ETSI ES 202 336-12 V1.2.1 (2019-02)

Environmental Engineering (EE);
Monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks);
Part 12: ICT equipment power, energy and environmental parameters monitoring information model

Reference
RES/EE-0266

Keywords
control, energy efficiency, interface, management, network monitoring, power, system

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Foreword

This ETSI Standard (ES) has been produced by ETSI Technical Committee Environmental Engineering (EE).

The present document is part 12 of a multi-part deliverable covering monitoring and control interface for infrastructure equipment (power, cooling and building environment systems used in telecommunication networks), as identified below:

Part 1: "Generic Interface";

Part 2: "DC power system control and monitoring information model";

Part 3: "AC UPS power system control and monitoring information model";

Part 4: "AC distribution power system control and monitoring information model";

Part 5: "AC diesel back-up generator system control and monitoring information model";

Part 6: "Air Conditioning System control and monitoring information model";

Part 7: "Other utilities system control and monitoring information model";

Part 8: "Remote Power Feeding System control and monitoring information model";

Part 9: "Alternative Power Systems";

Part 10: "AC inverter power system control and monitoring information model";

Part 11: "Battery system with integrated control and monitoring information model";

Part 12: "ICT equipment power, energy and environmental parameters monitoring information model".

The goal of the present document is to define the measurement of electrical power and energy consumption of ICT equipment as well as environmental parameters (temperature, hygrometry) in order to improve energy monitoring and to correlate the power consumption to equipment operation activity (telecom traffic, computation, etc.). It is also to define the transfer protocol of this measurement data from site to network operation centre. Knowing power consumption gives the possibilities to reduce energy consumption of equipment and/or network. Granularity, measurement period and accuracies are defined to meet these targets. They may depend on equipment types and location in the different segments of a network (customer termination, access, core, data-center, etc.). In addition, these measurements can be used to improve engineering and operation including more accurate dimensioning of power systems, network evolution modelling and prevision, audit on field, etc.

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document defines measurement and monitoring of power, energy and environmental parameters for ICT equipment in telecommunications or datacenter or customer premises.

It defines the power, energy and environmental parameters monitoring interface of ICT equipment based on generic ETSI ES 202 336-1 [1] interface so that correlations can be made with ICT equipment parameters (traffic, flowrate, number of connected lines, radio setting, QoS KPI, etc.) in the network management system.

Correlations of monitored data (power, energy consumption and environmental values) with the ICT equipment parameters and settings are not in the scope of the present document.

The monitoring interface covers:

- Internal power consumption measurement on the ICT equipment powered in DC and AC.
- Power consumption measurement external to the ICT equipment (if not implemented internally, e.g. legacy equipment).
- Energy metering based on power consumption measurement.
- Environmental parameters of the ICT equipment (e.g. temperature at air inlet of equipment).

The present document defines:

- The minimum set of exchanged information required at the interface, including parameters such as measurement type (e.g. RMS), accuracy, range, etc. and settings such as data acquisition and transmission period, etc. This includes the data preparation, recording and transmission functions.
- The testing method of some parameters and functions.
- Text tables in annexes A and B with data exchange described in "natural language".
- The XML files with tags and variables corresponding to the data in the tables of annexes A and B in complement to general rules defined in ETSI ES 202 336-1 [1] and ETSI ES 202 336-2 [3].

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI ES 202 336-1: "Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks); Part 1: Generic Interface".

[2] ETSI ETS 300 132-1: "Equipment Engineering (EE); Power supply interface at the input to telecommunications equipment; Part 1: Operated by alternating current (ac) derived from direct current (dc) sources".

[3] ETSI ES 202 336-2: "Environmental Engineering (EE); Monitoring and control interface for infrastructure equipment (Power, Cooling and environment systems used in telecommunication networks); Part 2: DC power system control and monitoring information model".

[4] ETSI ES 202 336-3: "Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks); Part 3: AC UPS power system control and monitoring information model".

[5] ETSI ES 202 336-10: "Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks); Part 10: AC inverter power system control and monitoring information model".

[6] ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 2: Operated by -48 V direct current (dc)".

[7] ETSI ES 202 336-4: "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".

[8] ETSI ES 202 336-6: "Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks); Part 6: Air Conditioning System control and monitoring information model".

[9] ETSI EN 300 019-2 (all subparts): "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 2: Specification of environmental tests".

[10] ETSI EN 300 019-1-3: "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-3: Classification of environmental conditions; Stationary use at weatherprotected locations".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] IEEE 802.1™ to 802.11™: "IEEE Standard for Local & Metropolican Area Network".

[i.2] ISO/IEC 8879: "Information processing -- Text and office systems -- Standard Generalized Markup Language (SGML)".

[i.3] ETSI ES 203 215: "Environmental Engineering (EE); Measurement Methods and Limits for Power Consumption in Broadband Telecommunication Networks Equipment".

[i.4] ETSI ES 202 706: "Environmental Engineering (EE); Measurement method for power consumption and energy efficiency of wireless access network equipment".

NOTE: ETSI ES 202 706 is revision of the ETSI TS 102 706.

[i.5] ETSI ES 201 554: "Environmental Engineering (EE); Measurement method for Energy efficiency of Mobile Core network and Radio Access Control equipment".

[i.6] ETSI ES 203 184: "Environmental Engineering (EE); Measurement Methods for Power Consumption in Transport Telecommunication Networks Equipment".

[i.7] ETSI ES 203 136: "Environmental Engineering (EE); Measurement methods for energy efficiency of router and switch equipment".

[i.8] ETSI EN 301 575: "Environmental Engineering (EE); Measurement method for energy consumption of Customer Premises Equipment (CPE)".

[i.9] ETSI ES 203 237: "Environmental Engineering (EE); Green Abstraction Layer (GAL); Power management capabilities of the future energy telecommunication fixed network nodes".

[i.10] ETSI ES 203 228: "Environmental Engineering (EE); Assessment of Mobile Network Energy Efficiency".

[i.11] Recommendation ITU-T M.3000 series: "TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits Telecommunications management network".

[i.12] Recommendation ITU-T M.3010 series: "TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits Telecommunications management network - Principles for a telecommunications management network".

[i.13] ETSI TS 132 101 (V15.0.0) (09-2018): "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Principles and high level requirements (3GPP TS 32.101 version 15.0.0 Release 12)".

[i.14] ETSI EN 302 099: "Environmental Engineering (EE); Powering of equipment in access network".

[i.15] ETSI EN 300 132-3-1: "Environmental Engineering (EE); Power supply interface at the input to telecommunications and datacom (ICT) equipment; Part 3: Operated by rectified current source, alternating current source or direct current source up to 400 V; Sub-part 1: Direct current source up to 400 V".

NOTE: ETSI EN 300 132-3 is currently under revision and will replace ETSI EN 300 132-3-1.

[i.16] ETSI ES 202 336 (all parts): "Environmental Engineering (EE); Monitoring and Control Interface for Infrastructure Equipment (Power, Cooling and Building Environment Systems used in Telecommunication Networks)".

[i.17] LT0511 RevB datasheet: "Linear Technology LTC 1966 precision micropower RMS to DC converter".

[i.18] Mark Strzegowski: "Realizing the Full Potential of Your AMI Deployment with Meter Diagnostic Data", Analog Device.

NOTE: Availablet at http://www.analog.com/en/technical-articles/full-potential-of-ami-deployment-with-meter-diagnostic-data.html.

[i.19] ETSI EN 300 019-1-4: "Environmental Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-4: Classification of environmental conditions; Stationary use at non-weatherprotected locations".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

NOTE: Terms referring to energy interface, equipment and distribution are described in power distribution standards ETSI ETS 300 132-1 [2], ETSI EN 300 132-3-1 [i.15], ETSI EN 300 132-2 [6] for ac and dc interface A and A3 and ETSI EN 302 099 [i.14] for access network equipment powering.

AC distribution power system: device or system that distribute AC voltage or convert DC voltage to AC voltage and provides electrical power without interruption in the event that commercial power drops to an unacceptable voltage level

alarm: any information signalling abnormal state, i.e. different to specified normal state of hardware, software, environment condition (temperature, humidity, etc.)

NOTE: The alarm signal should be understood by itself by an operator and should always have at least one severity qualification or codification (colour, level, etc.). alarm message structure are defined in ETSI ES 202 336-1 [1].

EXAMPLE: Rectifier failure, battery low voltage, etc.

board: electronic part of an equipment (e.g. a blade server)

cabinet: closed enclosure including several shelves or racks

Control Unit (CU): integrated unit in an equipment to monitor and control this equipment through sensors and actuators

Data Gathering Unit (DGU): functional unit used for several functions:

- collect serial, digital, and analog data from several equipment;
- option to send (output) serial or digital commands;
- forward/receive information to/from the Local/Remote Management Application via agreed protocols;
- mediation between interfaces and protocols.

NOTE: This function may be integrated as part of specific equipment.

DC back-up system: device or system that provides electrical power without interruption in the event that commercial power drops to an unacceptable voltage level

DC distribution power system: device or system to distribute DC voltage

ethernet: LAN protocol

NOTE: Equivalent to IEEE 802.1 to 802.11 [i.1].

event: any information signalling a change of state which is not an alarm: e.g. battery test, change of state of battery charge

NOTE: The event signal should be understood by itself by an operator It should be transmitted in a formatted structure with text message and other fields like for alarm. An event can be coded as an alarm with severity "0".

eXtensible Mark-up Language (XML): application profile or restricted form of SGML

NOTE: By construction, XML documents are conforming SGML the Standard Generalized Markup Language (ISO/IEC 8879 [i.2]) documents. XML is designed to describe data and focus on what data is. XML should be discerned from the well known Hypertext Transfer Mark-up Language (HTML) which was designed to display data and to focus on how data looks.

infrastructure equipment: power, cooling and building environment systems used in telecommunications centres and Access Networks locations

EXAMPLE: Cabinets, shelters, underground locations, etc.

module: closed unit including electronic boards forming part of a larger system (e.g. sub-unit of a base station in a cabinet or separated)

rack: sub part of the cabinet including ICT equipment rest

shelf: level in a cabinet

warning: low severity alarm

World Wide Web Consortium (W3C): consortium founded in October 1994 to develop common interoperable protocols and promote World Wide Web

NOTE: See http://www.w3c.org.

