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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

Standardization terms and trends in energy efficiency

Recommendation ITU-T L.1315

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Recommendation ITU-T L.1315

Standardization terms and trends in energy efficiency

Summary

Recommendation ITU-T L.1315 provides a high-level definition of energy efficiency, energy management requirement to increase the energy efficiency of information and communication technology (ICT) goods, networks and services.

History

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1.0	ITU-T L.1315	2017-05-24	5	11.1002/1000/13145

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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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Introduction

This Recommendation was developed jointly by ETSI TC EE and ITU-T Study Group 5 and published respectively by ITU and ETSI as Recommendation ITU-T L.1315 and ETSI Standard ETSI ES 203 475, which are technically equivalent.

Recommendation ITU-T L.1315

Standardization terms and trends in energy efficiency

1 Scope

This Recommendation specifies terminology, principles and concepts for energy efficiency and energy management.

The Recommendation establishes a common understanding on measurement methodology used to determine the energy efficiency of a good, service and network.

It is a framework for other ITU-T standards and other standard development organization (SDO) document for energy efficiency thematic.

2 References

The following Recommendations contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the reference's editions indicated are valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to check for latest published documents and using 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.1310] ITU-T L.1310 (2014), *Energy efficiency metrics and measurement methods for telecommunication equipment*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 active mode [ITU-T L.1310]: For small networking equipment, this is the operational mode where all ports (WAN and LAN) are connected, with at least one Wi-Fi connection, if a Wi-Fi function is available.

3.1.2 energy [ITU-T L.1310]: "The capacity for doing work". In the telecommunication systems, where the primary source of energy is electricity, energy is measured in Joules.

3.1.3 idle mode [ITU-T L.1310]: For small networking equipment, this means the same as active mode, but with no user data traffic (it is not zero traffic, as service and protocol supporting traffic are present) being used, although it is ready to be used (U1 in routers part).

3.1.4 low power (sleep) mode [ITU-T L.1310]: For small networking equipment, this means a state that happens after the device detects no user activity for a certain period of time and reduces energy consumption. For this state, no user-facing LAN ports are connected; the Wi-Fi is active but no clients are connected. The WAN port may be inactive. The device will reactivate on detecting a connection from a user port or device.

3.2 Terms defined in this Recommendation

3.2.1 functional unit: (based on [ITU-T L.1310] A performance representation of the system under analysis. For example, for transport equipment, the functional unit is the amount of data transmitted, the distance over which it is transported and its rate in Gbit/s. Sometimes the term is used to represent useful output or work.

3.2.2 small networking device: (based on ITU-T L.1310) A networking device with fixed hardware configuration, designed for home/domestic or small office use, with less than 12 wired ports. This device can have wireless functionality implemented. Wireless functionality is not considered a port.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC Alternating Current

CRT Cathode Ray Tube

EE Energy Efficiency

EER Energy Efficiency Rating

EUT Equipment Under Test

ICT Information and Communication Technology

LAN Local Area Network

LCD Liquid Cristal Display

LED Light Emitting Diode

PUE Power Usage Effectiveness (for data centre)

SDO Standards Development Organization

WAN Wide Area Network

5 Conventions

η Efficiency

6 Energy efficiency

6.1 General concept

Energy efficiency is a widely used term that has multiple meanings, and can be used in contexts such as "use the stairs, be energy efficient", and also in reference to an energy efficient office or house, or in many other contexts.

In the context of electrical devices, as a starting point, the following is a generic definition for energy efficiency applicable to energy converting devices:

$$\eta = \text{Energy}_{\text{output}} / \text{Energy}_{\text{input}} \tag{6-1}$$

"Energy Efficiency" that applies to any device that uses energy to do work can be defined as: "The percentage of total energy input to a machine or equipment that is consumed in useful work and is not wasted as useless heat". This could be expressed as follows:

$$\eta = \frac{EnergyForusefulWork}{TotalUsedEnergy} \tag{6-2}$$

By definition, "Energy Efficiency" is always in the range from 0 to 1, or 0 to 100% (if expressed as a percentage).

The goal of increasing energy efficiency (EE) is to realize solutions that will give the same or better functionality using less energy.

