Guide to using the IEC 61557-12 standard to simplify the setup of an energy measurement plan

White Paper Number 998-19721655_GMA-US

Revision 1

by Franck GRUFFAZ

Executive summary

Many facility owners and managers are setting up measurement plans to gather the broad range of information needed to improve energy efficiency, reduce operating costs, and ensure power reliability. To collect this information requires *power metering and monitoring devices (PMDs)* that go beyond the capability of the traditional revenue meter. Up to now, choosing the best PMD for each application has been difficult due to the lack of common references between vendors regarding accuracy, operating conditions, and quality. This guide will help electrical system designers use the IEC 61557-12 standard to more easily specify the appropriate devices needed to support an effective power and energy management plan.

Introduction

Measuring and managing – these two concepts go hand in hand. As the classic business adage goes, you cannot manage what you cannot measure. And you cannot see how well you are managing without measuring on an ongoing basis.

For decades, the standard revenue meter was the only measuring device within the electrical infrastructure of a building. With energy costs rising and the importance of good power quality on the rise, building owners and grid operators are seeing greater need for energy management programs on both the supply and demand sides of electricity transactions. This requires more information than just kilowatt-hour data, and from multiple locations throughout a typical commercial, industrial, or institutional facility.

Digital devices have started replacing analog instruments many years ago, bringing new capabilities for more accurate measurements and remote data access. Manufacturers are now proposing innovative solutions. This includes new measurement features at device level, as well as new installation architectures at the system level. Together, these enable an affordable way to spread multi-function devices deeper into the electrical distribution network.

However, specifying the right features at the right location could become problematic without a good and shared understanding of device capabilities and applications. In respect of this goal, this document will show the benefit of the IEC 61557-12 standard for "Power Metering and Monitoring Devices (PMDs)" to the electrical designer specifying metering systems for demand-side clients. The paper will not address supply-side cases as those are typically covered by utility specifications.

Figure 1

As part of a corporate energy management plan, measuring instruments are installed within switchboards or electrical cabinets throughout a facility.

Changing needs in a changing electricity supply and demand model

Today, electrical installation designers must specify solutions related to new needs on the demand side of electrical grid, as described in Figure 2. Solutions can be considered as being organized into three main categories, as follows:

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

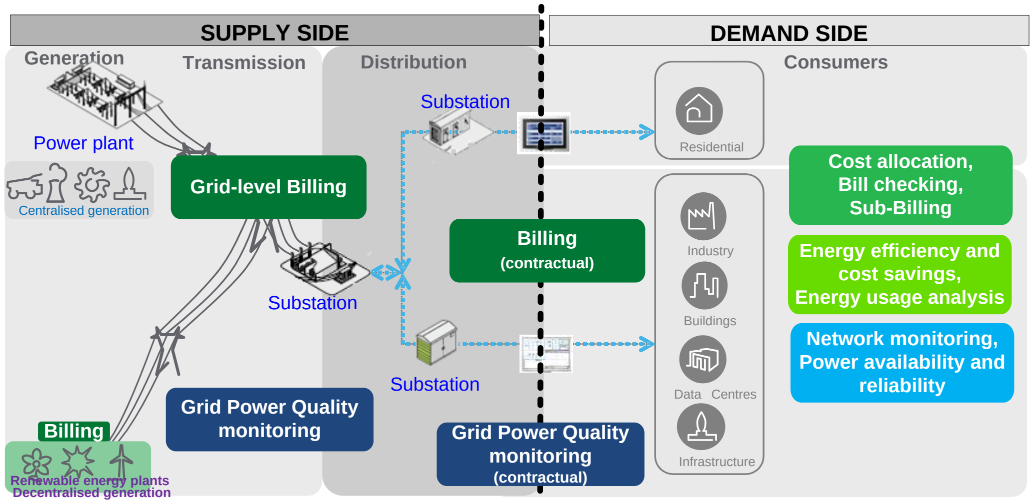


Figure 2

Measurement applications on the supply and demand sides of the electrical grid.

Demand-side needs are influenced by the growing impact of changes occurring within what has become known as the Smart Grid. In particular, this includes an evolving electricity generation structure with increasing numbers of decentralized power sources such as photovoltaic panels. In addition, there are new loads appearing, such as electric vehicle charging stations, and energy storage. These are shown in Figure 3.

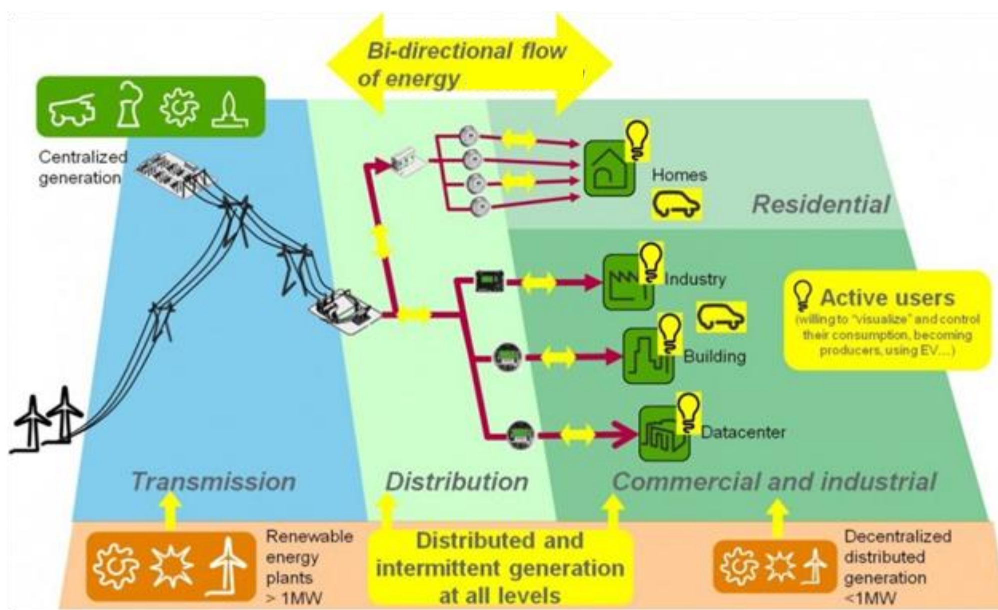


Figure 3

A typical Smart Grid, showing distributed and renewable energy generation, electric vehicle charging, and energy storage.