XML enabled CU (XCU): CU enabled to communicate using XML interface as defined in the present document

xDSL: global designation of the digital subscriber line (DSL) technologies

3.2 Symbols

For the purposes of the present document, the following symbols apply:

C	Capacitor
E	electric energy
I	electric current
f	frequency
P	electric power
R	Resistance
RC	time constant of a timer circuit
T	temperature
U	electric voltage or difference of potential
T_{acq}	Voltage and Current acquisition period
T_{rec}	PEE record time period for remote transmission
T_{rms}	RMS integration period
T_{trans}	Transmission period of data records

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

µC	Microcontroler
AC	Alternating Current
AD	Analog Digital
ADSL	Asynchronous Digital Subscriber Line
BB	Broad-Band
BBU	Base-Band Unit
BS	Base Station
CPE	Customer Premises Equipment
CU	Control Unit of an equipment
DC	Direct Current
DGU	Data Gathering Unit
DSLAM	Digital Subscriber Line Access Multiplexer
EEPROM	Electricaly Erasable Programmable Read Only Memory
EMAN	Energy Manager (abbreviation of IETF specification)
EMS	Energy Management System
E-UTRAN	Extended UTRAN

FAN	Fixed Access Network
GAL	Green Abstraction Layer
HTML	Hypertext Transfer Make-up Language
HTTP	HyperText Transfer Protocol
ICT	Information and Communication Technology
IETF	Internet Engineering Task Force
IP	Internet Protocol
KPI	Key Performance Indicator
LAN	Local Array Network
MSAN	Multiservice Access Network
NE	Network Element
NMS	Network Management System
OA	Operational Amplifier
OLT	Opitcal Line Termination
ONT	Optical Network Termination
ONU	Optical Network Unit
OSS	Operations Support System
PEE	Power, Energy, Environmental parameters
PF	Power Factor
PFC	Power Factor Correction
PSU	Power Supply Unit
RMA	Remote Management Application
RMS	Root Mean Square
RRU	Remote Radio Unit
SGML	Standard Generalized Markup Language
SMPS	Switched Mode Power Supply
TCP	Transmission Control Protocol for IP
TMN	Telecom Management Network

NOTE: As defined in Recommendation ITU-T M.3000 series [i.11].

UMTS	Universal Mobile Telecom System
UPS	Un-interruptible Power Supply
UTRAN	Extended Terrestrial Radio Access Network
VDC	Volt Direct Current
W3C	World Wide Web Consortium
x DSL	x Digital Subscriber Line

NOTE: x stands for many different type of DSL such as: A (Asymmetric), H (high-data-rate), RA (Rate Adaptive), S (Symmetric digital subscriber line), V (Very high speed), SH (Single-pair High-speed), G.SH (first version of SDSL).

XCU	XML enabled CU
XML	eXtensible Mark-up Language (see W3C)
XRMS	XML Remote Management Server

4 ICT power, energy and environmental parameters monitoring system

4.1 General description

The basic principles of power, energy and environment parameters measurements of ICT equipment (temperature, hygrometry) and their transfer to the network management systems (NMS) are shown in figure 1.

NOTE 1: The definition of specific NMS for mobile or fixed networks is out of scope of the present document. The same comment applies to OSS.

The following measuring device are used:

- wattmeter or energy meter (W, Wh); and/or
- Voltage (V); and/or
- current meter (A).

Voltage or current shall be recorded for monitoring when used to assess the power and energy consumption. Temperature shall also be measured and recorded.

NOTE 2: The energy consumption can be calculated from power measurement over a period of time.

NOTE 3: Humidity should be measured at the level of room or air conditioning, not at equipment level.

In the preferred implementation, power and energy measurements shall be taken down-stream of power supply interface A or A3 as defined in ETSI ETS 300 132-1 [2], ETSI EN 300 132-2 [6] and ETSI EN 300 132-3-1 [i.15] and inside the ICT equipment (type 1 measurement).

Otherwise e.g. on legacy equipment, power and energy measurements can be taken upstream of interface A outside the ICT equipment (type 2 measurement).

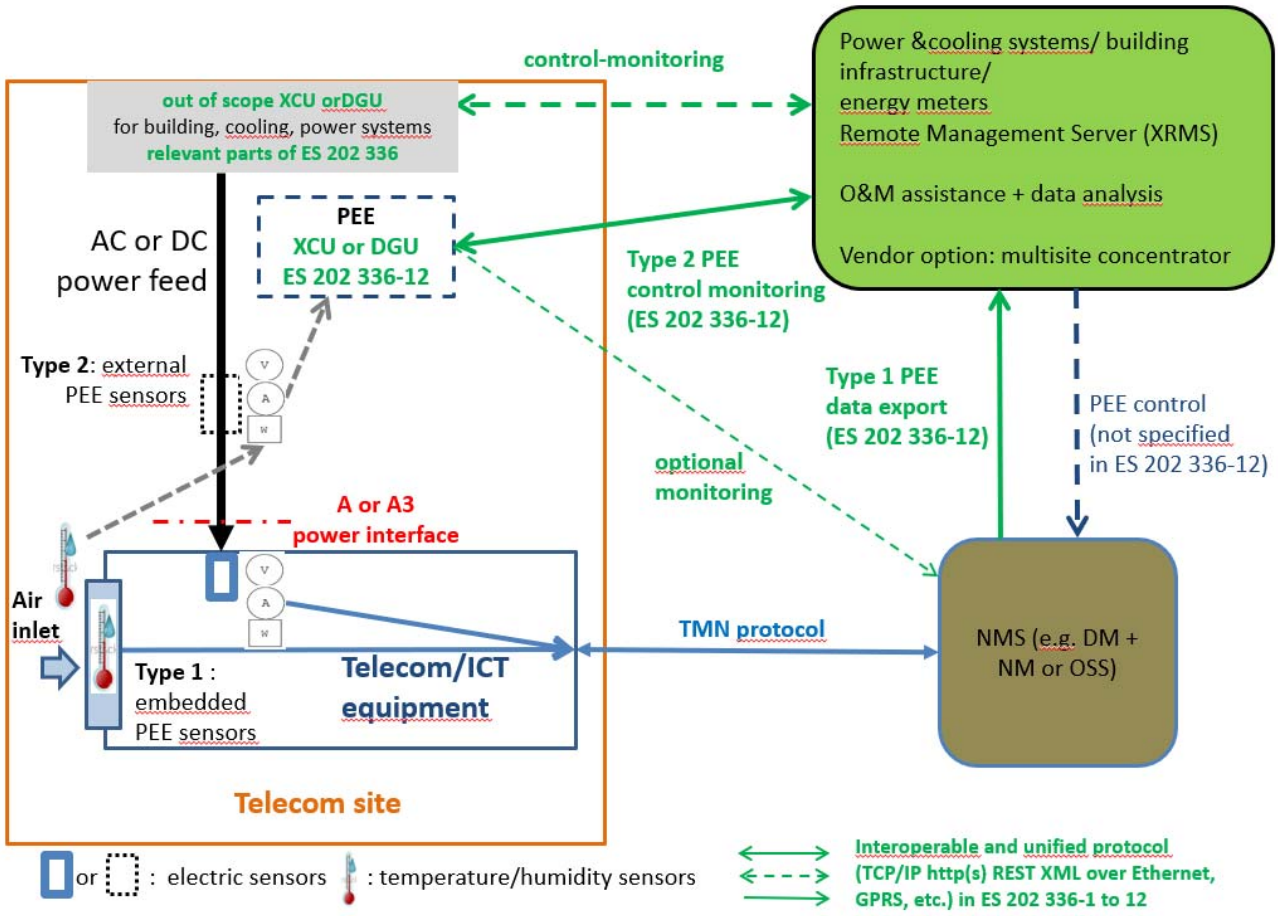
The electrical measurement sensors shall be located the closest as possible of the power electrical interface (A or A3) and the thermal environment sensors shall be placed in the air flow of the air inlet of the equipment.

PEE measurement values can be transmitted directly from XCU or DGU to XRMS or indirectly by the NE through the TMN protocol over the NMS to the XRMS. The direct and indirect transmission shall comply with ETSI ES 202 336-1 [1] and the present document's protocol.

NOTE 4: The Network Management System (NMS) is the functional entity from which the network operator monitors and controls the system at centralized level and manage operational and maintenance activities, it is using a TMN protocol not defined in the present document. The operation and Maintenance functions are based on the principles of the Telecommunication Management Network (TMN) of Recommendation ITU-T M.3010 [i.12] introduced by Recommendation ITU-T M.3000 series [i.11].

NOTE 5: The measurements done using the present document can be used as inputs for enabling:

- the assessment of Power Consumption in Broadband Telecommunication Networks Equipment [i.3], Transport Telecommunication Networks Equipment [i.6] and Customer Premises Equipment (CPE) [i.8];
- the assessment of Energy efficiency of wireless access network equipement [i.4], Core network equipment [i.5], router and switch equipment [i.7] and Mobile Network [i.10];
- the power management capabilities of the future energy telecommunication fixed network nodes with Green Abstraction Layer (GAL) [i.9].



NOTE 1: In figure 1, some ICT sites may not have all of the parts (building, power, cooling) and therefore monitoring interface would not be required.

NOTE 2: An ICT equipment of a vendor X is in general connected to the NMS of the vendor X, but the power/air conditioning /building infrastructure XRMS can be from a vendor Y.

Figure 1: Principle of the monitoring of ICT equipment power, energy and environment parameters

4.2 Complementarity to existing site power and air-conditioning measurements

The power/energy and environmental (PEE) parameters measurement on ICT equipment as standardized in the present document are complementary to the measurements defined at the site and room level on the power and air conditioning systems introduced in standard ETSI ES 202 336-1 [1].

In particular the standard ETSI ES 202 336-2 [3], ETSI ES 202 336-3 [4], ETSI ES 202 336-4 [7], ETSI ES 202 336-6 [8] and ETSI ES 202 336-10 [5] shall be used for definition of PEE measurements monitored by non ICT equipment in telecommunications or datacenter or customer premises (e.g. power, cooling and distributions systems):

- AC and DC current, voltage and or power sensors;
- AC and DC energy meters;
- Voltage, current, AC frequency measurement sensors;
- True Power factor measurement device;

NOTE 1: The true Power Factor includes the AC Displacement Factor (i.e. the cosinus of the phase angle between AC current and voltage of 50 Hz fundamental signals) and the current Distorsion Factor. The current distorsion is the highest factor for ICT load powered by SMPS as phase angle is close to 0. The distortion factor is a measurement of the performance of the PFC (Power Factor Correction) function.

- Sensors bus e.g. for power metering;
- Additional measurements.

NOTE 2: For very critical site, there could be additional power quality monitoring measurements (e.g. harmonic currents amplitude, power factor, distorsion, dips, etc.) as defined in ETSI ES 202 336-4 [7].

NOTE 3: All the PEE measurements transmitted through ETSI ES 202 336 (all series) [i.16] can be used to get measurements complementary to those defined in the present document e.g. DC current or power measurement compliant to ETSI ES 202 336-2 [3] at the output of a DC system supplying one or several ICT equipment.