For IT equipment, output energy does not represent useful output energy. Therefore, energy efficiency for IT equipment shows how much energy is used to perform a functional unit (which is specific for the device or solution). This key performance indicator (KPI) ratio can be called EER to distinguish it from EE. EE increase is one of many ways of managing and restraining the growth in energy consumption. A device is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input. For example, when a light emitting diode/liquid crystal display (LED/LCD) uses less energy than a traditional display based on cathode ray tube (CRT) to reproduce the video, the display is considered to be more energy efficient.

The goal of energy efficiency increase is to provide solutions that will support more functionalities while using less energy.

A trivial solution for the maximum energy saving can be achieved by simply switching off the device but that will eliminate the service delivered by the device. Likewise, EE will be zero as a result.

This is the major reason for which the energy efficiency (EE and EER) of an equipment should be considered, and not only its energy consumption. Energy efficiency is not an absolute metric, which implies that to compare two pieces of equipment, these must be of the same type and with similar functionality.

Energy efficiency (EE and EER) increase is important at all stages of the energy chain from generation to final consumption. Eventually the benefits of energy efficiency (EE and EER) increase will outweigh the costs, for instance, renovation costs.

Energy efficiency is not equal to energy conservation. Energy conservation is reducing or going without a service to save energy.

The formula below shows the power usage effectiveness (PUE) concept equivalent to EE applicable to data centres:

$$\eta = \frac{PowerForUsefulWork}{TotalUsedPower} \tag{6-3}$$

It is noted that in reality, formula (6-3) gives a ratio between two power values, which is an indication of energy efficiency (EE and EER). Technically, energy is the integral of the power in a time window, so it is possible to consider measuring energy efficiency as the ratio between two powers without any error only if the powers considered are constant during the time integration window.

6.2 Energy efficiency for ICT

When the energy efficiency (EE and EER) concept is applied to the information and communication technology (ICT) world, it is not possible to make reference to output to power or energy, and it is important to introduce the concept of a proxy for "useful work", changing formula (6-1).

In this case the energy efficiency rating of functionality shall be expressed as the ratio between the expected result normally called a proxy for useful work (similar to functional unit) and the energy used to realize that functionality.

The new formula will be:

$$EER = \frac{UsefulWork}{TotalUsedEnergy} \tag{6-4}$$

This formula in this case is not a ratio between two values with the same units, but between two different characteristics, so the indicator of efficiency realized will not be a pure number but a ratio between useful work and energy. The measurement unit will be different depending on the useful work selected for the service or equipment under test (EUT) e.g., bit/J in the case where the useful work is a throughput measured in bit/s.

In order to easily measure the energy efficiency (EE and EER) in the case of equipment without a big variation of energy consumption, it is preferable to measure the power of an equipment, in place of the energy. In this case the power will not be an instantaneous power but a power averaged in a time frame to eliminate the fluctuation of the instantaneous power measurements.

In the latter case of energy efficiency given above (formula 6-3), energy efficiency is expressed with the same terminology but using total power and not total energy in the numerator of the formula.

The energy efficiency rating (EER) is a device metric defined as a functional unit divided by the power. Various types of equipment have their own EER definitions.

6.3 Energy efficiency hierarchy

An energy efficiency metric can be defined at different levels as follows:

– network/solution level

– equipment/system level

– component level

In standardization, only metrics at network, and equipment or system level are normally considered, defined and used to test or evaluate the energy efficiency of the equipment or system. Metrics at the component level are given as suggestions only and could be used as a tool to improve the efficiency of an equipment.

6.3.1 Energy efficiency at the network level

Network level metrics are used to evaluate the energy efficiency of an entire network or parts of it (e.g., the access network of an operator). They are normally used to evaluate an internal network of an operator and to satisfy environmental goals. For this Recommendation, the network level EE is considered a metric that will cover not only one single product but all equipment used to build the telecommunication network, composed of different interworking equipment.

6.3.2 Energy efficiency at the equipment or system level

Equipment or system level metrics are mostly used to compare the telecommunication equipment of the same functionality and place in a network. They evaluate the overall energy efficiency performance at the equipment or system level, which is considered as a "single box" or "single entity", from the measurement and reporting point of view.

