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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

Total network infrastructure energy efficiency metrics

Recommendation ITU-T L.1332

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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.1332

Total network infrastructure energy efficiency metrics

Summary

Recommendation ITU-T L.1332 contains the basic definition of energy efficiency metrics and measurement methods required to evaluate the energy efficiency of a total network, including the energy consumption for:

– all telecommunication (TLC)/information and communications technology (ICT) equipment in the network;
– all facilities equipment (e.g., cooling systems, site monitoring systems, fire protection and lighting systems;
– energy losses in DC power station or AC UPS and in the power distribution;
– maintenance activities and site-visit energy used for transportation (e.g., by car);
– diesel generators used for emergency purposes.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1332	2018-01-13	5	11.1002/1000/13459

Keywords

Energy efficiency, facilities, methodology, metrics.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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.

NOTE

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Introduction

The facilities or infrastructure parts of an information and communication technology (ICT) network are composed, at a minimum, of the following:

– alternating current (AC) infrastructure;

– AC/direct current (DC) or uninterruptable power source (UPS) conversion with batteries;

– backup systems (e.g., diesel generators);

– cooling systems.

Without optimization, it is commonly considered that 50 per cent of the energy used in a telecommunication (TLC) installation is used or wasted by the infrastructure.

Figure 0-1 shows an example of the energy loss distribution in a generic TLC site from high-voltage (HV) to ultra-low-voltage equipment used inside an ICT site.