4.3 Different site cases

4.3.1 Simple site case

Two types (see figure 2) of PEE monitoring can exist in a simple ICT site, and the compatibility is ensured between these types with the remote monitoring:

- Type 1: built-in measurements inside ICT equipment down-stream from interface A (or A3).
- Type 2: external measurement at input junction box measurements up-stream from interface A (or A3).

Internal power consumption and environment sensors and external measurement connected to an energy metering/environment XCU shall be used as defined in clause 4.4. Humidity measurements are optional.

Data export from NMS to the power/cooling remote management server shall use the ETSI ES 202 336-1 [1] and the present document. The NMS can also be used for dialog with other type of server as explained in clause 4.5.

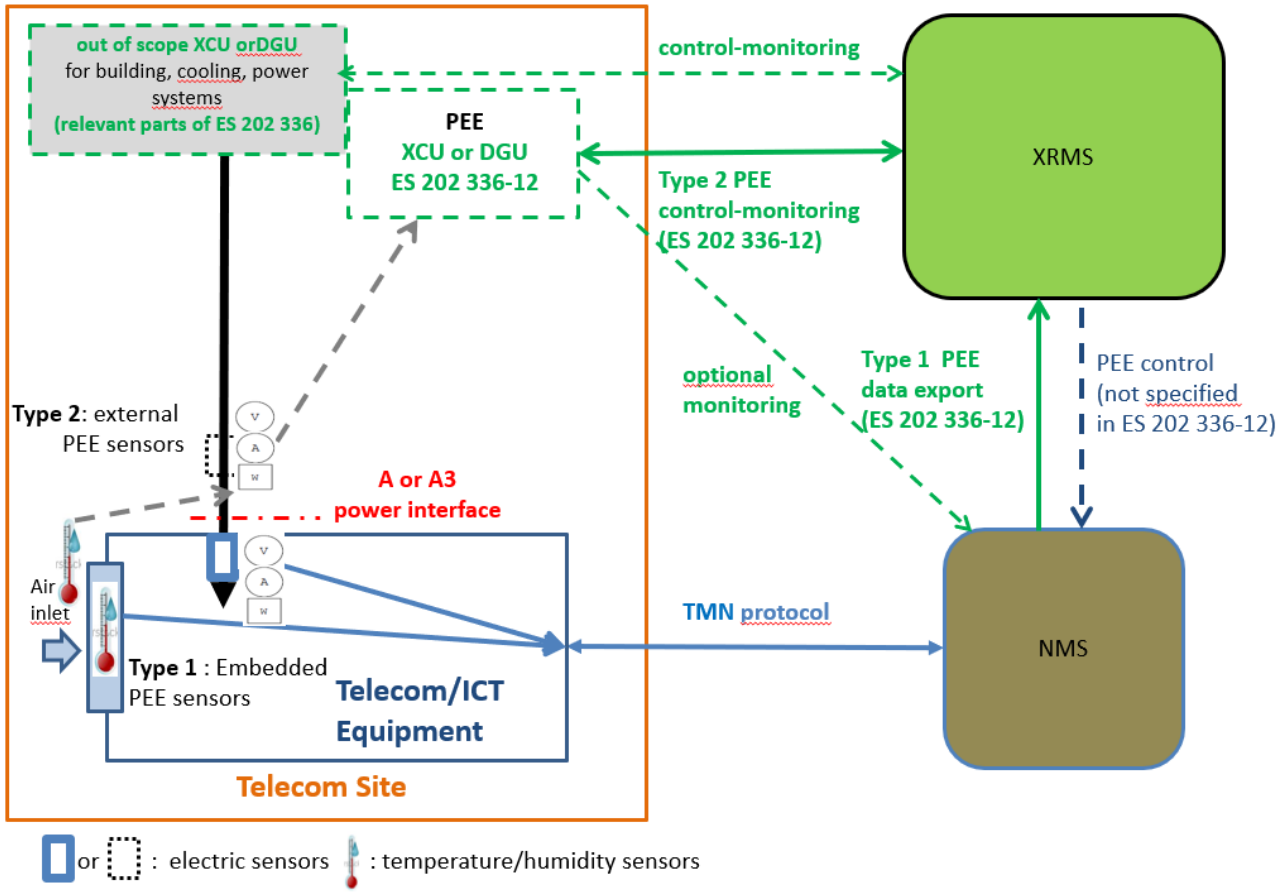


Figure 2: Example of possible implementation in a simple Telecom site (e.g. a radio mobile site with ICT/Telecom connected to an OSS/NMS)

4.3.2 Complex site case

Figure 3 gives example of 3 cases of monitoring of PEE that can exists in a complex ICT site, and how compatibility is ensured between these cases with the remote monitoring:

- Type 1: built-in measurements inside ICT equipment down-stream from interface A (or A3).
- Type 2: external measurement at input junction box measurements up-stream from interface A (or A3).
- Type 3: power frame measurement at output of power supply system.

On complex big sites with many equipment from different manufacturers and of different types, users require power and energy measurement of each ICT equipment and the global monitoring provided in power and air-conditioning is not sufficiently accurate.

For measurement on the power system and power distribution frame, the issue is to manage on the long run the cabling tracing and identification to be sure that the measurement always corresponds to the same considered ICT equipment. It often happen that a power output cable is common to several equipment, powered in room through a secondary distribution cabinet with smaller cables. With redundancy and double distribution from separate sources it is even more complicated. In addition the distribution is changing with the evolutive life of the site.

For air condition, this can happen that the sensors are not located close enough to the ICT equipment so that the sensor does not reflect the condition really seen by the ICT equipment.

So it seems much more reliable and stable to define the closest measurement as possible of the power input and of air inlet of the ICT equipment.

It is preferred to measure power inside the ICT equipment on the power input lines. If not possible it can be done outside but always downstream interface A or A3 as defined in ETSI ETS 300 132-1 [2], ETSI EN 300 132-2 [6] and ETSI EN 300 132-3-1 [i.15] of the considered ICT considered element under measurement.

When there are several power interface A or A3 inputs on the same ICT equipment, the sum of all power and energy measurements shall be provided in the monitored data in addition to individual values.

The temperature and humidity in which the ICT equipment is operating, shall be taken by an external sensor located at the air inlet of ICT equipment as defined in ETSI EN 300 019-2 series [9].

As in clause 4.3.1 for simple site, the data transmitted to the NMS shall be available on export line to another server as specified in clause 4.5.

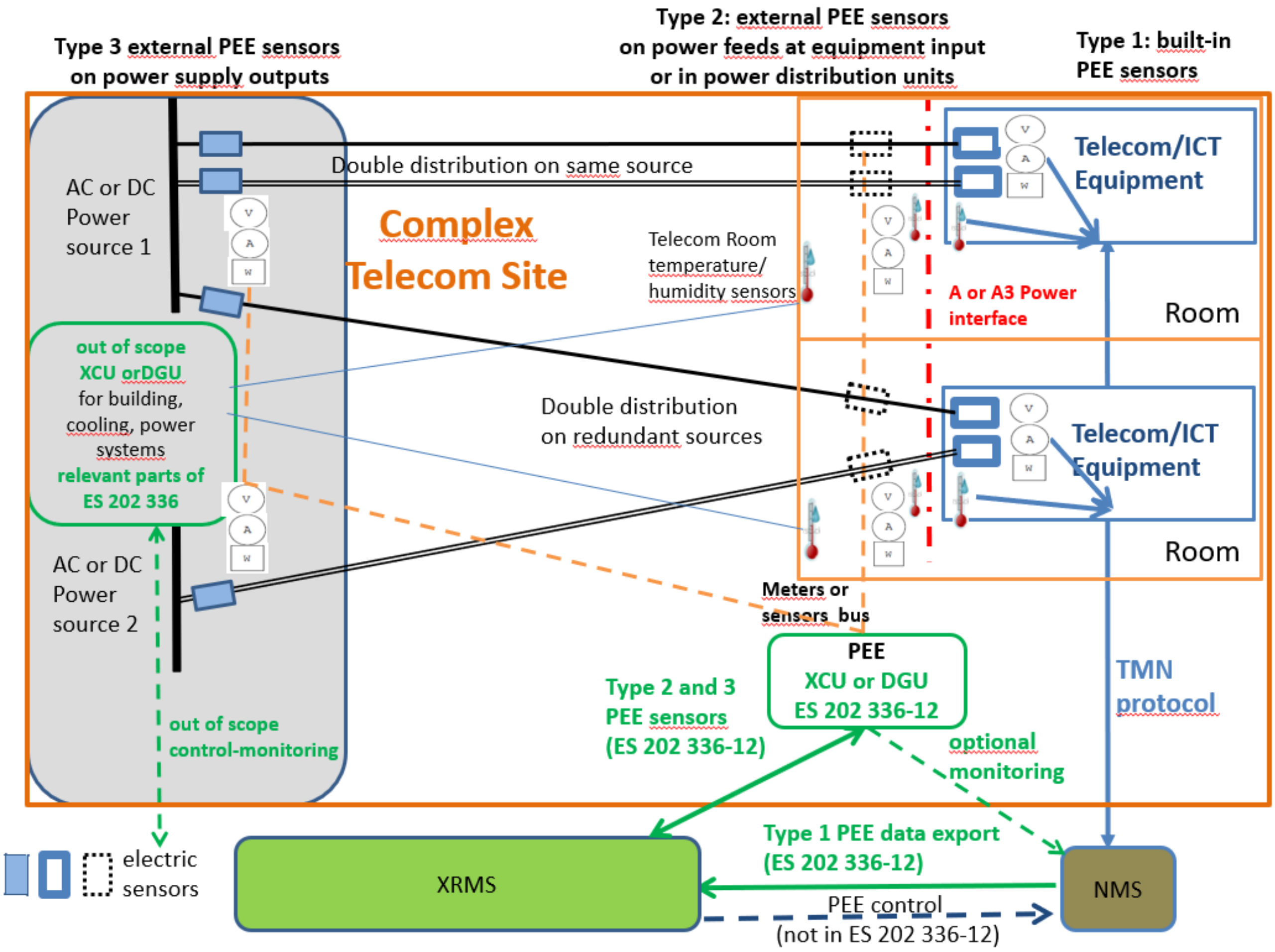


Figure 3: Example of cohabitation of ICT equipment internal and external power/energy/environment measurement acquisition in a site considering 3 cases of implementations (power frame measurement, input junction box measurements, built-in measurements)

4.4 Measurement and monitoring description

4.4.0 General description

This description of measurement is split in the 3 following clauses (clauses 4.4.1 to 4.4.3):

- downstream interface A or A3 built-in measurement for new equipment (type 1);
- upstream interface A or A3 measurement for legacy equipment (type 2);
- common requirements.

