC inputs. This is a very stable and reliable solution based on the same DC system manufacturer. There is no need for complex output power stages on the REN power system.

It may be difficult to mix manufacturers solutions as there is no interoperability standard between DC/DC converters and AC/DC rectifiers.

3) Double input up to 400 VDC system (optimized solution):

Rectifiers could be created with 2 inputs, one AC and one DC, avoiding additional rectifiers for REN as in solution 2). In this solution the priority of REN power shall be managed inside each converter.

NOTE – In the voltage follower solution 1), the additional voltage should be adjustable and not higher than 500 mV compared to the normal operation of the power system without the renewable energy system in order to avoid a too high floating voltage reducing the battery life.

A simple solution is to slightly reduce the battery floating voltage setting of the DC power system to avoid this overvoltage. For example, when using a PV system and adding a delta of +300 mV on the PV regulator, the control unit (CU) floating voltage could be set at −150mV in order to compensate. On day time, the voltage will be at +150 mV of the ideal floating voltage, on night time, it will be at −150 mV. These values are indicative and would need more feedback from field experiments.

Appendix II

Control/Monitoring considerations for renewable energy system connexion to AC and DC points in DC systems

(This appendix does not form an integral part of this Recommendation.)

This appendix provides some solutions (cases 1 and 2) of renewable energy power flow from a site or from a DC micro grid control to a single up to 400 VDC power source. This appendix also explains some typical issues identified in this situation.

Case 1:

Figure II.1 shows renewable energies interconnection to the up to 400 VDC power feeding system. With regard to this configuration, when the amount of power feeding energy of renewable energy sources exceeds the power consumption of the ICT equipment, there would be a flow of redundant energy to the 'storage for backup', which when it is fully charged could result in the battery being overcharged.

In order to avoid this situation, it would be necessary to detect the output current of the rectifier function (RF) using a current transducer (CT) sensor. This CT should give the capability of controlling the amount of current from the renewable source using the control unit, shown in Figure 1, in order for the output current of the RF not to be equal to zero or flow in reverse.

It should be noted that excess energy from the renewable source, which is not used for power feeding, will be kept in the local battery temporarily or sent back to the building's AC grid and air conditioning system in the case of power failure. When there is a shortage of renewable energy, the local battery would be discharged in order to stabilize the power feeding system.

The dotted line indicates different points of connexion for a DC power feeding system:

– when the renewable source is connected to the DC power feeding line in between the RF and the backup battery, all of the ICT equipment can be powered, alternatively

– when the renewable source is connected to the PSU, a specific ICT equipment can be powered, with which a different quality of power feeding would be possible.

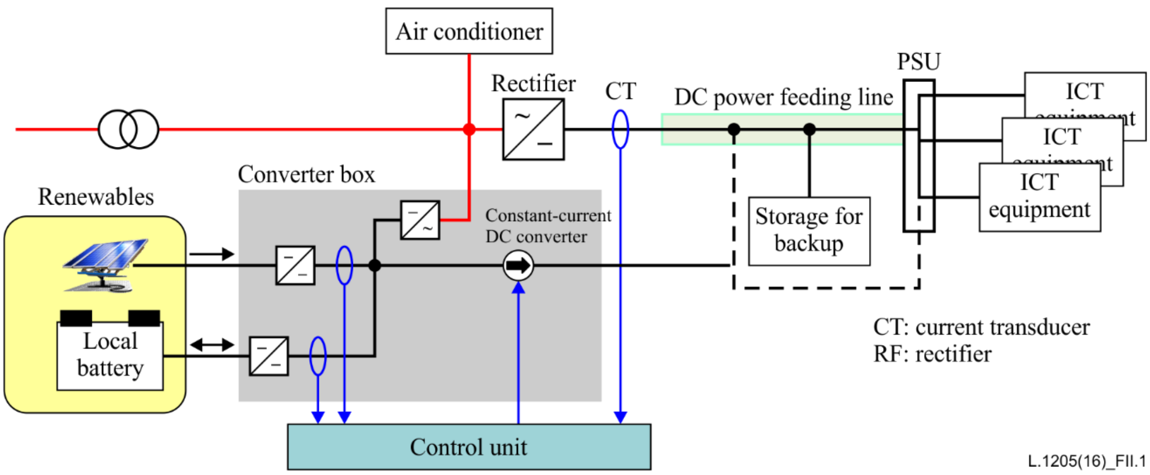

Figure II.1 – Renewable energies interconnection to the up to 400 VDC power feeding system (Case 1)

Case 2:

Figure II.2 shows a similar configuration to that in Figure II.1 except that there is no DC/DC convertor for charging/discharging the local battery. In this case, the voltage of the local DC bus in the converter box is equal to that of the local battery. This would make the voltage of the local DC bus stable due to the local battery.

