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Methodologies for evaluating the performance of an up to 400 VDC power feeding system and its environmental impact

Recommendation ITU-T L.1202

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Recommendation ITU-T L.1202

Methodologies for evaluating the performance of an up to 400 VDC power feeding system and its environmental impact

Summary

Recommendation ITU-T L.1202 is provided as a complement to Recommendation ITU-T L.1201, which describes the architecture of direct current (DC) power systems with an up to 400 VDC information and communication technology (ICT) equipment interface. The up to 400 VDC ICT equipment interface is described in Recommendation ITU-T L.1200.

Recommendation ITU-T L.1202 provides a framework for assessing performances of up to 400 VDC power feeding systems and the savings incurred when compared to other power feeding systems such as the –48 VDC power system and the AC uninterruptible power system (UPS) commonly used in information and communication technology (ICT) sites.

This Recommendation deals with performance factors such as efficiency, reliability/availability and environmental impact.

History

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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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Introduction

The architecture of direct current (DC) power systems with an up to 400 VDC ICT equipment interface [ITU-T L.1200] is recommended in [ITU-T L.1201]. This Recommendation compliments [ITU-T L.1201] providing a framework for assessing the performances of up to 400 VDC power feeding systems and savings incurred when compared to other power feeding systems such as the –48 VDC power system and the AC UPSs commonly used in ICT sites.

Energy efficiency results obtained by applying this Recommendation can be used as input for the evaluation of the energy efficiency performance of DC power systems for up to 400 VDC equipment in data centres and telecommunication centres. A comparative assessment approach as described in [ITU-T L.1320] allows an energy efficiency measurement of the up to 400 VDC power feeding system at the level of the equipment to be compared with the energy efficiency measurement of other power equipment.

A gain in energy savings of 5% to 20% has been assessed for the up to 400 VDC power feeding system in many papers and presentations (see Bibliography).

This Recommendation also reports other benefits in terms of reliability, maintainability, scalability and reduced electric power disturbance when compared to AC UPS and distribution systems.

This Recommendation provides assessment tools for reliability and recommends comparative assessment methods.

Gains are also foreseen in terms of battery use and in terms of the environmental impact and waste reduction with a reduced electronic conversion stage. As there is no loss in inverters with fewer current ripples, the battery can last longer or its capacity can be slightly reduced. This Recommendation recommends using the general life cycle environmental assessment method described in [ITU-T L.1410] as the basic approach.

Recommendation ITU-T L.1202

Methodologies for evaluating the performance of an up to 400 VDC power feeding system and its environmental impact

1 Scope

This Recommendation provides a comparative performance assessment of the up to 400 VDC power feeding system using the interface described in [ITU-T L.1200] and installed in telecommunications centres, data centres and customer premises, to determine the environmental savings of the new power feeding architectures defined in [ITU-T L.1201].

The performances evaluated include efficiency performance, reliability performance and environmental impact over life cycle, based on ITU-T Recommendations on metrics and assessment methodologies.

Other issues such as electrical disturbances, EMC, scalability and maintenance performance are partially covered.

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), <i>Direct current power feeding interface up to 400 V at the input to telecommunication and ICT equipment.</i>
[ITU-T L.1201]	Recommendation ITU-T L.1201 (2014), <i>Architecture of power feeding systems of up to 400 VDC.</i>
[ITU-T L.1320]	Recommendation ITU-T L.1320 (2014), <i>Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres.</i>
[ITU-T L.1410]	Recommendation ITU-T L.1410 (2014), <i>Methodology for environmental life cycle assessments of information and communication technology goods, networks and services.</i>
[IEC 62040-3]	IEC 62040-3:2011, <i>Uninterruptible power systems (UPS) – Part 3: Method of specifying the performance and test requirements.</i>
[ATIS-0600015.04.2010]	ATIS-0600015.04.2010, <i>Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting DC Power Plant – Rectifier Requirements.</i>

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 availability (performance): The ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.