4.4.1 Internal measurements type 1 (Built-in in ICT equipment)

Power consumption measurement are done inside the ICT equipment.

The priority of measurement is on power inputs downstream of interface A of equipment, to be intended for the purpose of the present document as interface A at shelf level (both for deployment in a rack or in a cabinet enclosure).

Optionally it can be provided measurement at board level.

In table 1, the power/energy/temperature measurement defined for each network element shall be applied.

Table 1: Description of measured equipment

Network Type	Equipment Type	Environment Type	Power interface	Equipment Identification
Radio Access Network	RRU, BBU, Wide area BS cabinet, Medium range BS, in 2G, 3G, 4G, 5G	Indoor and outdoor	A or A3 (DC) or A1 (AC)	Equipment single identification code i.e. for BBU and RRU, etc.
Fixed Access network	OLT, ONU, MSAN, DSLAM (xDSL, MSAN, other FAN equipment) Fixed BB cabinet as a whole that can include the previous equipment (indoor or outdoor)	Indoor and outdoor	Mainly A or A3 (DC)	Single NE identification code i.e. for ONU, xDSL, etc.
Mobile and Fixed node	Node, optical transmission equipment, etc. Each equipment at the shelf level for fixed network interface	Mainly indoor	A or A3 (DC)	
Backhaul/transport	Optical transmission equipment, microwave link, etc.	Indoor and Outdoor	A or A3 (DC)	
IP routers and core switches node	Each equipment at shelf level in a rack	Mainly indoor	A or A3 (DC)	See note
Servers	Each mass server (1 or 2U server generally in a shelf) Each Blade server equipment (generally in a shelf) Each mainframe unit (both for rack or cabinet deployment)	Mainly indoor: Datacenter, Server room Shelter	A or A3 (DC) or A1 (AC)	See note
Customer Premises Equipment	ONT, modem, routers/switches, etc.			See note
NOTE: Additional requirements can be found for IP equipment following IETF EMAN specifications referenced in ETSI EN 300 132-2 [6].				

The environment measurements (temperature, hygrometry) shall be done at the closest air inlet or/and on board.

The location of temperature sensors shall be justified by a precision measurement in factory test of the effect of different location (i.e. top, down, middle left, right) on a fully equipped system (rack or cabinet).

The identification reference of the ICT equipment defined by the operator in its database shall be associated with the power and cooling measurements to identify the equipment and its location.

The data shall be transmitted using the TMN monitoring protocol Recommendation [i.12] to the ICT management system.

If an ICT equipment includes a power/energy/environment parameters monitoring interface, it shall be compliant to ETSI ES 202 336-1 [1] and the present document for interoperability reason between ICT equipment or NMS and XRMS Interoperability on the TMN is out of the scope of the present document.

4.4.2 External measurements type 2 (external sensors) for ICT equipment

The measurement type 2 of the ICT equipment (same list as in table 1) is done externally upstream from interface A by the following means:

- Current, Voltage sensors or Power or Energy Meters installed in electrical junction box or final power distribution frames or by sensors for current.
- Multi sensor Acquisition unit.
- A PEE DGU or XCU.

NOTE: Sensors or meters can be interconnected to this XCU or DGU, by a bus.

The monitoring interface at the level of the XCU or DGU is ETSI ES 202 336-1 [1] with data information model of the present document.

Other environmental measurements (temperature, humidity) shall be associated in order to perform correlation with the power/energy measurements on the considered equipment. The temperature or humidity sensors have to be very close to the air inlet of this equipment, which means several measurements on a multicabinet system.

4.4.3 Common requirements for external (type 2) and internal (type 1) measurement

4.4.3.0 Principle of PEE measurement

The principle of the measured data acquisition, of the local processing and of the robust data saving for a reliable remote monitoring and control are described in clauses 4.4.3.1 to 4.4.3.7. More details are given in annex F on the data measurement chain and on state of the art measurement with fair accuracy.

PEE measurement type, accuracy, test methods and data preparation for remote transmission are defined in order to provide the mandatory monitoring/supervision information defined in annex A and non mandatory monitoring/supervision information defined in annex B.

4.4.3.1 Power and energy consumption measurement

The power and energy metering is mandatory. Monitored values are defined in annex A. The power is in Watt and the energy is the cumulated active energy metering in Wh or kWh at the input of the considered ICT Network Equipment defined in table 1.

Considering the record period Tr defined in clause 4.4.3.4, the physical expression of instant power P(t), power consumption E(Tr) and mean power P(Tr) over Tr are:

$$P(t) = u(t).i(t)$$

$$E(Tr) = \int_0^{Tr} P(t)dt$$

$$P(Tr) = \frac{1}{Tr}E(Tr)$$

Where u(t) and i(t) are instant values of voltage and current at the AC or DC power interface of the Network Element under measurement defined in table 1.

The equivalent discrete expressions are:

$$P(j) = u(j).i(j)$$

$$E(j) = P(j).Ta$$

$$E(Tr) = \sum_{j=1}^{n} E(j)$$

$$P(Tr) = \frac{1}{Tr} E(Tr)$$

Where u(j) and i(j) are values of voltage and current acquired over the Ta period by analog-digital conversion equipement of measurements at the AC or DC power interface of the Network Element under measurement defined in table 1.

NOTE 1: The physical formula apply to any variable signal (e.g. combination of AC and DC) with no limit in frequency. The discrete formula includes the limits of the sampling period Ta of voltage and current.

NOTE 2: The reactive power and energy are not measured and recorded as most often Network Element defined in table 1 are powered in DC at their power interface and when they are powered by AC they generally use power supply with a true power factor very close to one, corresponding to reactive power close to zero.

The true Power Factor is defined as follows:

- True Power Factor = [Displacement Factor] x [Distortion Factor], where:
  - The Displacement Factor is cosine of ø, where ø = the phase angle between AC current and voltage of 50/60 Hz fundamental signals.
  - The Distortion Factor is a function of how well the PFC (Power Factor Correction) is working and shall be as close to the value one ("1") as possible.

4.4.3.2 Voltage, current measurement

The electric voltage and current measurement defined in annex B are optional. When required or used for power/energy calculation, they shall be of RMS type in order to achieve accurate measurement of dynamic waveform as they are more and more observed on equipment e.g. with power adaptation to performance demand. To this intention, the RMS value informs on the heating potential (i.e. active power when applied to a pure resistive load) of a measured voltage or current independently of its waveform.

The evaluation formula of RMS value of variable measured value X over T_{rms} period is:

$$X\,rms = \sqrt{\frac{1}{Trms}\int_0^{Trms} X^2(t)dt}$$

where for the present document X can be the current or the voltage.

NOTE 1: The true RMS value is the more accurate and is evaluated as the root of the fast integration of the squared measured raw value over the T_{rms} period. The approximative RMS determination based on peak detection and average rectification should not be used as it is only accurate for a given waveform for which it is calibrated. For some other waveforms, the error can reach -40 % as reported in [i.17].

NOTE 2: The period T_{rms} of RMS calculation should be of one second at maximum as it is used to determine maximum and minimum values that will be recorded as defined in clause 4.4.3.4.

NOTE 3: The true RMS integration is considered as fast enough when it gives the defined accuracy at the maximum waveform frequency intended to be measured in the accuracy tests defined in clause 4.4.3.5. The acquisition period of measured values used in the RMS integration is Ta. A low frequency pass filter averaging the measured value over Ta can be used as described in annex F.

NOTE 4: There is no physical equivalent of RMS Power or Energy. Only active power or energy are defined in clause 4.4.3.1 to take into account fast variations waveforms of power mainly resulted from fast variation of current.

4.4.3.3 Accuracy of PEE measurement

The sensors, measurement and value processing chain shall provide a defined accuracy with very low derating with temperature over their whole lifetime.

The end to end measurement and processing chain from sensor to end recorded value is critical for maintaining accuracy over the whole lifetime time including evolution of the ICT equipment and power distribution in the site.

The measurement and processing chain includes pre-filtering (e.g. against noises and anti-aliasing as defined in [i.17]), data-acquisition and analog/digital conversion, calculation such as RMS value and software settings for better accuracy (e.g. corrections of offset, linearity, noises, etc.). The defined settings and processing software shall be saved locally and on remote server for restoration in case of maintenance or failure.

NOTE 1: Embedded self-calibrations and tests of measurement chain can be proposed to maintain measurement accuracy over the whole lifetime. Example of this solution is reported in [i.18] from one energy metering chip manufacturer.

Electrical measurement accuracy

The measurement of active power and the energy metering shall have the following accuracy:

- Accuracy 1 ±3 % from 25 % to 100 % of maximum load of the equipment (load range 1)
- Accuracy 2 ±5 % between 5 % and 25 % of maximum load of equipment (load range 2)
- For both accuracy, the 100 % load is specified as the maximum power of each considered ICT network equipment

The accuracies of the voltage and the current measurement, are defined in order to obtain the defined accuracy of power and energy and as optional in annex B: they should be as follows:

- Voltage accuracy ±1 %
- Current accuracy 1 ±3 % from 25 % to 100 % of maximum load of the equipement (load range 1)
- Current accuracy 2 ±3 % between 5 % and 25 % of maximum load of the equipement (load range 2)

NOTE 2: When power calculation is based on product of voltage and current. Power accuracy is driven by current accuracy.

The accuracies of power measurement and energy metering shall be defined in normal indoor operating temperature range of class 3.2 according to ETSI EN 300 019-1-3 [10].

When operating the equipment in outdoor environment defined in ETSI EN 300 019-1-4 [i.19] the power measurement and energy metering accuracy can be extended to ±5 % in load range 1.

The verification test of accuracy are defined in clause 4.4.3.6.

The Frequency measurement accuracy is not mandatory and accuracy is not defined in the present document. The monitoring of frequency is defined for AC distribution system control-monitoring in ETSI ES 202 336-4 [7].

Environment measurement type and accuracy

The temperature measurement shall have an accuracy of ±1 °C.

The humidity should be measured with a sufficient accuracy e.g. ± 3 % (see table B.1).

The temperature accuracies is defined in normal indoor operating temperature range of the relevant class according to ETSI EN 300 019-1-3 [10] for which the equipment is designed.

When operating the equipment in outdoor environment defined in ETSI EN 300 019-1-4 [i.19] the temperature accuracy can be reduced to ±2 °C.

NOTE 3: The accuracy of temperature and hygrometry are defined when the temperature is stable i.e. when the variation is lower than ±1 °C over 5 s.