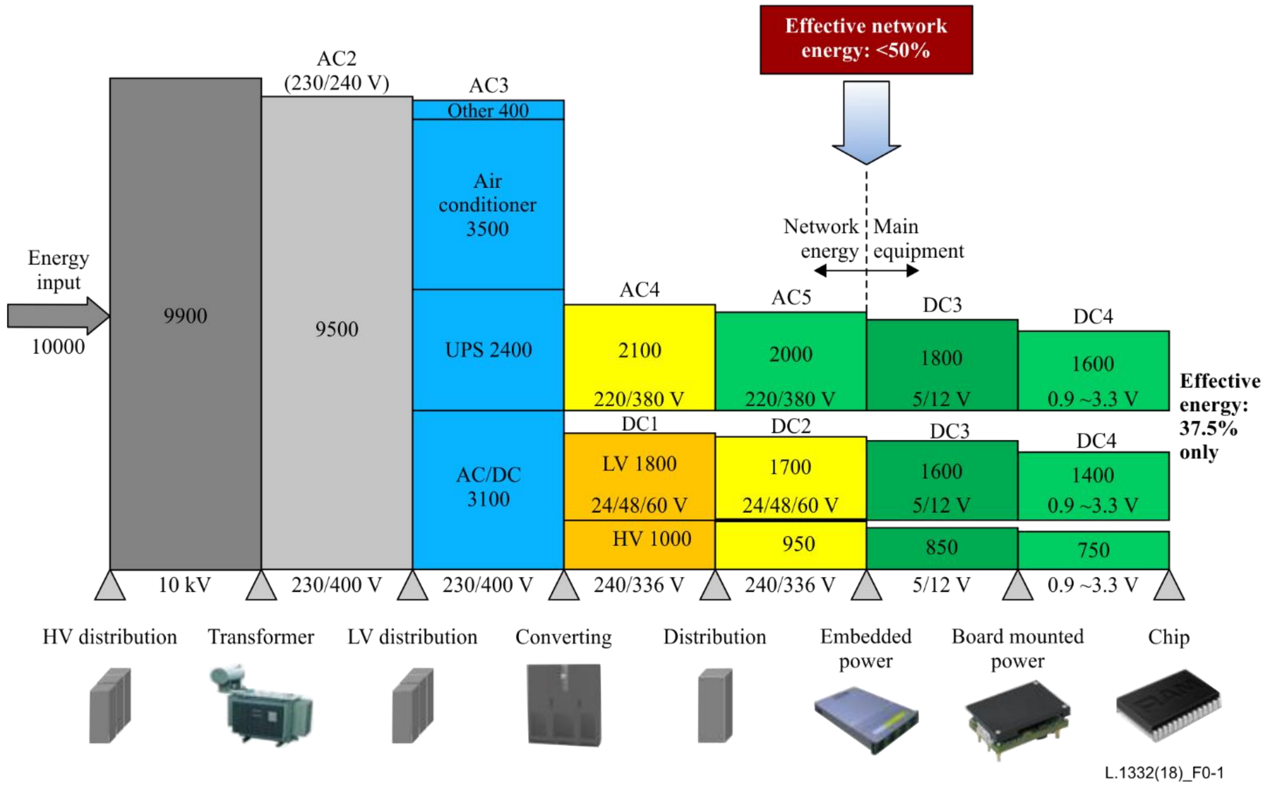

Figure 0-1 – Distribution of energy loss in an ICT site from HV electric input to final use in ICT chips at ultra-low voltage

To reduce the energy consumption and environmental impact of a TLC network it is useful to standardize a simple evaluation of the effect of power-reduction actions on the total energy consumption and wasted energy of the system.

An indicator that considers the distribution of energy consumption from site input to final load in a network is useful. The power usage effectiveness (PUE) indicator is commonly used in data centres. PUE is the following ratio:

$$PUE = \frac{Total\ power\ consumption\ at\ site\ input}{Load\ power\ consumption\ at\ load\ power\ interface}$$

This type of indicator does not give sufficient information to evaluate the environmental impacts of infrastructure and losses inside the equipment itself, nor for energy used for external operations and maintenance activities.

It is important to consider the total energy used by a network as this impacts the environmental and economic sustainability of the network.

For example, the use of renewable energy shall be taken into account when considering the total environmental impact. It is necessary to consider different infrastructure solutions, possibly with different classes of energy sources on the total energy, and not only focus on electricity consumption and losses in the network.

The total energy use includes energy consumption of:

– loads;
– power system losses (power station, UPS, feeder, transformer) including energy consumption of power cooling systems;
– power and environment monitoring systems;
– site and core-room fire protection systems;
– lighting of site and core-rooms;
– electric distribution losses;
– site-visit fuel consumed by vehicles;
– generators (diesel).

Some standards developing organizations (SDOs) are defining key performance indicators (KPI) for energy management of operational infrastructure; these indicators are more related to how energy is managed in a network or in its elements.

Recommendation ITU-T L.1332

Total network infrastructure energy efficiency metrics

1 Scope

This Recommendation specifies principles and concepts of energy efficiency metrics and measurement methods to evaluate the energy efficiency of an entire network consisting of telecommunication equipment and infrastructure equipment.

This Recommendation also develops the methodology to consider the influence on total energy consumption including maintenance activities; by establishing methodologies which consider the energy necessary for the transport activities embedded in the maintenance phase.

Energy sources of different natures are taken into account in this Recommendation.

For concepts of energy efficiency, see [ITU-T L.1315].

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.1315] Recommendation ITU-T L.1315 (2017), *Standardization terms and trends in energy efficiency*.

[ITU-T L.1330] Recommendation ITU-T L.1330 (2015), *Energy efficiency measurement and metrics for telecommunication networks*.

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

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 AC ICT load: Information and communication technology (ICT) equipment powered in alternating current (e.g., servers, routers).

3.2.2 DC ICT load: Information and communication technology (ICT) equipment powered in direct current (e.g., transmission equipment, access equipment).

3.2.3 high-voltage (HV) connection: High voltage is related to a powering solution in which the rms voltage is higher than 35 kV and lower than 230 kV.

NOTE – This definition is in line with the voltage range established by [b-IEC 60038].

3.2.4 load energy consumption: Energy consumption of ICT equipment present in the network under consideration.

3.2.5 low-voltage (LV) connection: Low voltage is related to a powering solution in which the rms voltage is higher than 100 V and lower than 1000 V.