NOTE 1 – This ability depends on the combined aspects of the reliability performance, the maintainability performance and the maintenance support performance.

NOTE 2 – Required external resources, other than maintenance resources do not affect the availability performance of the item.

3.2.2 dependability: The collective term used to describe the availability performance and its influencing factors: reliability performance, maintainability performance and maintenance support performance.

NOTE – Dependability is used only for general descriptions in non-quantitative terms.

3.2.3 reliability (performance): The ability of an item to perform a required function under given conditions for a given time interval.

NOTE 1 – It is generally assumed that the item is in a state to perform this required function at the beginning of the time interval.

NOTE 2 – Generally, reliability performance is quantified using appropriate measures. In some applications, these measures include an expression of reliability performance as a probability, which is also called reliability.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
COP	Coefficient of Performance
DC	Direct Current
EMC	Electromagnetic Compatibility
ICT	Information and Communication Technology
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
PDU	Power Distribution Unit
PFC	Power Factor Correction
PSU	Power Supply Unit
TEER	Telecommunications Energy Efficiency Ratio
THD	Total Harmonic Distortion
UPS	Uninterruptable Power System
VDC	Volts DC

5 Comparative evaluation of energy efficiency of up to 400 VDC systems

This clause presents parameters of up to 400 VDC power feeding systems concerning energy efficiency assessment such as the input power factor, power system energy efficiency and ICT equipment power supply unit (PSU) energy efficiency. The energy saving characteristics of up to 400 VDC power systems can be assessed and compared to UPS or –48 VDC systems.

The system energy efficiency shall be defined considering the general power feeding architecture to be as recommended in [ITU-T L.1201] and shall be assessed from the power feeding AC input (AC UPS, up to 400 VDC power feeding system, etc.) to the output of the alternating current (AC) or direct current (DC) PSU inside the ICT equipment. Figure 1 shows the basic architecture considered for this efficiency assessment from power input to output.

In AC and up to 400 VDC power feeding systems, when the rectifiers have no insulation, a transformer is used between the AC input and the rectifier input and its efficiency shall be taken into account. The energy efficiency measurement shall be made according to the assessment principle of [ITU-T L.1320].

In addition, for more precise determination and especially for a comparative benchmark between power feeding architectures, the efficiency shall be assessed in terms of instant power and in terms of consumed energy over a defined period. This is to take into account second order parameters such as load rate variation and thermal environments variation for components with power efficiency characteristics depending on these parameters. For this purpose, full characteristics of power system elements (rectifiers, AC UPS and AC or DC PSU) including their load rates and temperatures shall be provided by manufacturers upon user request.

The purpose of this Recommendation is to propose a more precise assessment of efficiency performance and a comparative benchmark of power feeding architectures e.g., –48 VDC or AC UPS or up to 400 VDC power feeding architectures, from the AC input to the input of the ICT device PSU.

According to [ATIS-0600015.04.2010], the evaluation of rectifier efficiency for up to 400 VDC power feeding systems shall be performed using the TEER ratio (see Appendix I.2). The telecommunications energy efficiency ratio (TEER) is measured from 30% to 80% load rates at every 10% on reference test loads at the output of the rectifier and system with defined AC input characteristics. These load rates are expected in the operational area of the rectifier in the field. Examples of efficiency values are given for different technologies (switched mode, ferro-resonant mode, etc.)

For AC UPS, annex J of [IEC 62040-3] shall be used as a reference. It specifies measurement load rate points of 25%, 50%, 75% and 100% efficiency on reference test loads with defined AC input characteristics.

AC or DC PSU efficiency is defined in clause 5.3.

5.1 Accuracy and additional measurements

The level of accuracy required for laboratory measurement devices used to assess the efficiency of DC systems is $\pm 1\%$ for each of the electrical parameters such voltage and current. This is in order to obtain repetitive measurements within a maximum range of $\pm 3\%$ accuracy on the power measurements made with the same measurement device on inputs and outputs. Note that accuracy and measurements for AC-UPSs are specified in [IEC 62040-3]. The measurement shall be carried out at an ambient temperature of between 20 and 25°C.