4.4.3.4 Local acquisition record

A local acquisition record of data over a defined record period T_{rec} consists in set of voltage, current, temperature/humidity, power, energy, and some indirect data such as minimum and maximum values.

Recorded values are defined as follows:

- Electric values (current, voltage, power) shall be average of the true RMS measurements over T_{rec} period.
- Energy shall be a cumulated value over T_{rec} period.
- Temperature and hygrometry are average value over T_{rec} period.
- Minimum and maximum values of current, voltage, power, temperature/humidity are captured during the same period and recorded.

NOTE: These minimum, average and maximum values are useful for site engineering optimization.

Considering periodic data recording:

- It shall be possible to set remotely the record period at 5 to 60 minutes.
- The recommended acquisition period is 15 minutes.
- A record period option of 1 mn should be also proposed.

All data records shall be associated with a time stamp (date/hour at 1 s accuracy) and an identifier including equipment reference and site reference (see annex A) in order to allow further services of analysis of data integrity and correlation of energy consumption to telecom performance state and activities on remote analysis servers.

4.4.3.5 Accuracy verification

The defined accuracy of recorded data defined in clause 4.4.3.3 shall be verified with true RMS laboratory meter with 1 % accuracy for electrical measurements and with laboratory thermometer at ±0,5 °C for temperature.

The hygrometry measurement verification should be made with sufficiently accurate relative humidity laboratory measurement:

- The accuracy 1 and 2 defined in clause 4.4.3.2 for power, energy, voltage and current shall be verified with the following current waveform applied over on the local record period T_{rec} at the power interface of Network Element ICT equipment:
  - DC:
    - DC current at 5 %, 10 %, 25 %, 50 %, 75 %, 100 % of maximum load of equipment defined in clause 4.4.3.2, with accuracy of ±1 %;
    - with constant reference voltage of 54 V for interface A2 or 380 VDC for interface A3 with accuracy of ±1 %;
    - at least for 10 % and 50 % load at minimum and maximum voltage of the DC interface with accuracy of ±1 %.
  - AC:
    - AC current at 5 %, 10 %, 25 %, 50 %, 75 %, 100 % load;
    - with sinusoidal reference voltage 230 V 50 Hz with accuracy of ±1 %;
    - at least at 10 % and 50 % load at minimum and maximum voltage of the AC interface (considering narrow European voltage range) with accuracy of ±1 %.
  - Fast electric waveform:
    - a load variation from minimum to maximum load of the range at a period of 1 ms using a sinus waveform;
    - the test is done in DC at reference voltage of 54 VDC for interface A2, 380 V for interface A3 or in AC at reference voltage 230 V 50 Hz depending on equipment input type with accuracy of ±1 %.

Considering temperature condition and possible impact, the accuracy shall be verified at:

- at 25 °C ±2 °C at for all loads and voltage defined in this clause;
- at 5 °C and 40 °C for 10 %, 50 % and fast electric waveform loads only at the reference voltage with accuracy of ±1 %.

4.4.3.6 Data transmission period

The transmission period is a parameter that can be set remotely from 5 to 60 minutes.

T_{trans} shall be equal or higher to T_{rec}.

When T_{rec} is lower than T_{trans}, several records of data are transmitted together in a single transmission.

Transmission of local records shall be synchronized with NMS data transmission period.

4.4.3.7 Local record saving

The local data record defined in clause 4.4.3.5 shall be stored locally in case of network failure or delay for transmission as defined in clause 4.4.3.7. In general local storage shall include data records for a few days with a minimum of 4 days in this case. In case of normal operation with NMS the storage duration should be aligned with NMS requirement.

For longer saving time requirement, there can be in addition an aggregation of the recorded values taking a longer averaging period in order to keep minimum data retention over long time. For example the memory capacity is of several months of hourly averaged values on a remote BS on standalone energy and difficult access to the site.

4.5 PEE data analysis services

A user can leverage services of analysis of Power/Energy/Environment data in addition to display and record. This can be Energy data analysis services which include various reports, with database management, and potential correlation services to understand the power consumption structure and optimization possibilities and progress.

NOTE 1: This kind of services can be done by a third party enterprise specialist of this kind of environmental analysis about any consumption, impacts, resources use in buildings and organizations such as any energy type use (electricity, liquid fuels and gas, etc.), water use, paper use, etc.

NOTE 2: The analysis services may refer to big data analytics and artificial intelligence technology, but this does not mean that this kind of smart services compensate the lack of accurate data acquired at relevant period on ICT equipment and network. This means that they can help to find interesting results and optimization in a more automatic and efficient way.

Figure 4 is showing what is in the scope and out of the scope of the present document.

The power/energy/environmental parameters data records shall be stored by this service for 2 years, for example in NMS or OSS.

To avoid database oversizing, data stored from more than 2 years could be daily average, minimum/maximum data.

The export of PEE data to the Remote Management System XRMS, from NMS or OSS shall use data transmission and protocol defined in ETSI ES 202 336-1 [1] and data defined in the present document providing the information model.

NOTE 3: In the future, there could be also other data exchange protocol not yet specified to a third provider of power energy/energy analysis services common to many sites and many customers.

NOTE 4: One possible protocol could be based on 3GPP and E-UTRAN unified protocol under definition Itf-N, see annex A in ETSI TS 132 101 (V15.0.0) [i.13].

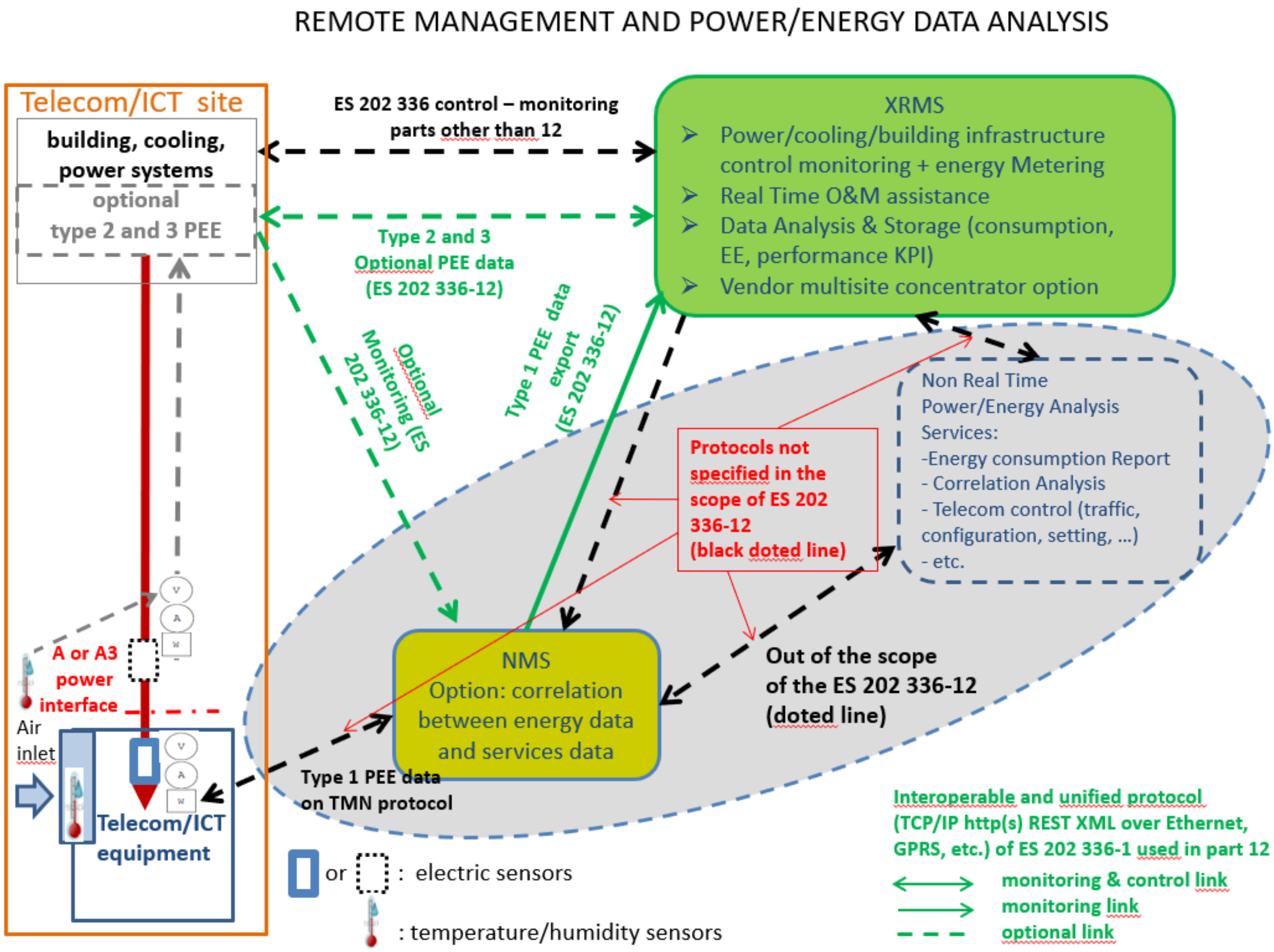


Figure 4: Limits of the scope of the standard about additional energy analysis services

Table A.1 (see annex A) corresponds to mandatory data that shall be provided for ICT equipment power/energy and environment monitoring model.

Table B.1 (see annex B) corresponds to non-mandatory data that shall be provided in addition to mandatory for ICT equipment power/energy and environment monitoring model.

Annex C standardizes XML coding structures for these data.

Annex A (normative): Summary of mandatory monitoring / supervision information and functions

A.0 General description of mandatory monitoring / supervision information and functions tables

This annex defines the minimum set of information needed for the XML remote monitoring of power/energy and environment of ICT equipment.

NOTE 1: Table A.1 does not specify the equipment by itself. This table refer to subsets or devices that are not necessarily present in each equipment configuration. As a matter of fact, one alarm and its class apply only in case of the presence of this subset or device.

When an optional alarm that requires a parameter set is present, the corresponding parameter set is mandatory in the control section in order to allow remote adjustment under appropriate login procedure.

According to their types (Description, Alarm, Data, etc.), as defined in ETSI ES 202 336-1 [1] the information shall be provided by the Control Unit (XCU).

NOTE 2: If there is no XCU this data should be provided by the Data Gathering Unit (DGU).

When a CU has a field data bus connected to the DGU, at least, the DGU shall store data (record measurements, log files). The XCU which has the XML interface over Ethernet TCP/IP shall store these data.

