Guide to energy measurement applications and standards

White Paper Number 998-19721656_GMA-US

Revision 1

by Franck GRUFFAZ

Executive summary

Utility engineers, facility managers, and energy management professionals are demanding rich power and energy data from more locations to help them understand and ensure the reliability, efficiency, and cost effectiveness of their power distribution systems and the energy generated or consumed. These goals can be achieved when supported by a complete energy measurement plan that includes properly specified power metering and monitoring devices (PMDs). This guide describes the most common measurement applications, associated standards, and the type and capabilities of measuring devices that will deliver the required data.

Introduction

For decades, the basic revenue meter was the only metering equipment within electrical installations. Now, across the electrical grid and throughout every kind of campus, building, or plant, there are multi-function power metering and monitoring devices (PMDs), each dedicated to one or more applications.

Utility engineers, facility managers, and energy management professionals now require more than just kilowatt-hour data. They are demanding rich power and energy data from many locations, with guaranteed and reliable accuracy. This data is essential to helping understand and ensure the reliability, efficiency, and cost effectiveness of their power distribution systems and the energy generated or consumed.

To achieve these goals requires a complete energy measurement plan supported by a network of PMDs installed in key locations through a grid or facility. A good understanding of the different kinds of measurement applications is critical to choosing the proper type and capabilities of measuring devices for each location that will deliver the required information.

This guide offers an overview of the different categories of measurement applications, with detailed descriptions and illustrations of each, including all relevant international standards.

Figure 1

Power utilities and energy consumers are both demanding a broader range of power and energy data to help improve efficiency, cut costs, and optimize operational performance.

Measurement needs on the supply and demand side

Power generation, transmission, and distribution are typically termed the supply side of energy. Within this side, there are two main categories of contractual applications:

- BIL: Billing
- GPQ: Grid power quality

Industrial, commercial, and institutional facilities represent the demand side of energy. For these users, electrical system designers must specify solutions within three categories of application:

- APP1: Cost allocation, bill checking and sub-billing
- APP2: Energy efficiency and cost savings, energy usage analysis
- APP3: Power availability and reliability, network monitoring

These categories of application are illustrated in Figure 2.

Figure 2

Categories of measurement applications on the supply side and demand side.