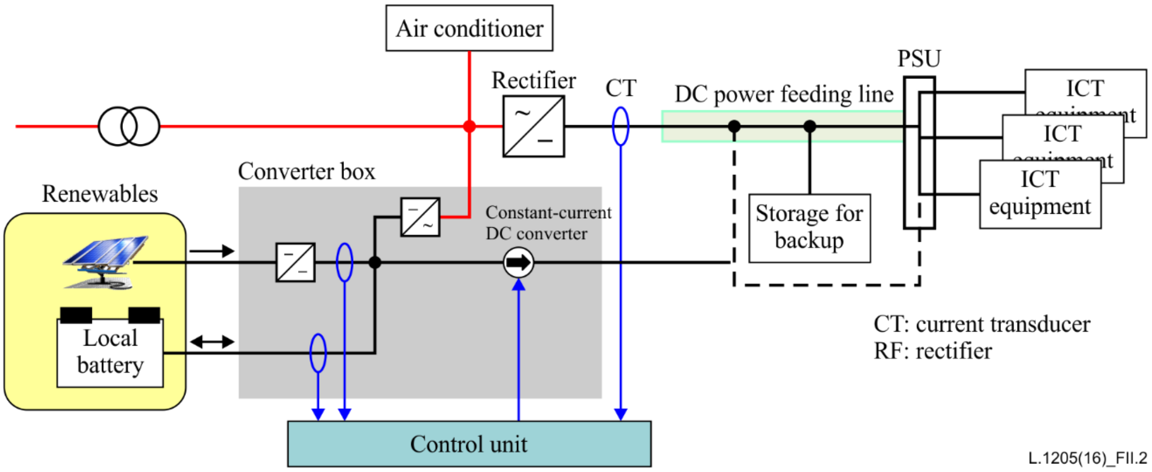

Figure II.2 – Renewable energies interconnection to the up to 400 VDC power feeding system (Case 2)

Appendix III

General consideration for sizing and power coupling of REN system to up to 400 VDC systems

(This appendix does not form an integral part of this Recommendation.)

III.1 General conditions impacting on the REN sizing and power coupling

The effects and interactions of REN or distributed power on the site power system are linked to the REN system power sizing.
The specification of proper power sizing of the REN system connected to the 400 VDC takes into account:

– the power range of the generator
– the variability of production (e.g., zero power by night on PV)
– the self-consumption condition
– the availability of excess of production at some periods
– the authorization of injection in the building AC distribution or in DC micro grid or in public AC grid as it introduces another level of complexity
– the level of possible interactions to the 400 VDC system stability and reliability

III.2 Monosource system

Power thresholds or limits to renewable energy injection e.g., site self-consumption can be defined for a mono REN source with or without battery storage.

Table III.1 gives an example of a rough estimation of energy self-consumption and power and energy injection on an external grid. Precise calculation should be done considering local data for renewable energy and a precise local power consumption profile.

Table III.1 – Example of estimation of energy self-consumption and power and energy injection on an external grid with average French meteo data and a constant power telecom use

Study case	REN peak power/average used power (Pu)	Energy storage (h)	REN yearly energy production: % of Pu*8766	Injected power on grid/Pu	Energy excess injected to grid
1	1	0	5 to 20%	0	0
2	3	0	20 to 40%	2	50 to 90%
3	3	12 to 24	60 to 80%	2	0
4	10	12 to 24	80 to 100%	9	2 to 300%

It appears clearly that case study 1 corresponds to a simple and efficient self-consumption

Case 3 is an improvement of case 2, by adding a reasonable energy storage and leads to a high rate of self-consumption, avoiding a grid connection or losing to much excess of REN production.