6.3.3 Energy efficiency at the component level

Component-level metrics can be used in the design, development and manufacture of energy efficient equipment. These metrics consider equipment as an "open box" and evaluate the energy efficiency performance of its individual components. Measuring and understanding the energy efficiency or energy consumption of each component within the equipment helps to identify the "hot spots" and key components in a system with regard to energy saving. It should be borne in mind that these kinds of metrics may lead to sub-optimizations unless considered in the context of the overall equipment's energy efficiency.

7 Useful work concept for ICT

Useful work is a general expression used to define the expected results to be delivered by a device.

Considering that ICT devices are very complex, it is not simple to find a correct functional unit/ proxy for useful work. Using the output energy of devices is not possible because the equipment is not only designed to send energy at its output ports, but also to realize other types of activities such as data switching/routing, area coverage and data computation.

These activities are different depending on the type of equipment. Examples are the data throughput of a port or system, the computational capacity, the area coverage, the transmitting distance or a combination of the above, depending on the equipment usage or application being considered.

In the wired technologies that include, routers, switches, transport and fixed access equipment the following concept can be utilized:

- Utilization
  - Port utilization: Port throughput expressed as a percentage of a theoretical maximum.
  - System utilization: System throughput expressed as a percentage of the maximum demonstrated throughput.
- Throughput
  - Port throughput: Rate of traffic (in b/s) passing through a port on a sustained basis in either direction, including minimally needed line overhead.
  - System throughput: Sum of throughput on all system ports in the egress direction (b/s). Example: Maximum throughput for 1 Gigabit Ethernet port is 1 Gb/s (measured in a specified topology).
- Line rate: Indicates the actual speed with which the bits are sent onto the wire (or via wireless connection).

In wireless technologies it is also necessary to consider the following:

- Coverage area: This is the geographical area in which mobile radio stations provide the service.
- Path length: In radio technologies another important factor to be considered is the radio link length. For example, the distance between the two radio stations of the radio link.

For facility equipment, other factors are considered such as the cooling capacity and the energy output.

In case of future EER application to a network or solution, some useful work will be done related to:

- Number of users
- Service per user
- Level of oversubscription
- Total network egress traffic – Energy used by facilities
- Combinations of the above.

8 Energy management

The energy management concept (defined in [b-ETSI DCEM]) does not cover the efficiency of equipment but how the energy is used by an equipment or a network, how it is managed or delivered from different available sources as it is used, and how waste energy is reused.

Energy management does not directly affect the energy efficiency (EER) of the equipment or the network services. However, it helps to manage the effect that equipment, networks and services have on the environment by utilizing and managing energy derived from less environmental impacting sources such as renewable energy, or reusing energy that, without adequate management, would just be wasted. For example, energy derived from hot air or water in a cooling system, or by using external or internal network management tools to shut down or bring back energy to the network devices, depending on network usage schedule.

9 Renewable energy sources

The use of renewable energy from sources such as solar, wind, hydroelectric, etc. contribute to the reduction of the environmental impact of an equipment, network or service, but they have no influence on energy efficiency.

Energy consumption from renewable energy sources that are not connected with the grid shall be included in the total ICT equipment or network energy consumption calculation.

It is clear that the increase the use of renewable energy sources is an important factor that contributes to environmental friendly solutions. Energy efficiency is independent from energy sources.

10 Functioning status/mode and EE

Functioning status and utilization are other important factors to be considered during the EER measurements and calculation, as they have a large impact on the energy consumption of equipment.

In the case of EER for equipment having different utilization levels, the different utilization levels need to be taken into consideration during the calculations.

For equipment for which it is possible to define a typical percentage of utilization for a defined period, the EER can only be one number using weight factor for the energy consumption corresponding at different functioning status with the higher weight used for typical utilization to reflect realistic usage.

The following formula is an example of this concept, taken from [ITU-T L.1310]:

$$EER = \frac{0.6 * Tidle + 0.3 * Tlowpower + 0.1 * T\int \mathrm{max}imum}{0.6 * P\,idle + \quad 0.3 * Plowpower + 0.1 * P\int \mathrm{max}imum} \qquad \text{(Mbit/s/W)} \qquad (10\text{-}1)$$

Weighting factors based on estimated time for use of EUT in each mode.