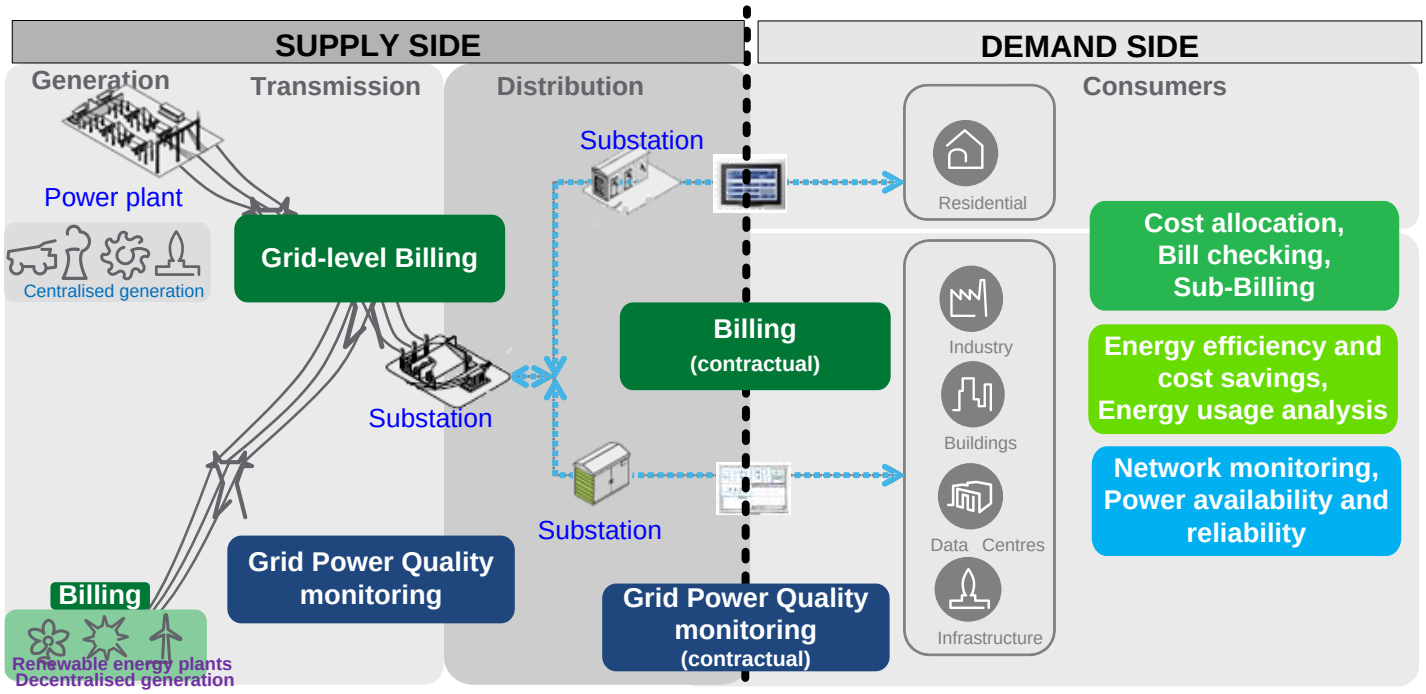


Table 1 provides a definition of the most common measurement applications within these categories.

Table 1

Definition of measurement applications on the supply and the demand sides of energy

Category	Application	Definition
BIL	Billing	The process that allows energy suppliers or their representatives to invoice their customers according to a defined contract, for measured usages or services. *Note: These applications may be covered by international standards or covered by regulations such as MID in Europe or NMI in Australia … sometimes in addition to utility specifications.*
GPQ	Grid power quality monitoring	The process that allows energy suppliers and/or their customers to verify the quality of energy delivered/received is in line with a defined contract or regulation. *Note: Limits for European public networks is defined in EN 50160.*
APP1	Cost allocation	The process that allows a facility manager to allocate energy costs to internal cost centers that consume energy (e.g. plants, workshop …)
APP1	Sub-billing or tenant metering	The process that allows a landlord, property management firm, condominium association, homeowner association or other multi-tenant property to spread out invoice over tenants (assign portions of invoice to tenants), for measured usages or services. This fee is usually combined with other tenant's facility fees. *Note: These applications are sometimes covered by regulations in some countries, e.g. UK, Canada or some states in the USA…*
APP1	Bill checking	The process that allows customers to check if invoice sent by energy suppliers or their representatives is correct.
APP2	Energy efficiency and cost savings, energy usage analysis	The process that allows a facility manager to assign energy consumption/costs to zones (plant, floor, workshop…) and to usages (HVAC, lighting, appliances, process…) over the time in order to allow optimization of energy consumption and energy costs.
APP3	Power availability and reliability, network monitoring, facility planning	The process that allows a facility manager to monitor its electrical installation in order to ensure availability and reliability of energy as well as asset durability.

Description of applications

The chapters below describe each measurement application in more detail, including applicable standards.

BIL: Billing

The term *grid-level billing* is related to commercial transactions between utilities, energy providers, or states. The simpler term *billing* is related to a commercial transaction between an energy provider and an energy consumer (customer). Grid level billing and billing are both related to legal metrology.

Legal metrology usually applies to measuring instruments used in:

- Commercial transactions (e.g. weight-price scales for retail stores, petrol pumps, water meters, etc.), when there is a need to protect both the buyer and the seller.
- Operations concerning public health or safety (e.g. gas analyzers, tachographs, radar speed detectors, breathalyzers, etc.).

For more detailed information on legal metrology applications, refer to the following resources:

- OIML website
- LNE website

Billing meters (also known as revenue meters, electricity meters or utility meters) are covered by regulations such as MID (Measuring Instruments Directive) in Europe. Standards and regulations applicable to billing are shown in Table 2.