NOTE – This definition is in line with the voltage range established by [b-IEC 60038].

3.2.6 medium-voltage (MV) connection: Medium voltage is related to a powering solution in which the rms voltage is higher than 1 kV and lower than 35 kV.

NOTE – This definition is in line with the voltage range established by [b-IEC 60038].

3.2.7 total network: ICT network managed by an operator, consisting of: radio access network, fixed access network, core network and data centres that belong to the same operator.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
DC	Direct Current
EloadAC	Energy consumption of AC load
EloadDC	Energy consumption of DC load
HV	High Voltage
ICT	Information and Communications Technology
KPI	Key Performance Indicator
LV	Low Voltage
MV	Medium Voltage
NIEE	Network Infrastructure Energy Efficiency
PUE	Power Usage Effectiveness
RFT-C	Remote Feeding Telecommunication Current
RFT-V	Remote Feeding Telecommunication Voltage
RMS	Root-Mean-Square
SDO	Standards Development Organization
TLC	Telecommunication
UPS	Uninterruptable Power Source

5 Conventions

None.

6 Energy flow in telecommunication networks

Figures 1, 2 and 3 show examples of energy flows from the grid to large, medium and small telecommunication (TLC) installations, respectively.

These examples show only cases where there is no locally generated electrical energy from renewable sources or from engine generators.

Depending on the energy consumption of the site, it is possible to classify sites depending on their grid connection:

– high-voltage (HV) connection;

– medium-voltage (MV) connection;

– low-voltage (LV) connection.

On very large sites e.g., national data centres, the HV connection is adapted to the high-energy consumption of the site.

In this case, located on the information and communications technology (ICT) site there will be a conversion from HV to MV and then a conversion from MV to LV.

The AC LV is used to power the following equipment:

– uninterruptable power source (UPS) for the ICT load/services that need permanent AC;

– AC load, such as air conditioners, that do not need permanent AC;

– DC (direct current) power stations for the ICT load/services.