In this formula:

T*idle* is the throughput in idle mode in which the power is P*idle*

T*lowpower* is the throughput in low throughput mode in which the power is P*lowpower*

Tm*aximum* is the throughput in maximum throughput mode in which the power is P*maximum*

It is noted that in reality formula (10-1] gives a ratio between throughput and power, considering this is an indication of energy efficiency. Technically, energy is the integral of the power in a time window, so it is possible to consider measurements of energy efficiency as a ratio between throughput and power without any error. In this case the power is considered to be constant during the time integration window.

The functioning status of a device can be one of the following:

Idle mode

The device is not being used, but it is ready to pass traffic or return to full functionality in no time. It is in any case an active mode with the expectation of lower power consumption.

Low power mode

A state into which a device enters after a certain period of inactivity or idle mode. It is characterized with very low power consumption.

Standby mode

A condition where the device is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only the following function, which may persist for an indefinite time: reactivation function or reactivation function and only an indication of enabled reactivation function, and/or information or status display;

Networked standby

A condition in which the equipment is able to resume a function by way of a remotely initiated trigger via a network connection.

The following concepts also apply to EE:

Non-drop rate

It is the observed system throughput at which no packet drops are recorded.

Full mesh traffic topology

For EUT where all ports have identical roles, traffic with identical capacity streams between all ports shall be used, so each port in a system with N identical ports has N-1 traffic streams.

Partial uplink-downlink mesh topology

For systems where EUT ports can be grouped into "network/uplink" and "access/downlink" sides, according to vendor discretion, traffic shall be run from every "network" side port to every "access" side port and vice versa, thus forming full mesh traffic between two groups. All streams originated from every port shall be the same capacity.

11 General measurement conditions

This clause and its sub-clauses give the general conditions to measure the energy, power values and the useful work to define the concept of energy efficiency outlined in previous clauses.

They describe normal environmental conditions for an energy efficiency test of ICT products. Some types of ICT devices intended to be used in abnormal conditions should be tested in the appropriate conditions reflecting the intended use.

11.1 Environmental considerations

11.1.1 Temperature

The equipment shall be evaluated at temperature of 25°C ± 3°C (77 ± 5°F).

11.1.2 Humidity

The equipment shall be evaluated at a relative humidity of 30% to 75%.

11.1.3 Barometric pressure

The equipment shall be evaluated at a barometric pressure between 1060 and 812 mbar.

11.2 Voltage

11.2.1 DC powered equipment

The equipment powered by -48 Vdc source shall be evaluated at a DC voltage of –53V ± 2V.

Equipment using nominal DC voltages other than -48 Vdc shall be evaluated at ± 4% of the specified float voltage.

11.2.2 AC powered equipment

The equipment shall be evaluated with a source providing the following conditions:

– Total voltage harmonic distortion </=3% up to and including the 13th harmonic

– At either of the following

- Single phase, 120 Vac ± 5%, 60 Hz ± 1%
- Single phase, 230 Vac ± 5%, 50 or 60 Hz ± 1%
- Three phase, 208 Vac ± 5%, 50 or 60 Hz ± 1%

Unless otherwise specified in a supplemental standard to this general requirement standard, equipment using other nominal AC voltages shall be evaluated at ± 5% of the specified voltage and ± 1% of the specified frequency.

11.3 Power source

DC power sources used to provide power to the equipment under test shall be capable of providing a minimum of 1.5 times the power rating of the equipment under test.

11.4 Power measurement equipment

The measurement equipment used to measure voltage and current for the purposes of determining energy or power for the equipment under test shall have the following minimum characteristics:

- A minimum digitizing sample rate of 40 kHz.
- Input circuitry with a minimum bandwidth of 80 kHz.
- Ability to log and store data for the total measurement period.
- Overall measurement accuracy shall be within +/- 1%.

Measurements may be performed with a variety of instruments. These range from voltage and current meters with data acquisition capability to power analysers capable of fully integrated measurement.

NOTE – Measurement equipment with higher digitizing rates and higher accuracy may be desirable to ensure accurate measurement when power spikes are possible.

Bibliography

[b-ETSI DCEM] ETSI, Dataprocessing & Communications Energy Management. <http://www.etsi.org/images/files/ETSITechnologyLeaflets/DataprocessingCommunicationsEnergyManagement.pdf>

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