Table 2

Standards for BIL applications

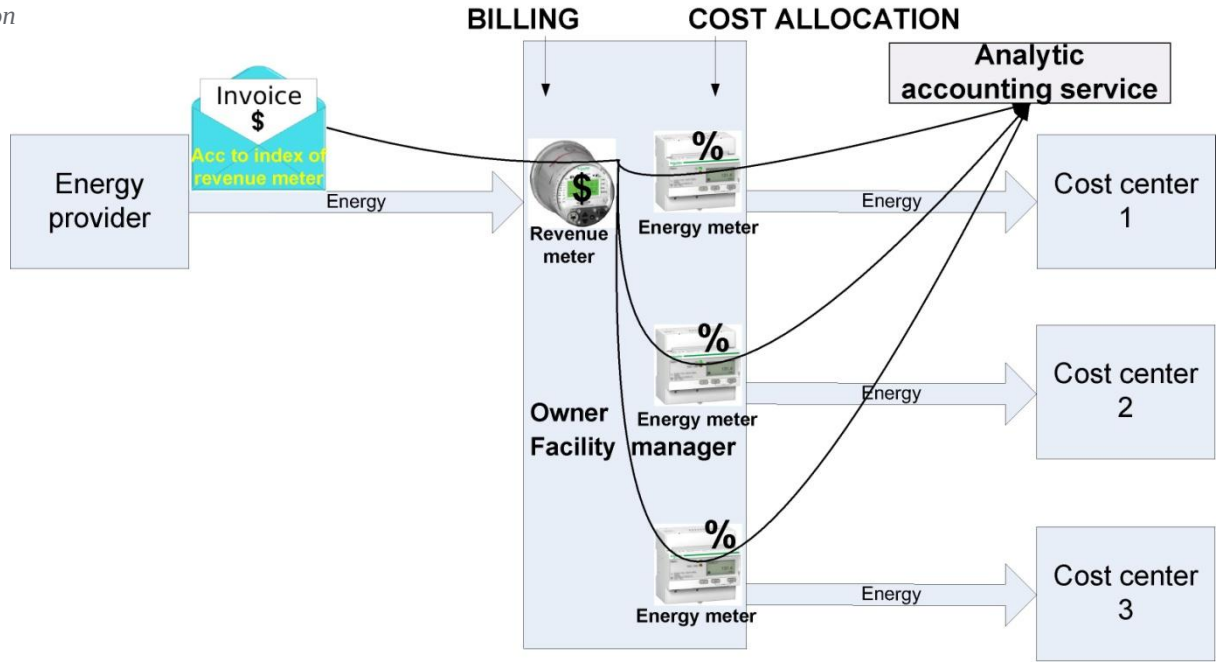
Application Assessment Standards or Rules	Methods Standards	Product Standards
Any countries can define its own regulation and/or can refer to international documents, such as the IEC International standards or OIML guide	---	**IEC 62052-xx** **IEC62053-xx**
	---	**OIML R46** (Organisation Internationale de la Métrologie Légale)
European regulation (MID Measuring Instruments Directive)	WELMEC guides	**EN 50470-1** **EN 50470-3**
US regulation	---	**ANSI C12.1, ANSI C12.20**
Australian regulation	---	**NMI M-6**
Indian regulation	---	**IS 16244, IS 15884, IS 13779, IS 14697**
Chinese regulation	---	**JJG 596**
Canadian regulation	---	**LBM-EG-07**

APP1a: Cost allocation

In this application, a revenue meter measures the total energy cost. Then, the energy meters measure the ratio (in percentage) of energy consumption for each cost center for accounting purposes, as described in Figure 3.

Figure 3

Cost allocation application

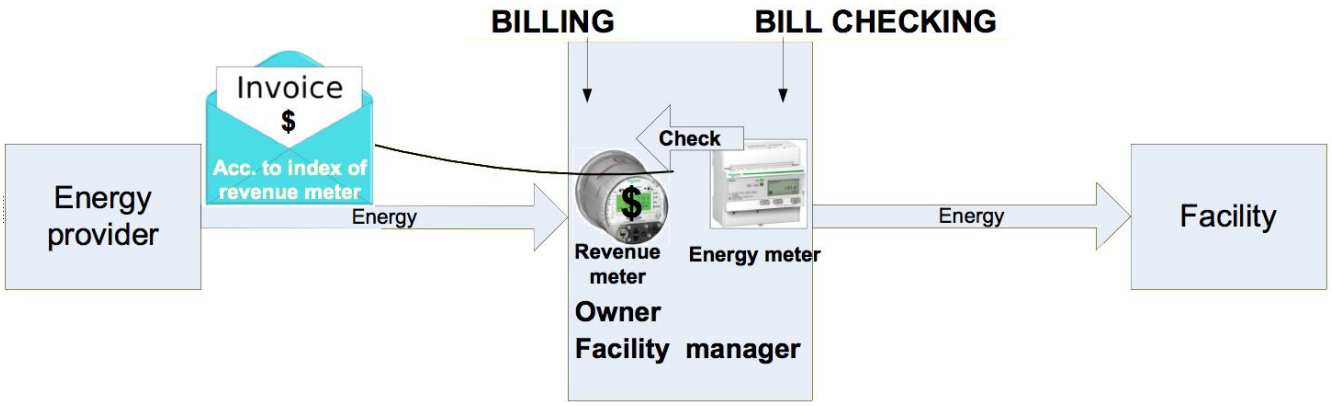


APP1b: Bill checking (also called shadow billing)