Case 4 is a case where the REN generator covers more the local use but would have to send much more energy on an external grid to be competitive as it is highly oversized related to the local load.

III.3 Multisources management and balance between power sources and backup batteries

During the condition of unbalanced power supply in which much more power than the power consumption of ICT equipment is supplied from distributed power sources to the power feeding system, there is a high risk of accelerating the degradation of backup batteries that are in a floating condition. Therefore, it is necessary to adjust the balance of supplied power among multiple power sources.

It is necessary to make a balance adjustment among power sources.

When there is no possibility of injecting the excess of produced renewable energy from the site into an external electric grid, it can be interesting to use other batteries than those optimized for back-up and floating, in order to absorb as much of the maximum renewable power as possible and give it back when renewable energy is not productive (e.g., by night for PV)

The best choice of battery could be cycling batteries that can stay in a partial charge state without degradation. This is one problem of the lead-acid technology, it needs a full recharge regularly to avoid sulphating degradation mode. Lithium and nickel technologies do not suffer from partial charge ageing. Even for lithium it is the contrary as it ages faster when fully charged.

Bibliography

[b-ITU-T L.1204] Recommendation ITU-T L.1204 (2016), *Extended architecture of power feeding systems of up to 400 VDC*.

[b-ITU-T L.1302] Recommendation ITU-T L.1302 (2015), *Assessment of energy efficiency on infrastructure in data centres and telecom centres.*

[b-ITU-T L.1350] Recommendation ITU-T L.1350 (2016), *Energy efficiency metric of a base station site.*

[b-ITU-T L.1410] Recommendation ITU-T L.1410 (2014), *Methodology for environmental life cycle assessment of information and communication technology goods, networks and services.*

[b-ETSI EN 302 099] ETSI EN 302 099 V2.1.1 (2015), Environmental Engineering (EE); *Powering of equipment in access network.*

[b-Arena] Australian Government – Australian Renewable Energy Agency <http://www.agf.org.uk/pubs/pdfs/1232web.pdf>

[b-ecodesigned DC] C. JAOUEN, B. MULTON, F. BARRUEL (2011), *Wiring design based on Global Energy Requirement criteria: a first step towards an eco-designed DC distribution scheme*, IREED 2011, Lille 23-24 March, 7 p.

[b-Emerson Case Study] Sara Maly Lisy, Mirna Smrekar Emerson Network Power, IEEE/Intelec (2014) paper quoted on Emerge Alliance, *Three Case Studies of Commercial Deployment of 400V DC Data and Telecom Centers in the EMEA Region*, http://www.emergealliance.org/portals/0/documents/events/intelec/TS01-2.pdf

[b-Emerson DC REN] 400V DC Power Solutions from Emerson Network Power, *Innovative Power Architecture for Data Center and Telecommunications Sites.* http://www.emersonnetworkpower.com/documentation/en-US/Products/DCPower/ensys-400v-ac-dc-power-systems/Documents/400V-DC-Power-Solutions-Brochure.pdf

[b-greenstar] K.K. NGUYEN et al. (Projet GreenStar) (2011), *Renewable Energy Provisioning for ICT Services in a Future Internet Future Internet Assembly, LNCS 6656 (open access at SpringerLink.com)*, pp. 421–431.

[b-huawei] Micro grids: *A bright future*, http://www1.huawei.com/enapp/198/hw-110948.htm

[b-IEC Vocab] IEC vocabulary: http://www.electropedia.org/iev/iev.nsf/index?openform&part=191

[b-IEEE/Intelec 2013] IEEE/Intelec 2013, Hamburg, Toshimitsu Tanaka et al. NTT, *DC power wide spread in Telecom/Datacenter and in home/office with renewable energy and energy autonomy.*

[b-Starline] David E. Geary, STARLINE, *Phasing Out Alternating Current Directory: An Engineering Review of DC Power for Data Centers.*

[b-Vicor Stephen] Vicor White paper, Stephen Oliver, *High-voltage DC distribution is key to increased system efficiency and renewable-energy opportunities*, http://www.vicorpower.com/documents/whitepapers/wp-High-voltage-DC-Distribution.pdf

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