NOTE 3: The "Explanation" column provided in the data tables of annex A has been used where necessary to further explain the statements in the "Monitored information" column. The "Type" column gives the assigned name used in XML coding and the "Monitored information" column provides details of the condition or state being monitored. The identifiers used in the "Type" column of the tables of annex A are described in ETSI ES 202 336-1 [1].

NOTE 4: Partial communication network failures e.g. XCU link fault should be detected by an upper element of the network e.g. the RMA (refer to figure 1 of ETSI ES 202 336-1 [1]).

NOTE 5: Clause 9.4.4 of ETSI ES 202 336-1 [1] details the parameters associated with XML elements e.g. time delay, severity of alarm element. The tables of annex A do not include the application of these parameters.

A.1 Table for ICT equipment power, energy and environmental parameters measurements

Table A.1

Type	Monitored information	Explanation
Description	Site and ICT equipment reference identification. The equipement are defined in table 1.	Site and ICT equipment mapping identification + Identification of measurement equipment Site identification is defined by each operator Equipment identification is defined by manufacturer in OSS in the element manager (see annex D)

Type	Monitored information	Explanation
	XCU and measurement data issued configuration	High level description of equipment type (indoor, outdoor), measurement configurations (AC, DC, etc.)
Alarm	Sensors failure (current, voltage, temperature or power meter)	Additional detected failure can be too high noise, abnormal values, etc.
	Partial network failure (high error rate, XCU or DGU link fault to the sensors, etc.)	This is the monitoring network that is considered
Event	Alarm set and clear (data log)	The start and end of alarm are recorded with time stamp in the datalog file of XCU, DGU or of Network Equipment with embedded measurement
	Information of any configuration and/or parameters change	idem
Data	Average active power	Value in W, accuracy and conditions are defined in clause 4.4.3
	Min active power	
	max active power	
	Active energy consumption over a period of time	Value in kWh for each input Sum of all inputs corresponding to one referenced equipment shall be provided Accuracy is defined in clause 4.4.3. It can be index of Energy since start of operation or just the energy consumed over T_{rec}
	Temperature of the equipment/ICT	Measure done at the level of fan tray when it exists Position to be justified by factory measurement on fully equipped equipment (see note)
	Time stamp of a set of measurements	
Data Record	Records of set of data defined in table A with time stamp at period T_{rec}	Frame of records transmitted at the transmission period T_{trans}
Config	Hardware configuration relevant to ICT equipment power consumption	Identification and description of power input at interface A. It can be at shelf level in a cabinet or rack mounted. Detailed power input configuration can be: Single, double, this should help to associate input corresponding to the same equipment consumption (A+B, A+B+C, etc.). This shall be available at remote management level to analyse data
	Complementary hardware information	E.g. telecom shelf system cabinet description for big Telecom sites

Type	Monitored information	Explanation
	Time-date setting (mandatory for any energy measurement) - not required if provided by NMS or EMS of the ICT equipment	yyyy/mm/day hh:mn:ss It is essential to have a precise time/date stamp to energy measurement for correlation to ICT configuration and status (traffic, settings, etc.)
	Alarm parameters setting	The setting threshold value for alarms e.g. for sensor failure detection
	Measurement parameters setting: energy, power, current record period	It is recommended to limit record time if fast acquisition to avoid excess of data amount
Control	For external XCU alarm/event/test/command parameters (time-out, counter, thresholds, etc.) if any	It is required for internal measurement in the ICT equipment
	For external XCU program download with default to previous release	Hexadecimal file It is required for internal measurement in the ICT equipment
NOTE: The room temperature measurement is already defined in ETSI ES 202 336-6 [8].		

Annex B (informative): Summary of non-mandatory monitoring / supervision information and functions

B.0 General description of non mandatory monitoring / supervision information and functions tables

According to their types (Description, Alarm, Data, etc.), as defined in ETSI ES 202 336-1 [1], the information should be provided by the Control Unit (XCU) or by the Data Gathering Unit (DGU).

The non mandatory information of table B.1 are provided in addition to the mandatory information defined in table A.1.

NOTE: The "Explanation" column provided in the data table B.1 has been used where necessary to further explain the statements in the "Monitored information" column. The "Type" column gives the assigned name used in XML coding and the "Monitored information" column provides details of the condition or state being monitored. The identifiers used in the "Type" column of table B.1 are described in ETSI ES 202 336-1 [1].

Table B.1 gives a list of useful non mandatory information for ICT equipment power, energy and environmental parameters measurements.

B.1 Table for ICT equipment power, energy and environmental parameters

Table B.1

Type	Monitored information	Explanation
Description	Additive information	
Alarm	RMS current or active power consumption out of range after time-out	Above high threshold, it means overconsumption with respect to the maximum value specified by the manufactured for the defined equipment configuration. Below low thereshold, it means probably a failure or incorrect settings of equipment. In both cases it can be also a measurement problem. The time-out can be used when required to filter fast current variation such as inrush current
	Temperature sensor measurement out of range	It would means in, general sensor of measurement failure

Type	Monitored information	Explanation
	Too instable measurement - need an average or RMS filter	On new ICT equipment, power can vary too fast which can give large measurement error rate without appropriate data acquisition conditioner stage
	Power capacity management (ratio) = Used/Installed max power required	It need maximum configuration active power consumption value to make this calculation
Event	Details of any change of configuration	
Data	RMS voltage on a power input at interface A or A3 (DC) or A1 (AC)	Value in V Accuracy is commonly ±1 % and independent of load. It is defined in clause 4.4.3
	RMS current on a power input at interface A or A3 (DC) or A1 (DC)	Value in A Accuracy is defined in clause 4.4.3 should ensure with power and energy measurement accuracies defined in clause 4.4.3
	Active power at board level	It can be useful for big telecom system. Accuracy as defined in clause 4.4.3. It can be data of several boards with appropriate identifier
	Temperature at the board level ±0,5 °C	It can be useful for big telecom system. Accuracy as defined in clause 4.4.3. It can be data of several boards with appropriate identifier
	Humidity	Measured at the equipment air inlet or at fan tray level when it exists (e.g. for ADSL). Accuracy 3 % The room humidity measurement is already defined in ETSI ES 202 336-6 [8]
Data Record	Local record with data of table A and B with time stamp at period T_{rec}	Frame of records transmitted at the transmission period T_{trans}
Config	Sliding time window to capture power consumption	Period of time over which power data logging is carried out
	All XCU alarm/event/test/command parameters (time-out, counter, thresholds, etc.)	
Control	Parameters setting: alarm current, voltage, power, temperature thresholds (low, high)	
	Parameters setting:active energy counters	kWh
	Parameters setting: voltage loss time-out	hhmm

Annex C (normative): Mandatory XML structure and elements

C.1 Structure of an XML document for ICT Power/Energy/Environment metering (PEE)

In the site DGU XML data structure as described in ETSI ES 202 336-1 [1], a power/energy monitoring system of ICT equipment is a child of a site.

The XML structure shall be as follows:

NOTE 1: It indicates precisely the generic mandatory XML structure and where to put the information if it exists (where it starts and stops). Every equipment and element, should be considered as a folder in the XML structure.

NOTE 2: Site, equipment name and id values are just given for example in the XML file.

```
<site id="23" status ="normal">
    ....
    <Equipment management system id="1" status="normal">
        <description_table>
        …
        </description_table>
        …
        <PEE metering system id="1" status="normal">
            <description_table>
            …
            </description_table>
            <alarm_table>
            …
            </alarm_table>
            <event_table>
            …
            </event_table>
            <data_table>
            …
            </data_table>
            <data_record_table>
            …
            </data_record_table>
            <config_table>
            …
            </config_table>
            <control_table>
            …
            </control_table>

            …

        </ PEE metering system >
        …
    </energy metering system>
</site>
```

A Telecom-ICT Power/Energy/Environment condition metering XCU will only generate the XML document "PEE.xml". This file can be downloaded by the DGU of the site and embedded in the "site.xml" document. In this case, the structure of the document is as follows:

```
< Power, energy, environment measurement system id="1" status="normal">
    <description_table>
    …
    </description_table>
    <alarm_table>
    …
    </alarm_table>
    <event_table>
    …
    </event_table>
    <data_table>
    …
    </data_table>
    <data_record_table>
    …
    </data_record_table>
    <config_table>
    …
    </config_table>
    <control_table>
    …
    </control_table>

    …
</ Power, energy, environment measurement system >
```

Annex D (informative): 3GPP and E-UTRAN Management reference model and unified interface Itf-N

The 3GPP has defined for UTRAN and E-UTRAN a Performance Management Architecture and Model with a Unified Control-Monitoring interface Itf-N that could provide data of Power, Energy, Environment conditions, and Telecom equipment configuration, setting and state at a Network Manager (OSS) with some granularity.

Information on the reference model is given in ETSI TS 132 101 [i.13].

Annex E (informative): Fixed network Management reference model and unified interface

It has not been identified standardized reference models or unified interface for fixed network implemented in products; vendor proprietary solutions are usually adopted.

Standardized control interface of the network nodes can be found in ETSI ES 203 237 [i.9].

It is recommended to refer to the latest models or unified interfaces inside the relevant standards or vendors documents.

Annex F (informative): State of the art of power, energy measurement and monitoring systems

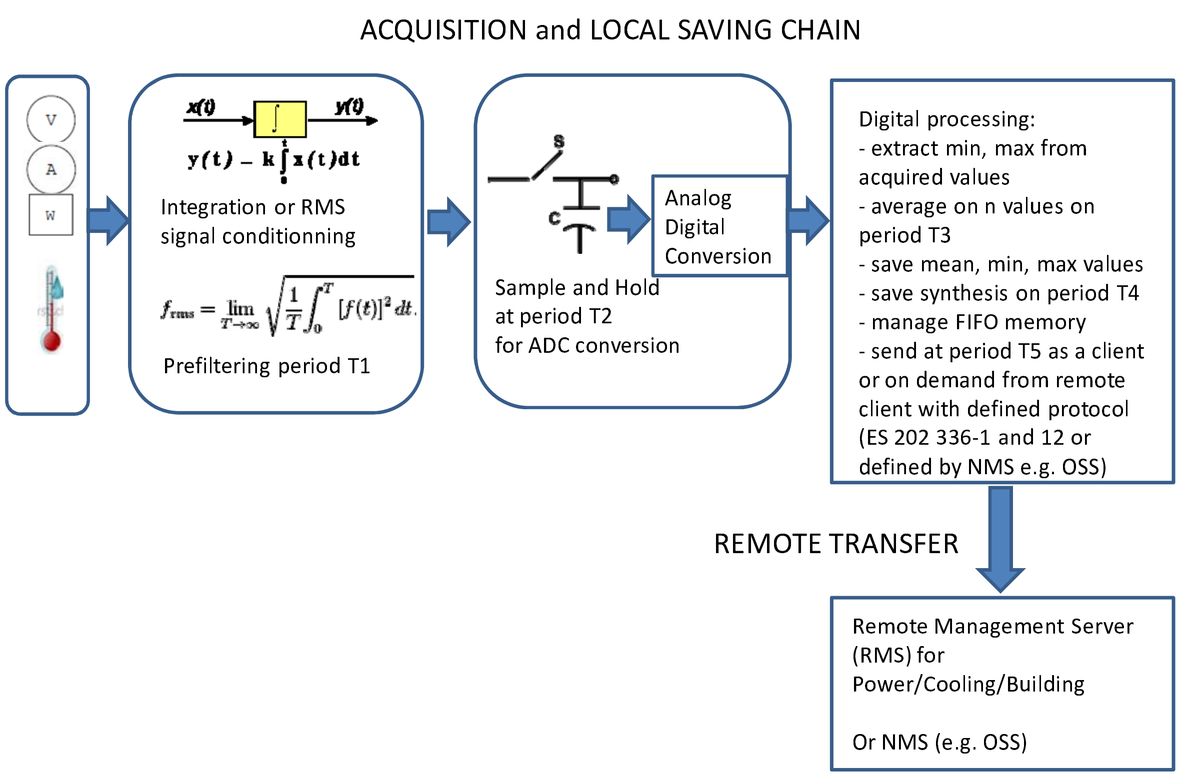
F.0 Introduction

The goal of the annex F is mainly informing on state of the art of mass production electrical power/energy metering chain giving a fair accuracy.