In this application, an energy meter within the energy user's facility is used to check that there is no discrepancy with the measurements made by the energy provider's revenue meter, as described in Figure 4. The verifications usually concern obvious mistakes, e.g. phase missing, configuration mistake, wrong sensor ratio. In such a case verification is based on energy consumption. Verification can also concern other parameters included in the contract between energy provider and customer.

Figure 4

Bill checking application



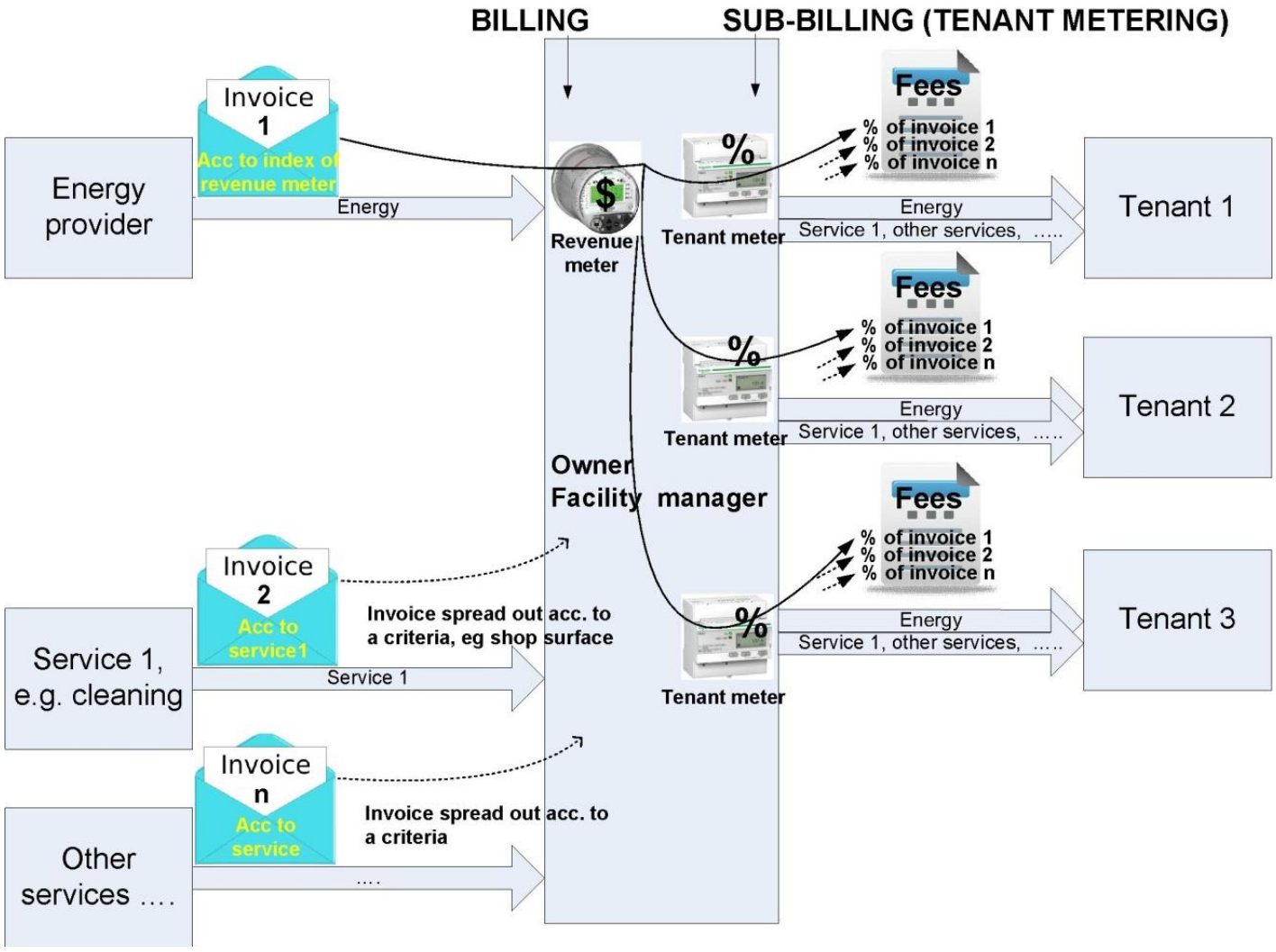
APP1c: Sub-billing (also called tenant metering)