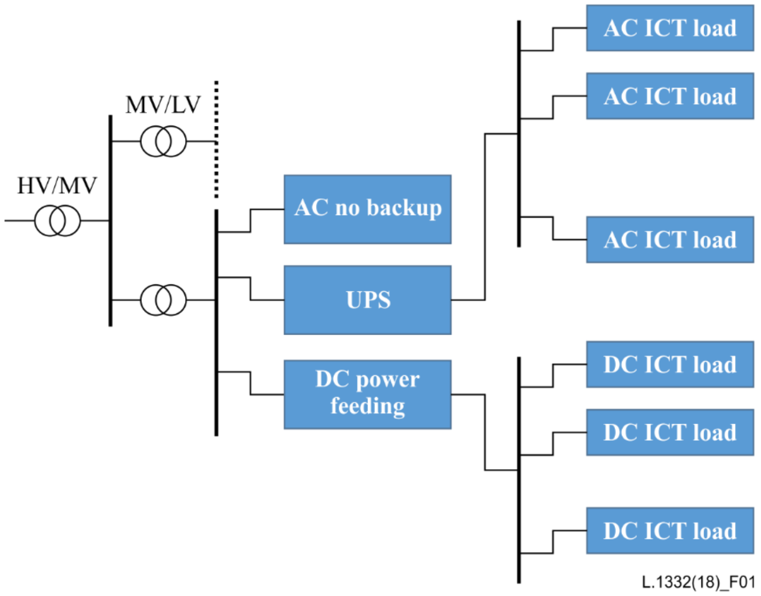

Figure 1 – Energy flow from grid to ICT equipment: large ICT installation

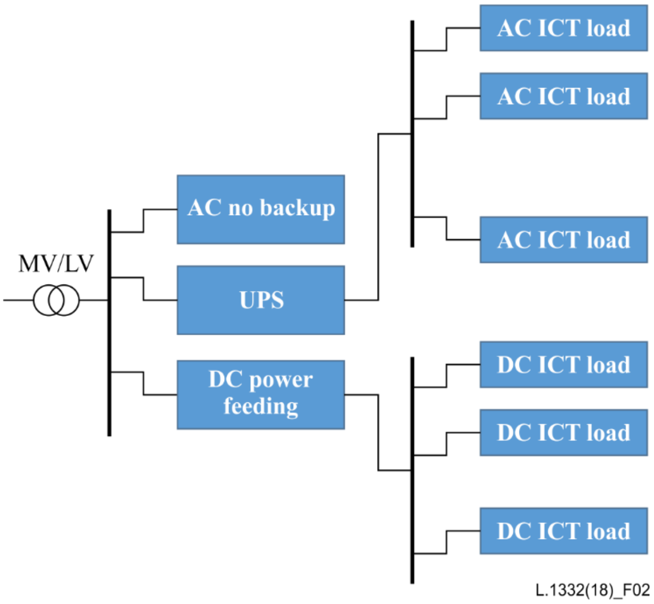

Figure 2 – Energy flow from grid to ICT equipment: medium ICT installation

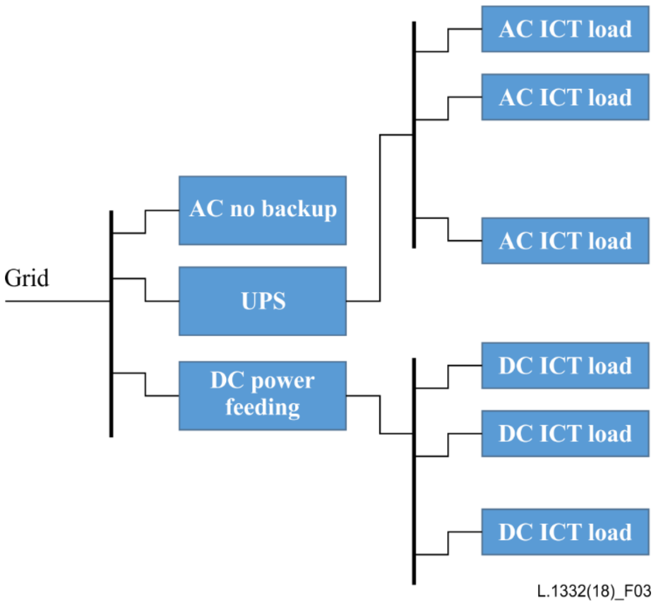

Figure 3 – Energy flow from grid to ICT equipment: small ICT installation

Small ICT sites, use energy flows that do not come only from the grid, but come from renewable energy sources as well.

Two architectures are possible.

Figure 4 shows the case in which renewable energy sources are connected to AC LV power distribution.

Figure 5 shows the case in which renewable energy sources are connected to DC power distribution.