It is based on industrial know-how and documentation of already available monitoring systems and components used in electrical voltage, current and power/energy parameters measurements.

There may be other solutions not described here.

F.1 Acquisition and remote metering principles



NOTE: The ideal RMS calculation is a mathematical limit at infinite time, but a very precise RMS value may be practically obtained on an integration period much lower than 1 second when the acquisition frequency is of some kHz as achieved by many common integrated chips.

Figure F.1: Principle of measured data acquisition, local processing, robust saving and transmission to remote servers

Measurement and signal conditioning (period or time constant T1)

In figure F.1 sensors refered with symbols V, A, W and a thermometer are giving electrical measurements signal x(t) and in general there is a prefilter or signal conditioner on the rough analog measurement. Forenvironmental parameters, it could be a simple averaging circuit by a low bandpass or integration filter over the period T1.

For more precision on electrical currents signals with a lot of harmonics due to fast and strong dynamic variations, a RMS value is a Root Mean Square calculation. For example RMS is root of a summation of squared rough measurement acquired at 1 ms period. The analog prefilter would then be of about 1 ms time constant. The integration period can be T1 as well using 1 ms sampled values from analog prefilter output. In [i.17] the described circuit can measure up to 100 kHz sinus signal. The true RMS calculation is done by analog circuitry and the prefiltering period could be even much smaller than 1 ms.

- T_{rms}, T1:
  - T1 = 1 s and T_{rms} <= 1 s for electrical analog averaging time constant or RMS integration period.
  - T1 can be the same as T2 for environmental parameters temperature or hygrometry, as their variation is very slow compared to electrical parameters.

Local Acquisition

The value are saved at period T3 used for first signal processing, and is in general acquired at minimum at period T2 equal to some period of the measurement prefiltering:

- T2:
  - T2 = 1 s between analogic/digital conversion of electrical parameters.
  - It can be T2 = 5 s for slow variation environmental parameters.
  - Minimum and maximum values should be captured for site engineering optimization at that level.
- T3:
  - T3 = 5 s to 1 minute and T3 can be set as a parameter for averaging the RMS values and store them locally in a FIFO memory.The minimum and maximum values over this period.
  - T3 = 1 minute is sufficient as default value in many case of small power variations.
  - T3 = 5 s is recommended only if there is fast and strong changes of values which would be more common with fast dynamic power and settings managements. This could allow a special focus on one site and in case of special event, and when the event is finished the period could be extended to reduce data storage memory.
- T4:
  - It can be decided to keep synthesis of data every minute for example, ready to be gathered in a data record frame that will be sent at period T5. More can be found on this possibility this clause on progressive data aggregation.

Data transmission period and data record details

The data transmission period T5 is the period of the record of collected set of values at period T3. The record of data consists in voltage, current, temperature/humidity, power, energy, min/max over the record period. All data record should be associated to a time stamp (date/hour at 1 s accuracy) and to an identifier including equipment reference and site reference in order to allow further analysis of data integrity and correlation to telecom state and activities.

- T5:
  - Default value is 15 minutes. T5 parameter can be set from remote site from 5 to 60 minutes. There could be different levels of aggregation T5 for each measured value to prepare data for transmission to remote server in order to limit amount of data stored in remote servers.

- For example every T5 = 15 minutes, are sent all sets of values of U, I, P (refered as V, A, W on figure 1), synthesis of every min (T4 = 1 minute) while just one data set of Energy and Temperature average are sent every 15 minutes. The minimum and maximum of the measured values over the 15 minutes and time stamp can be given at beginning and end of the global data record corresponding to an XML file. Exceptionaly this transmission may contain a specific data record used for monitoring fast changes of electrical parameters as defined in T3 local acquisition description.

Long Data Record local saving period

The data to be transmitted, should be stored in case of network failure or delay for a retransmission, after reparation of the network. In general the period is of some days with a minimum of 4 days.

Progressive data aggregation for long term data retention

There can be an aggregation of the saved value at period T4 equal to some T3 period in order to have a long data retention of the synthesis of values (several months), in case of very long period between data retrievial.

The aggregation can be progressive, i.e. save 4 days all detailed values (U, min, max, I, min, max, P, min, max, W, T), same 6 months hourly average data (U, I, P, min, max, W, T, min, max), save 2 years daily average data (U, P, W, T).

- T4 = 60 minutes by default and T4 can be set as a parameter from 1 minutes to 24 hours.

NOTE: For difficult access sites, the record period of data synthesis can be greater of 1 month to avoid loss of value, when the repair time of the network is very long. For example it can useful to have memory of several months, with synthesis every hours on a remote BS on standalone energy and difficult access to the site.

F.2 General description of measurement

F.2.1 General principle

The following clause gives an indication of state of the art medium accuracy measurement solutions of Voltage, Current, Power and Energy reachable. In general, the measurement subsets consist in sensor, followed by signal conditioner, A/D conversion and calculation in a digital circuitry (logic array or specialized or general purpose programmable controller). These subsets are more or less integrated in the same chip.

Last clause gives an assessment of local and remote data storage volume.

On new electronic device, power and energy metering are obtained from voltage and current multiplication and then integration or summation on time.

Some circuit can do directly the RMS power calculation as in multimeter for voltage or current and as in power meter e.g. in pass through plugs with display for a very low cost and accuracy of ±1 % on a wide range from some Watt to some kW.

In this later case, the true RMS value is obtained by integrating or summing the instant power (product of instant voltage by instant current) over a defined time. For example voltage and current are acquired at ms, while averaging is done on 1 second. For AC measurement the meter is also able to give the phase shift between U and I in term or cosines value, or even the power factor integrating many harmonics of AC 50 Hz till rank 7 or 9 times the fundamental period.

F.2.2 Measurement sensors

Voltage measurement

There is no sensor. The only error comes from bad connexion of measurement points, parasitic voltage in case of very low voltage due to electrochemical potential between 2 metals or asymmetrical metal connexion, creating a thermoelectric Seebeck voltage.

This is not a problem for measurement of power with ten's of Volt at interface A.

An accuracy of ±1 % is easy to obtain as will be explained in the section about AC or DC signal conditioning of this clause.

Current Hall sensors effect

The Hall sensor uses the Hall effect which is a creation of voltage in a semi-conductor material when crossed by a current in a magnetic field.

There are 2 types of Hall effect sensors:

- open loop: giving the absolute value, in general low cost but not accurate and stable with time and temperature. The variation of field will affect the offset of the measure (small residual value observed at Zero current due to magnetization of the sensor);
- closed loop: a current in a coil is compensating the measured field to read 0 volt on the Hall effect sensor. They are in general more accurate as they work in a linear zone and with no persistent field so no magnetical hysteresis issue. It is reducing the offset value derating. There can be some improved demagnetization solution.

Even on laboratory measurement device reaching ±2 % accuracy is difficult, and especially impossible for long period without frequent calibration.

It is even more difficult for open clips, because of the leakage of the magnetic circuit where it opens so that it is more disturbed by external magnetic fields. This is currently observed on best of class laboratory clip.

To sum-up many sources of errors are affecting the accuracy at long run of Hall effect sensors:

- Persistent magnetic field.
- Proximity field and magnetic disturbance created by other conductors.
- Centering of the wire in the clip.
- Sensitivity to temperature and power supply voltage fluctuation of the device itself as it affects the offset.

Shunt measurement

The shunt is a very stable resistance with time. In general it has a very low temperature coefficient thanks to the use of some special metallic alloy. The basic measurement principle is based on Ohm law:

$$U = R.I$$

with:

- U: the voltage drop at resistance terminals;
- R: the value of the resistance;
- I: the current passing through the resistance.

As R is chosen to be constant, independently of temperature, the read voltage corresponds precisely to the current and it is very linear with no offset at 0 A, corresponds 0 V with only some noise.In general, resistance of Shunt type is used and currently gives ten's of mV at the maximum current to be read in order to avoid losses and temperature rise of the metal from which it is built.

A very common accuracy is ±1 %. It is possible to have a ±0,25 % with 4 points (2 for power terminals, 2 for reading terminals).

For example, a 50 mV 100 A shunt, dissipates 5 W. 10 mV is better for this with only 1 W, but there is a trade off to find as the difficulty will be on the amplifier precision and noise to be able to increase the voltage for a proper AD conversion.

Measurement of the current I on a shunt is sensible to parasitic voltages. So it is recommended to (see also AC or DC signal conditioning section in this clause):

- Use symmetrical power supply on OA to have specified offset when voltage close to zero.

- Avoid noise on power supply by proper PSU design and close filtering on OA and AD circuitry.
- Avoid capacitor with some residual potential in filtering circuits.
- Avoid asymmetrical battery effect on contact (use unoxydized contact metals and water proof contacts).
- Avoid symmetrical Seebeck thermo-electric effect contacts.
- Use the shortest as possible measurement cables with same length with no loop to avoid induction. Shieded cable are used in high class solution.

AC transformer sensor or Rogowski coil sensor

The well known current transformer or Rogowski coil sensor are measuring the fields though a magnetic flow variation with time in a precisely designed secondary coil. The measurement based on these sensors are precise and stable with time. Hysteresis is not a problem with non persistent magnetic field finely devised magnetic core with very small Eddy current losses at 50 Hz and very small hysteresis.