Sub-billing is used where fees need to be issued by a facility manager (for dividing the invoiced cost of energy between tenants), while billing is used to generate the invoice issued by an energy supplier (in the framework of a commercial transaction).

In this application, a revenue meter measures the total energy cost. Measurements from tenant meters are then used to calculate the ratio of energy consumption (and energy cost) for each tenant, as described in Figure 5.

Figure 5

Sub billing (tenant metering) application



The standards and regulations relevant to the APP1 category of measurement applications described above are shown in Table 3.

Table 3

Standards for all APP1 applications

Application Assessment Standards Or Rules	Methods Standards	Product Standards
APP1a (Cost allocation) **APP1b** (Bill checking) **APP1c_gen** (Sub-billing, in general)	---	**IEC 61557-12** Power Metering and Monitoring devices (PMD) *Certified "C-PMD" devices are recommended for these applications. For more information, refer to White Paper 998-19721655_GMA-US, Guide to using the IEC 61557-12 standard to simplify the setup of an energy measurement plan*
APP1c_reg (Sub-billing, when covered by local or regional regulation)	---	Standards related to billing meters upon local or regional regulations. See **BIL** application.

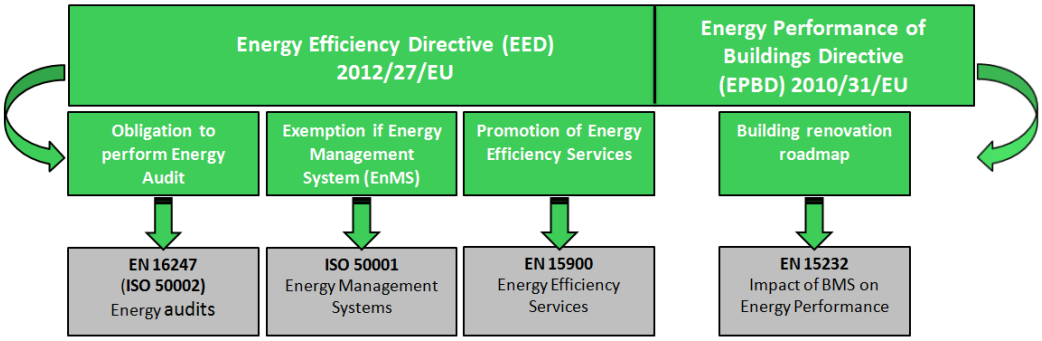
APP2: Energy efficiency and cost savings, energy usage analysis

This application is driven by several rules.

- In Europe, the Energy Efficiency Directive requests companies to either perform energy audits on a regular basis, or to set up an energy management plan as described in Table 4.

Figure 6

European Energy Efficiency directives



- Alternatively, other local or regional norms may be referred to as specified in Table 4.

Table 4

Other local or regional norms for energy efficiency

Green building certification	Influence
LEED EB O&M	USA
BREEAM-In-Use	UK
NF HQE Exploitation	FRANCE
CASBEE	JAPAN
DNGB for Existing Building	GERMANY
IGBC, GRIHA	INDIA

Today, ISO 50001 can be considered as the most common standard used to assess the energy efficiency of a plant or building.

Standards and regulations applicable to APP2 are shown in Table 5.

Table 5

Standards for APP2 applications

Application Assessment Standards Or Rules	Methods Standards	Product Standards
ISO 50001 Energy Management Systems – Requirements with guidance for use	**ISO 50006** Energy Baseline (EnBs) & Energy Performance Indicators (EnPIs) **IEC 60364-8-1** NEW! Low voltage installations – Part 8-1: Energy Efficiency **FD X30-147** NEW! Measurement plan for energy performance monitoring	**Power Meters** **IEC 61557-12** Power Metering and Monitoring devices (PMD) **Gateways, energy servers, data loggers** **IEC 62974-1** NEW! Monitoring and measuring systems used for data collection, gathering and analysis – Part 1: Device requirements

Document AFNOR FD X30-147 (available in English in Annex 5 of document BT152/DG10049/DC) provides guidance about the means to build a measurement plan, according to 3 levels of achievement to be selected by the facility manager (basic, medium and high), for instance in Annex B, annex D and Annex F.