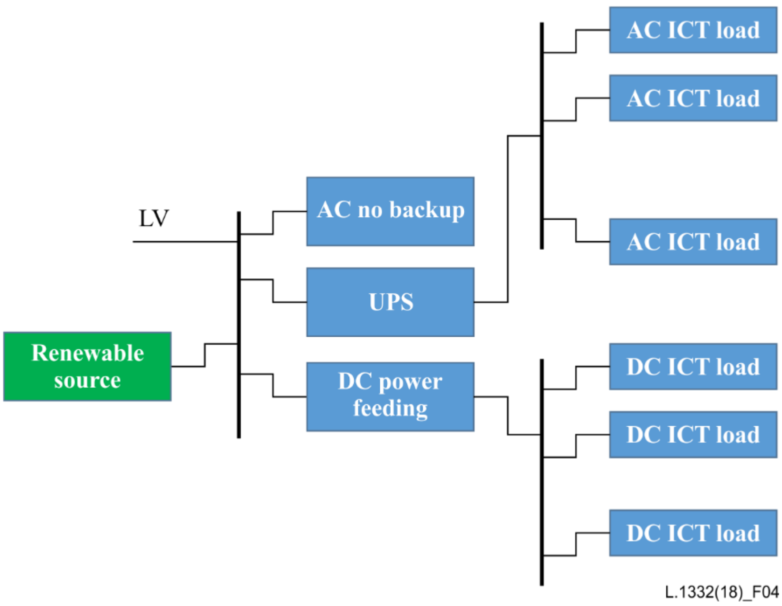

Figure 4 – Renewable energy sources connected to the AC LV power distribution

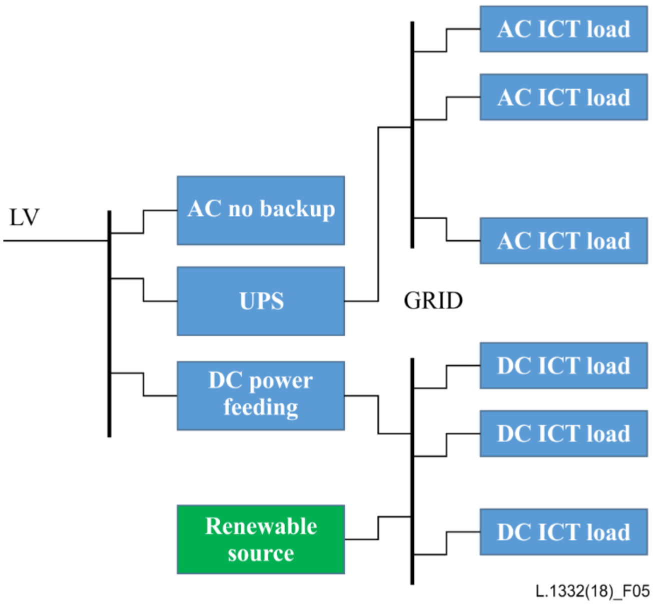

Figure 5 – Renewable energy sources connected to the DC power distribution

When an ICT installation is not connected to the grid, the site could be connected to a renewable energy source and/or to an engine generator in the case of a hybrid solution.

7 Maintenance activities

Maintenance activities in a network or in an ICT installation are normally not considered; however, maintenance routines can have a substantial impact on the energy used in network operations, this is especially true in the case of wide-area networks (e.g., mobile radio networks).

The contribution of the maintenance energy consumption to the total energy budget should be assessed, but the method is not fully developed, at this stage, to provide more than a rough estimation. Further study is needed to provide more accurate maintenance activities characterized by:

– periodicity;

– distance.

The periodicity is the frequency of interventions at the same site: it depends on the equipment or solution installed at a site and also on the site location, e.g., free cooling equipment needs a maintenance routine to clean or replace air filters; this maintenance periodicity is influenced by pollution conditions at the site.

Distance is the distance between TLC/ICT sites and the maintenance centre. The distance shall be calculated in km.

7.1 Maintenance activities contribution to total energy budget

Maintenance activities consist of three phases:

1) travel to site;

2) performance of the maintenance;

3) travel back to maintenance centre.

This Recommendation suggests considering the energy contributions of phases 1 and 3 only, because the energy used during phase 2 is negligible in respect of the energy consumption of the travelling phases.

The travelling distance shall be collected from records of all travelling maintenance activities. If this it is not possible; the distance can be calculated as an average distance between maintenance centres and TLC/ICT sites multiplied by the number of sites.

Using a conversion factor depending on the type of vehicle used, the distance can be converted into energy. This conversion factor depends of the car type/brand and it is suggested that an average value is used for the maintenance vehicle float.

8 Metric for total network

To define efficiency, networks use several types of indicators.

The simplest indicator that can be used is one that considers only the utilization of energy inside the network. One such indicator is used to check the efficiency of facilities in a data centre.

A proposed indicator for network efficiency is the ratio between the energy used by the load and the total energy consumed in the network.