A ±1 % accuracy is very common with high linearity and there is no offset at condition of PF close to 1.

This sensor can read distorsed current but may have problems with non sinusoidal current and bad power factor that may create saturation of the core and consequently measurement errors.

Other current sensors

It exists some other effect that can be used to read current with stable accuracy. The effect discovered by Louis Néel of giant non linear superparamagnetism begins to be used with good result. But in general sensors based on this effect are very expensive, and so not adapted to the application presented in the present document.

AC or DC signal conditioning

The proposed solutions of sensors signal conditioning are worth for DC or AC.

➔ Method 1

This method is based on operational amplifier (OA) and microcontroller (µC) with AD channels.

The OA are defined as follows:

- high precision (OA) with very low offset and bias current are used;
- they are arranged in differential mode to accept common mode voltage drop;
- for voltage measurement a simple voltage attenuator can be used e.g. divide by 25. 50 V will give 2 V;
- for current, amplification is required, e.g. a gain of 50 will give 2,5 V for 50 mV voltage on the shunt which is a common value to have low power loss in the shunt. At 20 A - 50 mV, the loss is 1 W for 1 kW load in 48V;
- a 0,25 % precision shunt for less than 100 A could have low cost. A 0,5 % could be very low cost.

Then the acquisition is done by the µC on AD channel with precision corresponding to 1 bit over 10 to 12 bit, which means a resolution of less than 1/1 000 of full scale e.g. 5 V. 10 bit resolution corresponds to 5 mV. With gain 50, the input will be 100 µV on the 50 mV shunt corresponding to 0,2 %.

To obtain the required accuracy between 1 and 2 %, the following choices are recommended:

- Use 0,1 % accuracy resistance for voltage measurement gain or attenuation, these high precision resistances having very low ageing and temperature derating.
- Use lower than 50 µV offset OA with no derating for 0,1 % accuracy at full scale of the shunt.
- Chose OA of chopper type for regular offset compensation by periodical measure of artificial zero at input. Non chopper OA exists and is much less noisy which is better for very low voltage measurement on shunt.
- The major manufacturers of precision OA have these components with detailed datasheet and application notes to obtain the best of these components.

The AD should use a voltage reference of 1 % error maximum that can be internal or external. When external, it can be the power supply of the µC, or a specific voltage reference. 1 % accuracy is reachable on the reference.

The µC can aquire every ms the U and I values, calculate the U.I product and sum-up them over 50 to 100 ms. An average value of P RMS can be obtained every 1 s. In addition Pmin and Pmax can be logged.

The precision of time can be of 1 % with the internal RC timer of the µC, but can reach some ten's of ppm, on an external Quartz then the µC can aggregate over 1 to 60 minutes as required.

All parameters are easy to set.

All values can be logged in EEPROM not to be lost in case of power supply interruption.

Additional calibration tuning can be done to allow higher accuracy when required.

➔ Method 2

Another alternative is to use a low cost specialized integrated circuit for AC power measurement. The circuit has build-in analog amplifier and 24 bit AD converter and 25 ppm voltage reference of high precision and an arithmetic and logic unit able to calculate instant power and RMS values. The circuit has a serial bus of serial type for communication or record on serial EEPROM or to a host processor.

It requires only some passives components (resistors and capacitors) to operate and consumes less than 20 mW under 3 to 5 V. A voltage divider is used for voltage input, and a differential amplifier for current input from shunt or current transformer or Rogowski coil.

For example the circuit of figure F.2 is showing the typical precision of the AC power measurement with different PF on a dynamic of 1 to 4 500 for a single phase AC energy meter and figure F.3 was result of one measurements of linearity done in Laboratory on an energy meter integrated circuit.

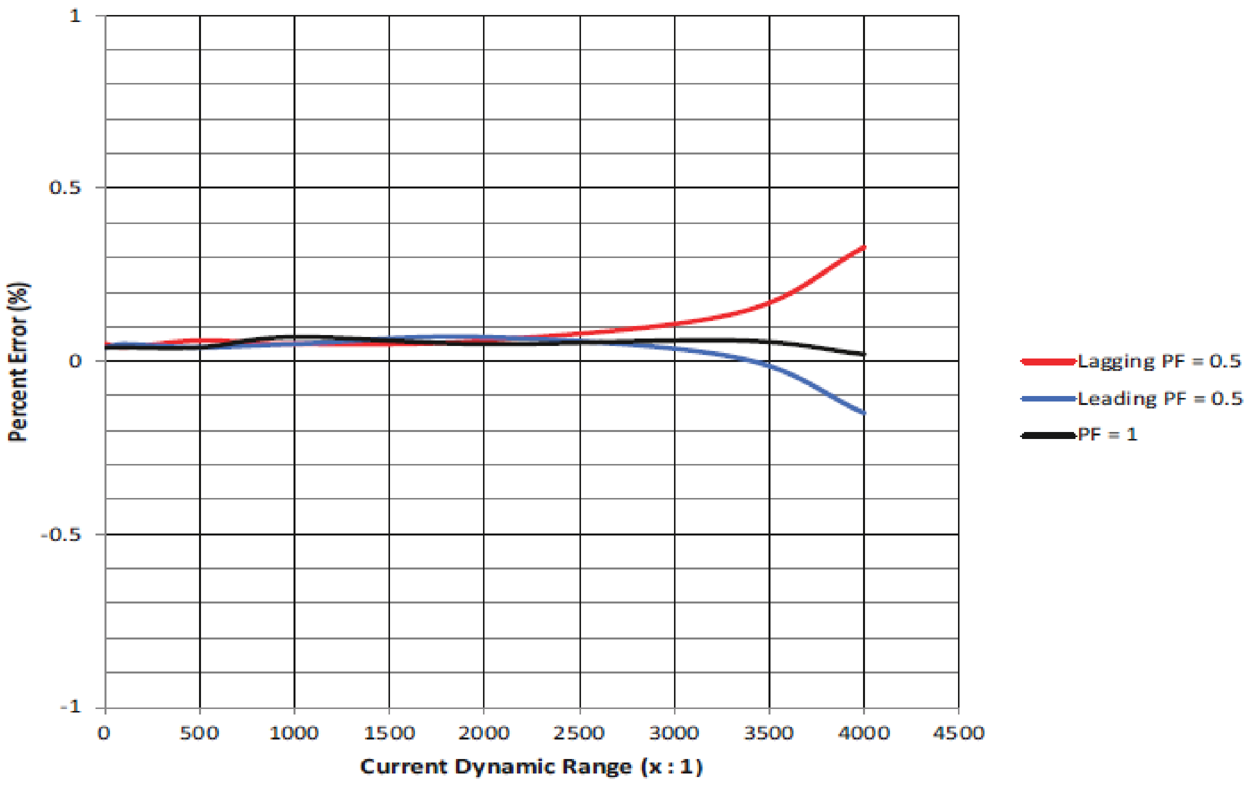


Figure F.2: Example of electric AC energy metering accuracy

Measurement have also been done on DC with an older version of the component and have resulted in the following linear graph (figure F.3). The linearity is quite good on a wide area of load. ±1 % RMS power precision is achievable on a wide range of measurement and there is about no offset.

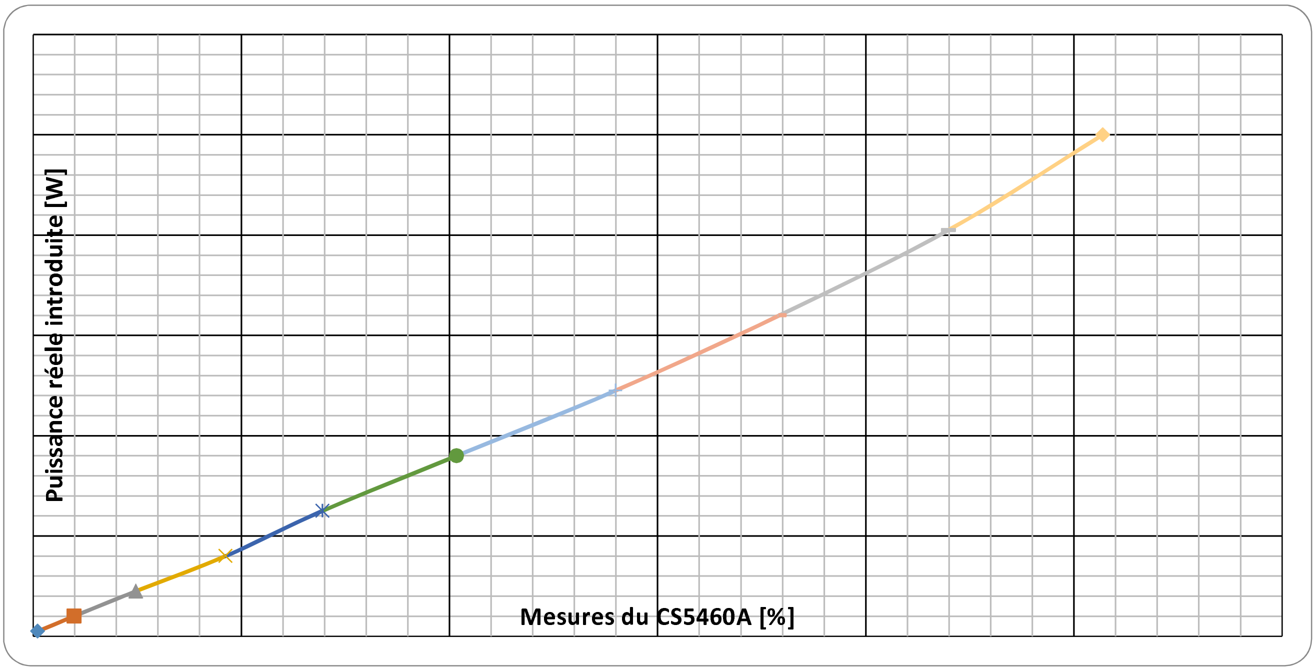


Figure F.3: Circuit linearity test done on a older generation of energy meter component

Annex G (informative): Bibliography

3GPP TS 32.452: "Telecommunication management; Performance Management (PM); Performance measurements Home Node B (HNB) Subsystem (HNS)".

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3GPP TS 32.425: "Performance measurements Evolved Universal Terrestrial Radio Access Network (E-UTRAN)".

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History

Document history		
V1.1.1	June 2015	Publication
V1.2.1	December 2018	Membership Approval Procedure MV 20190202: 2018-12-04 to 2019-02-04
V1.2.1	February 2019	Publication