Additional measurements in different conditions should be provided:

- Efficiency values at 5-10°C, 20-25°C and 30-35°C
- Efficiency values with different AC input voltages e.g., at maximum and minimum values of the public grid voltage range considered in the country
- These measurement shall be carried out at the load rate as defined in clause 5.

NOTE 1 – In the efficiency assessment of an up to 400 VDC power feeding system and DC PSU, shunt resistance or current transformers should be used for current value measurement. When using current transformers, the current transformer should be arranged in relation to the cable direction in order to minimize measurement errors. Points of voltage measurement and length of power cables should be carefully considered

to avoid systematic errors due to losses and additional disturbances induced in the cables that should be accounted for separately as shown in Figure 1.

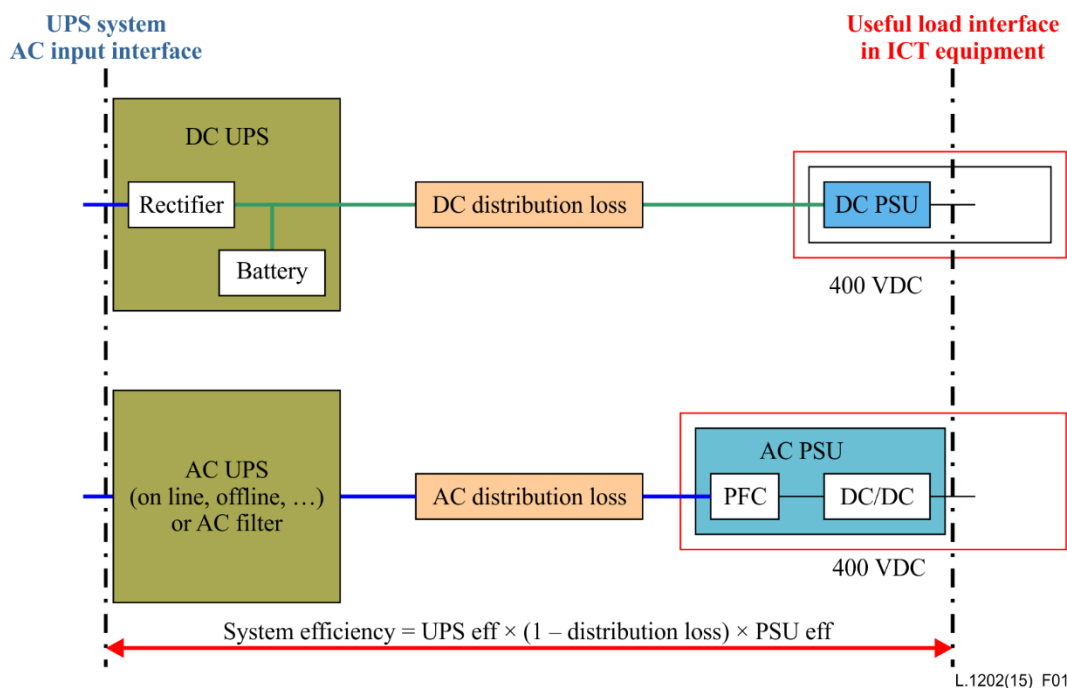


Figure 1 – AC/DC power feeding architectures and components efficiency

NOTE 1 – Not all elements (e.g., transformers) are represented in Figure 1.

NOTE 2 – DC energy injection (e.g., from renewable energy) in the power chains is not considered in this Recommendation.

5.2 AC input power factor

The AC power factor correction (PFC) is generally performed in the rectifier input stage of the AC or up to 400 VDC power feeding system and inside the AC PSU of the ICT equipment.

In general, it is considered that the PFC stage efficiency does not significantly affect the power rectifier or AC PSU efficiency values, as the loss of the PFC is mainly compensated for by the higher efficiency of the DC/DC stages that follow.