8.1 Total network infrastructure energy efficiency definition

The metric for the total network infrastructure energy efficiency (NIEE) is defined as:

$$\text{NIEE} = \frac{\text{ICT load energy consumption}}{\text{Total energy consumption of the network}}$$

where:

Total energy consumption of the network includes:

– total input of electrical energy in network sites, excluding the energy provided by diesel/gas generators;
– energy produced by diesel/gas consumption from fixed generators;
– energy produced by renewable sources;
– diesel consumption for movable generators (optional);
– gasoline consumption of vehicles used for maintenance;
– energy consumption of other infrastructure activities e.g., routine test on batteries, control/ monitoring systems, building fire detection, building access control, lighting.

NOTE – The energy consumption from transportation (vehicles used for maintenance) is complex, as the fuel used in vehicles is only part of the required energy. The consumption depends on many parameters such as vehicle type (e.g., gasoline, diesel), average consumption in Wh per km, corrections for wind, temperature, road type, altitude, speed and driver behaviour, etc., would be applied. Only a rough averaged factor can be used e.g., considering 150 Wh/km. Then it needs to define periodicity and distance as presented above to calculate a value. For example, average low-maintenance travel of 100 km/year per site leads to 15 kWh/year per site. For a small base station of 1.5 MWh per year it means 1% of its electric consumption. A more accurate assessment would need further study.

9 Measurement methodology

International standards shall be used to measure the data necessary for NIEE calculations. In cases where international standards are not available, assessment data using the metrics defined in this Recommendation shall be collected as defined below.

The sum reported in the previous formula shall cover all ICT sites for which it is intended to report the indicated NIEE.

Figure 6 shows measurement points for all necessary values in the NIEE formula.