As it is recommended to make measurements by zone and by usage while taking into account influencing factors, Table 6 provides recommendations for achieving this level of measurement.

Table 6

Guidance extracted from "measurement plan AFNOR FD X30-147".

Table B.1 — Breakdown by zone/use			
Levels / Criteria [a]	**Basic**	**Medium**	**High**
Tracking consumptions by zone	Each tariff meter determines a zone.	Each building is considered a zone and its consumptions are tracked	Each floor or activity zone (workshop, office, etc.) of each building is considered a zone and its consumptions are tracked
Tracking consumptions by use	The predominant uses (at least 2) are tracked	The predominant uses (at least 2) are tracked for each of the tracked zones	The predominant uses (at least 2) are tracked for each of the tracked zones The tracked uses shall represent at least 80% of the consumption.

Table B.2 — Consideration of the influencing factors			
Levels / Criteria [a]	**Basic**	**Medium**	**High**
Consideration of the main influencing factors for consumption by zone and/or use	The influencing factor for the most energy-consuming item is considered	The predominant influencing factor for the most energy-consuming item by zone and/or use is considered	The predominant influencing factors for the most energy-consuming items by zone and/or use are considered

Table B.3 — Consideration of the reading techniques			
Levels / Criteria [a]	**Basic**	**Medium**	**High**
Reading of consumptions	The data are derived from the suppliers' bills	Measurement reading is manual or automatic	Measurement reading is automatic, linked to the level of temporal granularity and zone and/or use
Calculation of energy performance indicators in accordance with ISO 50006 (EnPI, consumption ratio, energy baseline, etc.) according to consumptions	Simple, close to the raw consumption	Simple, close to the raw consumption	Personalized by activity (accounting, energy manager, communication to personnel, etc.)
Frequency of calculation of energy performance indicators	Calculated at the billing frequency, according to zones, uses and tracked influencing factors	Calculated each week according to zones, uses and tracked influencing factors	Calculated each day according to zones, uses and tracked influencing factors

Table B.4 — Monitoring the installation			
Levels / Criteria [a]	**Basic**	**Medium**	**High**
Monitoring the electrical installation	Continuous measurements at point of delivery.	Continuous measurements at point of delivery and at the distribution switchboards.	Continuous measurements at point of delivery, at the distribution switchboards and at the major loads.
Monitoring other fluids in the installation	---	---	---

Table B.5 — Capitalizing on the measured data			
Levels / Criteria [a]	**Basic**	**Medium**	**High**
Utilization of an energy performance supervision and reporting application (consumption report, EnPI, alarms, etc.), by type of energy, by use, by zone and over time	Not necessary	Advise, to facilitate remote reading, archiving and analysis of consumptions	Necessary for automatic collection and archiving, information distribution, management chart, alarm management and decision-making

[a] *See recommendations given in Annex F, Article F.6 about the quantities to measure.*

Table 7 offers important additional guidance regarding measurement needs within an electrical installation.

Table 7

Appropriate measurements according to the type of outgoing line, incoming line, generator, or energy exchanger, extracted from "measurement plan" AFNOR FD X30-147".

		Types of appropriate measurements [b]		
		Basic	**Medium** (in addition to basic)	**High** (in addition to medium)
Point of delivery	- at point of delivery	Active energy	U (voltage) / I (current) f (Frequency) Power Factor (or cos phi) Reactive energy Active/reactive power THDu and THDi (total harmonic distortion)	Individual current and voltage harmonics
Distribution switchboards	- for each outgoing line of at least 100kVA[a] power (e.g.: 160A, 400V 3-phase)	Active energy	U (voltage) / I (current) Power Factor (or cos phi) Reactive energy Active/reactive power THDu and THDi (total harmonic distortion)	Individual current and voltage harmonics
	- for each outgoing line of at least 40kVA[a] power (e.g.: 63A, 400V 3-phase)	Active energy	Active energy U (voltage) / I (current) Active/reactive power Power Factor (or cos phi)	THDu and THDi (total harmonic distortion)
Load	- for each outgoing line of at least 3.5kVA[a c] power (e.g.: 16A, 230V single-phase)	---	---	Active energy
Transfo	- Electrical transformers	---	Efficiency	Uinb (Phase unbalance) U (upstream and downstream voltage)

[a] The power depends on the type of installation and the buildings: tertiary, commercial, industrial, infrastructure, etc.