The power factor value shall be provided at the load rates defined in clause 5 for the TEER of DC rectifiers, AC UPSs and PSUs. The measurements shall be carried out at an ambient temperature of between 20 and 25°C. Additional measurements in different conditions should be provided as defined in clause 5.1.

5.3 System energy efficiency

The system energy efficiency is the combination of the efficiency of the different elements in series.

$$\text{System efficiency} = \text{UPS efficiency} \times (1 - \text{distribution loss}) \times \text{PSU efficiency}$$

In this approach, the UPS and PSU can be of AC or DC input type.

A hybrid architecture with both DC and AC inputs can be considered in which the AC UPS may be replaced by an AC filter without battery only suppressing fast surges and transient of the AC grid. Power feeding system topologies are shown in Figure 10 of clause 6.1. The efficiency measurement of the AC filter shall be provided with same load requirements provided for the UPS in clause 5 for AC UPS.

The efficiency measurement points are important in the system efficiency calculation. The measurement points should be from 30% to 80% load rate at 10% intervals or from 0% to 100% load

rate at 25% intervals. The efficiency measurement points (i.e., load rates at 10% intervals and 25% intervals) should be the same when comparing AC systems and DC systems.

NOTE – In the efficiency assessment of up to 400 VDC power feeding systems and DC PSUs, shunt resistance or DC current probes should be used for current value measurements. When using DC current probes, the position of the DC current probe must be adjusted in order to get accurate data.

Additional measurements in different conditions should be provided as indicated in clause 5.1.

5.4 Energy efficiency of ICT equipment PSU

The assessment shall comply with assessment principles indicated in [ITU-T L.1320].

The efficiency of ICT equipment PSUs may vary according to load rate and temperature. With the same PSUs the efficiency can vary significantly according to room temperature dependent on internal fans operation. Differences in PSU efficiency may depend on load rate. When the PSU is a replaceable module, PSU efficiency should be measured by manufacturers in laboratory conditions.

PSU efficiency measurement points should be from 30% to 80% load rate at 10% intervals or from 25% to 100% load rate at 25% intervals. An additional 10% load should also be provided for the consideration of low load operation.

The efficiency measurement accuracy is as defined in clause 5.1. Additional measurements in different conditions should be provided as defined in clause 5.1.

5.5 Comparative energy efficiency of the power feeding system

The efficiency performance range of some AC and up to 400 VDC systems or hybrid AC/DC system architectures can be assessed for performance comparison purposes. See Table I.2 in Appendix I for an example of an efficiency comparison between various power feeding architectures.

For DC or hybrid AC/DC configurations, the topology refers to [ITU-T L.1201]. In the interests of simplification, only redundant configurations are considered, but efficiency values could be slightly better in non-redundant architecture, mainly due to a higher load rate on the UPS and PSU. There may be relatively significant differences between minimum and maximum efficiencies.

The proposed values were sourced from papers listed in the Bibliography. Other values can be found in existing and future products by applying the measurement method defined in this Recommendation for the AC or DC power feeding system. Appendix II also provides measured efficiency values for AC UPS and up to 400 VDC power systems.

6 Methodology for evaluating the reliability/availability performance of up to 400 VDC power feeding systems

6.1 Reliability model for system failure rate and availability assessment

As for efficiency, reliability can be compared between DC systems and AC UPS in terms of failure rate, simplicity of operation and maintenance and weaknesses and strengths of the architecture.

A rough comparison is provided in Appendix VII giving the range of reliability or availability commonly recognized through general approaches described in Appendix III. The up to 400 VDC power feeding systems appear to have advantages compared to AC power feeding systems with respect to reliability.

A more detailed reliability and availability calculation needs a lot of environmental and use conditions to be defined for determining precise reliability data for components such as that used for rectifiers in the availability calculation. More information on other approaches for reliability/availability assessment is also provided in Appendices V and VI.