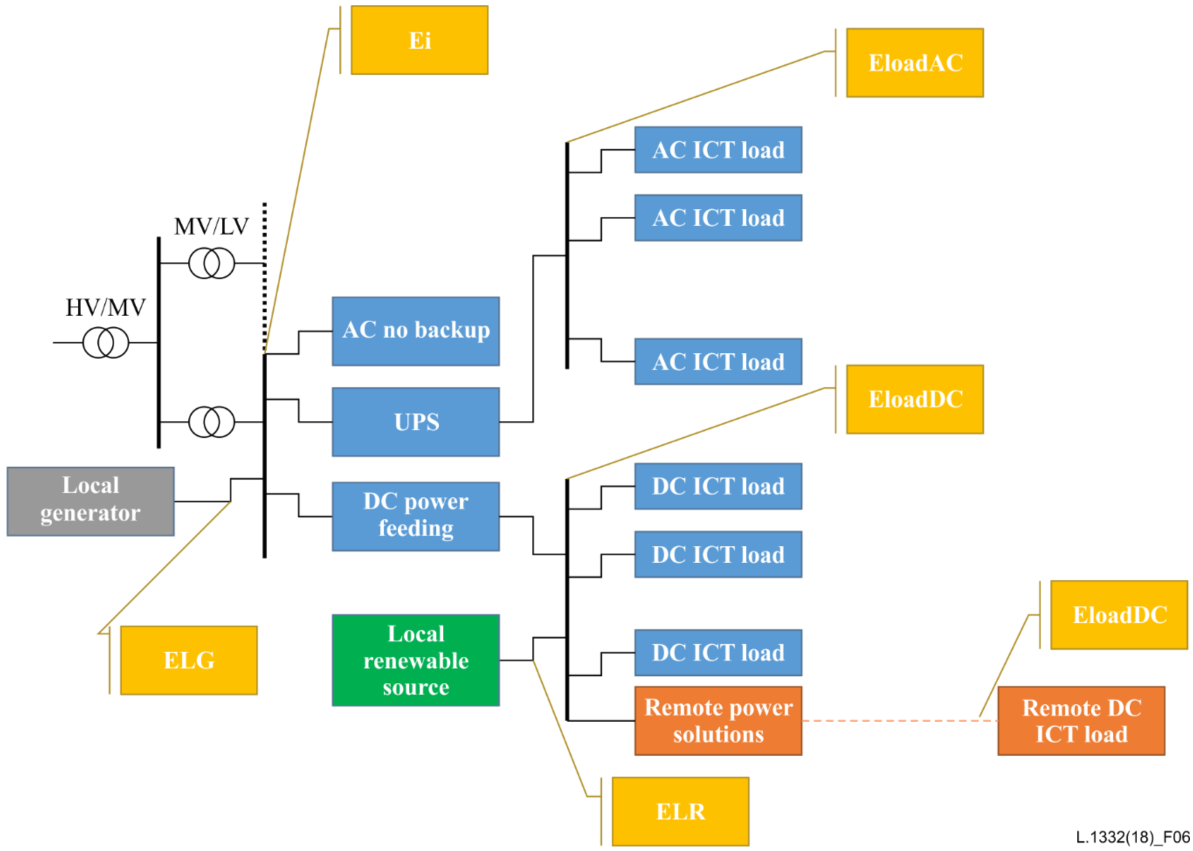

Figure 6 – Measurement reference points for a generic installation with HV input, local generation in LV and renewable source in DC

9.1 Test instrument requirements

The accuracy of testing equipment shall be compliant with the requirements from clause 8.1, Table 1 of [ITU-T L.1350].

Considering that energy consumption is not constant and that the presence of harmonics distorts current loads, the measurement of current needs to be true root-mean-square (rms) and then averaged to avoid this effect.

NOTE – Class 1 measurement systems are for energy-measurement accuracy and should refer to Class 1 of [b-IEC 62053-21].

9.2 Observation period

Examples of factors that influence metrics for the assessment of energy efficiency on networks include:

– number of users covered by a network, especially for a mobile radio network;

– climate conditions of sites, such as temperature and humidity, and environmental requirements for air conditioning;

Metrics of energy efficiency vary with seasonal and load variances. Increasing the minimum frequency of measurements provides a larger and more accurate dataset to analyse. Continuous real-time monitoring is one option to manage site efficiency so that historical trending and statistical analysis can be carried out.

Other benefits of continuous real-time monitoring include early detection of unexpected variations that could indicate system issues. In cases where continuous real-time monitoring is not practical or economically justifiable, some form of repeatable, defined processes should be in place to capture metrics as often as possible for comparison purposes.

When reporting metric values, network site owners should use the average NIEE measured over a one-year period to get an averaged value.

For ICT sites without real-time monitoring, metrics of energy efficiency shall be collected in a repeatable fashion and the methodology documented for review.

9.3 Load energy consumption

Load energy consumption shall be assessed site by site and summed as reported in the formula below to calculate the global indicator.

$$\text{Load energy consumption} = \sum_{1}^{n} (EloadAC_{site\_i} + EloadDC_{site\_i})$$

ICT energy consumption shall be directly measured or reported by using the measurement defined in [b-ETSI ES 202 336-12].

The measurement point of the energy consumption of AC load (EloadAC) and the energy consumption of DC load (EloadDC) should be at the power feeding interface of the telecommunication equipment considering the energy losses of the cable.

Figure 6 also shows a remote powering case; this Recommendation does not detail solutions used for remote powering (e.g., remote feeding telecommunication current (RFT-C), remote feeding telecommunication voltage (RFT-V), 400 V DC) but the EloadDC, in this case, is measured at the input of equipment in remote locations. The losses due to remote powering are part of the total energy consumption, Ei.

Depending on the nature of the load, energy consumption shall be realized using kilowatt-hour (kWh) meters that report active energy for loads powered by AC.

For loads powered by DC, the EloadDC can be the mathematical product of volts, amperes and the timeframe of the measurement duration as power delivery provides DC.

Measurement of load energy: EloadAC and EloadDC, shall be reported in kWh.