[b] depending on the application and the objectives, other measurements can be put in place (example: unbalance, alarm when threshold is exceeded, etc.)

[c] Buildings such as datacentres necessitate monitoring of the loads of more than 2.3 kVA (e.g. 10A, 230V)

APP3: Network monitoring, Energy Power availability and reliability, asset management, facility planning

Standards and regulations applicable to the APP3 category of measurement are shown in Table 8.

Table 8

Standards for APP3 applications.

Application Assessment Standards or Rules	Method Standards	Product Standards
APP3a: Voltage, current or frequency indication	---	**Analog electrical measuring instruments** **IEC 60051** Direct acting indicating analog electrical measuring instruments
APP3b: Electrical Distribution Monitoring, asset management, facility planning	---	**Power meters** **IEC 61557-12** Power Metering and Monitoring devices (PMD)
APP3c: Electrical Distribution Monitoring, asset management, facility planning when consistent measurement is requested at plant level (comparison between several devices measuring at different locations).	**IEC 61000-4-30, class S** Testing and measuring techniques – Power quality measurement methods	**Class S Power meters** **IEC 61557-12** Power Metering and Monitoring devices **Combined with** **IEC 62586-2** NEW! Power quality measurement in power supply systems - Functional tests and uncertainty requirements (*Compliance to IEC 62586-2 means compliance to IEC 61000-4-30)*

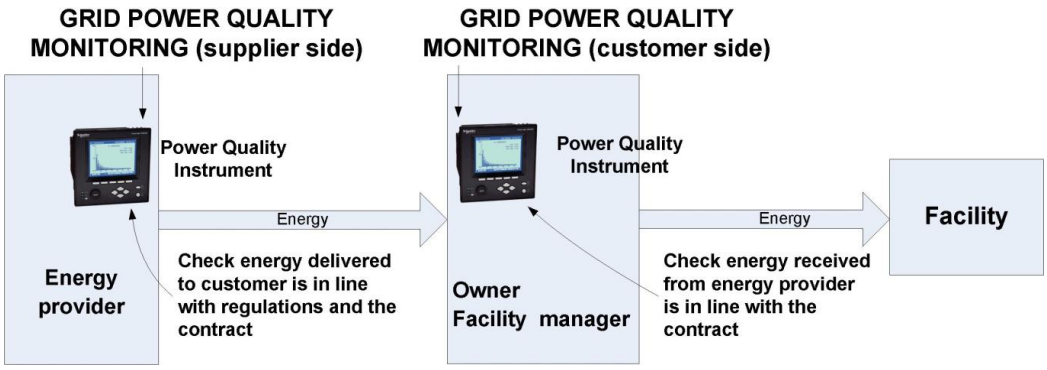
GPQ: Grid power quality

Grid power quality is mainly related to verifying compliance of power quality parameters to the relevant regulations, standards, or contracts. Energy providers check power quality on their side while customers check power quality within their facility, as described in Figure 7. Class A power quality instruments are usually requested for this purpose.

Surveys within the utility grid may be also in the scope. Class S devices are suitable for this purpose.

Figure 7

Typical grid power quality monitoring measurements.



Standards and regulations relevant to the GPQ application are shown in Table 9.

Table 9

Standards for the GPQ application

Application Assessment Standards or Rules	Method Standards	Product Standards
EN 50160 Voltage characteristics of electricity supplied by public electricity networks **IEC/TS 62749** NEW! Assessment of Power Quality – Characteristics of electricity supplied by public electricity networks	**IEC 61000-4-30, class A** Testing and measuring techniques – Power quality measurement methods [(a)]	**Relevant product standard** **Combined with** **IEC 62586-2** NEW! Power quality measurement in power supply systems - Functional tests and uncertainty requirements (*Compliance to IEC 62586-2 means compliance to IEC 61000-4-30)*

[(a)] *IEC 61000-4-30 provides the following definitions:*

- *Class A: This class is used where precise measurements are necessary, for example, for contractual applications that may require resolving disputes, verifying compliance with standards, etc. Any measurements of a parameter carried out with two different instruments complying with the requirements of Class A, when measuring the same signals, will produce matching results within the specified uncertainty for that parameter.*
- *Class S: This class is used for statistical applications such as surveys or power quality assessment, possibly with a limited subset of parameters. Although it uses equivalent intervals of measurement as Class A, the Class S processing requirements are much lower. Some surveys may assess power quality parameters of several measurement sites on a network; other surveys assess power quality parameters at a single site over a period of time, or at locations within a building or even within a single large piece of equipment.*

Conclusions & summary

Achieving power reliability, energy efficiency, and operational cost goals, whether on the utility grid or within a facility, requires a strong strategy. This needs a complete measurement plan, covering the relevant applications, and supported by power metering and monitoring devices (PMDs) that provide the required measurements.

Depending on the measurement or monitoring application, different types of power PMDs must be used. Compliance with relevant standards will ensure that PMDs are reliable, measurements are accurate, and data can be trusted.

Most measurement or monitoring applications in electrical systems can be covered by PMDs complying with the IEC 61557-12 standard and by power quality instruments complying with the IEC 62586 standard, as summarized in table 10.

Table 10

Summary of measurement applications and standards

Applications	Device	Regulations and/or product standards			
		Europe	USA	Australia	Other countries
Billing	Revenue meter, utility meter, electricity meter, billing meter (for legal metrology applications)	MID EN 50470	Local regulations ANSI C12.20	Local regulations NMI M6	Local regulations Standards
Sub-billing (tenant metering)	Legal tenant meter or legal sub-meter (for legal metrology applications)	If MID applies EN 50470	If local regulations apply ANSI C12.20	If local regulations apply NMI M6	If local regulations apply Local standards
	Tenant meter or sub-meter	IEC 61557-12 (C-PMD1, i.e. with active energy independently certified, covered by manufacturing audits, meeting measurement durability requirements and providing an indication of manufacturing date for periodic verifications)			
Bill checking	Power meter	IEC 61557-12 (C-PMD1, i.e. with active energy independently certified, covered by manufacturing audits, meeting measurement durability requirements and providing an indication of manufacturing date for periodic verifications)			
Cost allocation		IEC 61557-12 (PMD1)			
Energy efficiency	Power meter	IEC 61557-12 (PMD1, PMD2 or PMD3)			
Network monitoring	Analog electrical measuring instruments	IEC 60051			
	Power meter	IEC 61557-12 (PMD2 or PMD3)			
	Class S power meter	IEC 61557-12 (PMD3) embedding IEC 61000-4-30 class S functions (tested according to IEC 62586-2)			
Grid power quality monitoring	Power quality instrument	Relevant product embedding IEC 61000-4-30 class A functions (tested according to IEC 62586-2)			

NOTE - Some devices are providing qualitative data, resulting from reduced acquisition performance or from simplified calculation algorithms. These approximate values are used for indication (e.g. current flowing or not), comparison (e.g. significant variation in consumption of an equipment between two time-periods) or estimation (e.g. low level of Power Factor) and cannot be compared to measurements provided by the above devices.

Next steps

For more information on PMD selection, refer to White Paper 998-19721655_GMA-US, *Guide to using the IEC 61557-12 standard to simplify the setup of an energy measurement plan*.

To design a complete power and energy management solution that takes full advantage of the data from your energy measurement plan while matching your energy and financial goals, budget, and workflow, you should consult with a solution provider that can offer a complete range of PMDs, software applications, services, and expertise.

About the author

Franck Gruffaz spent half of his career in R&D as a project manager or technical manager in the field of Industry, MV and LV protection and measurement before moving to standardization activities. He is now a senior standardization manager at Schneider Electric in topics such as power quality, energy efficiency and power metering, and is involved in IEC committees such as IEC TC85, IEC SC77A, IEC SC65A and IEC SC77B.

Acknowledgements

Special thanks to **Tarek Boumegoura, Matthieu Guillot, Benoit Leprettre, Severino Mussi, Piotr Przydatek** and **Christophe Piraud** for their strong contribution and support.

Bibliography

BT152/DG10049/DC: CEN-CLC JWG 'Energy measurement plan for organisation - AFNOR revised proposal.