9.4 Total network energy consumption

Total energy consumption shall be assessed site by site and summed as reported in the formula below to calculate the global indicator including optional contributions due to movable generators and maintenance activities.

$$\text{Total network energy consumption} = EM + EMG + \sum_{1}^{n} (Ei_{site\_i} + ELG_{site\_i} + ELR_{site\_i})$$

where:

EM: energy generated by movable generators (optional) in kWh

EMG: gasoline consumption in kWh of vehicles for maintenance (optional). This value can be assessed by conversion, in kWh, of average fuel litter consumption in a year and with a defined conversion factor

Ei_{site_i}: total input electric energy of site and core-rooms excluding the energy provided by diesel/gas generators of site *n*

ELG_{site_i}: energy produced by diesel/gas consumption for fixed generators of site *i*

ELR_{site_i}: energy produced by renewable sources of site *i*.

The energy provided by a public grid can be measured, as LV connections to the public grid, by means of metering information provided by utility suppliers or by measurement systems, see [b-ETSI ES 202 336-12]. Locally generated energy can be measured by meters installed on site. Moreover, sensors can be used to measure site and equipment energy consumption.

In some cases, due to the difficulty of analyzing large or widespread networks, a detailed measurement of energy consumption from all sites is not possible by using direct measurements, but rather by using an estimation of total energy consumption based on reports/energy bills from utilities.

In this case, the energy generated locally by engines and renewable sources at different installations shall be taken into account.

Measurement of total energy consumption: Ei, ELG and ELR, shall be reported in kWh.

NOTE – The ETSI ES 202 336-series considers an interoperable monitoring and control system for different types of infrastructure existing in a network:

– [b ETSI ES 202 336-9] for alternative power system (e.g., solar wind, fuel cell);
– [b ETSI ES 202 336-4] for AC distribution power system;
– [b-ETSI ES 202 336-5] for AC diesel-backup generators.

9.4.1 Total electric energy of site- and core-rooms

The total energy consumption, Ei, of site and core rooms shall be measured at the point reported in Figure 6; this is valid at LV level considering that normally the measurement at HV and MV is not available at the user level.

The efficiency of transformers used in voltage conversion HV/MV and MV/LV should be included when considering all losses present in the installation.

The energy shall be measured with a meter that is able to directly report the active energy.

9.4.2 Energy from fixed generators

Energy consumption derived from fixed generators shall be measured at the point indicated in Figure 6. The energy shall be measured with a meter that is able to directly report the active electrical energy.

9.4.3 Energy from movable generators

Energy consumption derived from mobile generators shall be measured at the output of the generator.

The energy shall be measured with a meter that is able to directly report the active electrical energy.

10 Global indicator relationship

The NIEE can be used with other indicators, such as the ratio of service/equipment present in the network, to obtain a global indicator of the network that considers the facilities and telecommunication/service parts.

$$NEE = \frac{\sum T_s}{\sum E_{site}} = \frac{\sum T_s}{\sum E_{Ts}} \times \frac{\sum E_{Ts}}{\sum E_{site}} = \frac{\sum T_s}{\sum E_{Ts}} \times NIEE$$

Assuming:

– NIEE is the global network efficiency;
– T_s is the service provided by various parts of the network;
– E_{site} is the energy consumption of a site;
– E_{Ts} is the energy consumption of telecommunication equipment.

The term $\frac{\sum T_s}{\sum E_{Ts}}$ is the network telecom energy efficiency indicator and can be obtained using the methodology defined in [ITU-T L.1330].

Bibliography

[b-ETSI ES 202 336-4] ETSI ES 202 336-4 V1.1.1 (2013), *Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks); Part 4: AC distribution power system control and monitoring information model*.

[b-ETSI ES 202 336-5] ETSI ES 202 336-5 V1.1.1 (2010), *Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks); Part 5: AC diesel back-up generator system control and monitoring information model*.

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[b-IEC 60038] IEC 60038:2009, *IEC standard voltages*.

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