This new context is driving the need more extensive metering and monitoring installations that include more types of measurements, with higher accuracy, remotely retrievable from deeper within each demand-side facility.

Building owners and facility managers need access to this data and must be able to depend on it. Therefore, electrical system designers need to specify the appropriate power metering and control devices to satisfy these measurement requirements. The following sections detail each category of measurement application.

What do I need to measure?

APP1: Cost allocation, bill checking, sub-billing

This application requires measurement of active energy as well as time-of-use (TOU) and related tariffs. See Table 1.

Table 1

Useful measurements in APP1 applications.

Electrical quantities to measure	Symbol	Benefits of measurement
Active energy	E_a	Calculate energy consumption per time of use and energy cost.

IEC 61557-12 compliant devices are suitable for sub-billing applications unless otherwise required by local or regional regulation. For example, in the UK sub-billing is considered a legal metrology application requiring a billing meter. For more detailed information on this application, refer to White Paper 998-19721656_GMA-US, Guide to Energy Management Applications and Standards.

APP2: Energy efficiency and cost savings, energy usage analysis, contract optimization, regulatory compliance to ISO 50001

Guidance on this topic is provided in the following documents:

- ISO 50001, Energy Management Systems – Requirements with guidance for use
- IEC 60364-8-1, Low voltage installations – Part 8-1: Energy Efficiency
- AFNOR FD X30-147, Measurement plan for energy performance monitoring
- European regulations (Energy Efficiency Directive, Energy Performance Building Directive) or good practices documents (e.g. LEEDS, BREAM, HQE)

Among the electrical quantities, active energy needs to be measured by zone and by usage, but this is not the only quantity worth measuring. See Table 2. For more detailed information on this application, refer to White Paper 998-19721656_GMA-US, Guide to Energy Management Applications and Standards.

Table 2

Useful measurements in APP2 applications.

Electrical quantities to measure	Symbol	Benefits of measurement
Active energy	E_a	Monitor energy and manage costs more closely, by zone and/or usage.
Reactive energy	E_r	Monitor the operation of reactive loads e.g. motors, transformers, capacitors.
Power, power demand	P	Better control the demand in order to optimize the supply contract.
Power Factor	PF, cosφ	Optimize power factor to avoid penalties.
Voltage and current harmonics	THD_u THD_i	Detect non-positive-sequence harmonics causing excessive energy losses in motors or transformers.
Frequent deviations of voltage	U	Detect devices frequently operating outside their specified range and over consuming energy.
Voltage unbalance	U_{nb}	Detect non-positive-sequence components causing excessive energy losses in motors.

All of these measurements are covered by the IEC 61557-12 standard.

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

Table 3 provides a non-exhaustive list of electrical parameters useful in APP3 applications.

Table 3

Useful measurements in APP3 applications.

Electrical quantities to measure	Symbol	Benefits of measurement
Current	I, I_N	Detect overheating or conditions that may lead to nuisance trips.
Voltage	U, V	Detect abnormal supply conditions of sensitive loads (e.g. motors) leading to premature failure.
Frequency	f	Detect abnormal speed of rotating machines.
Individual voltage and current harmonics, THD	U_h, I_h, THD	Monitor non-positive-sequence harmonics causing overheating of components (motors, transformers, cables, capacitors…), and motor shaft vibrations, resulting in premature failure.
Voltage unbalance, Current unbalance	U_{nb}, I_{nb}	Monitor non-positive-sequence voltage causing motors and generators to overheat and fail prematurely.
Voltage dips, voltage interruptions	U_{dip}, U_{int}	Detect degradation of supply quality before it leads to process stoppages with financial impact.
Power demand or Current demand	P	Optimize the load distribution, determine where new loads may be placed or which feeder needs to be upgraded to serve the planned capacity.

All of these measurements are covered by the IEC 61557-12 standard.

For more detailed information on this application, refer to White Paper 998-19721656_GMA-US, Guide to Energy Management Applications and Standards.

How the IEC 61557-12 standard helps compare devices from different vendors

From analog watt-hour meters to modern multi-function devices

The International Electrotechnical Commission (IEC) developed the IEC 61557-12 standard to make it easier for engineers and other professionals to compare and select the relevant device (PMD) for any given application. This includes guidance on reading the related manufacturer information.

The full title of the standard is "Electrical safety in low voltage distribution systems up to 1000 Vac and 1500 Vdc – Equipment for testing, measuring, or monitoring of protective measures – Part 12: Power Metering and Monitoring devices (PMD)." It establishes a common set of reference requirements for electrical measurements. It outlines PMD parameters and requirements for several important characteristics, including the full range of PMD functions and required equipment markings, along with defining several performance classes.

To discover more information regarding the IEC and its standards, visit www.iec.ch

IEC 61557-12 aims at helping the user to select the right devices for electricity cost management as well as allowing state of the art electrical management on the demand side of the electrical network. To that end, the IEC 61557-12 standard specifies not only energy measurements, but also many other critical electrical quantities, unlike the electricity metering equipment standards which focus only on energy measurements.

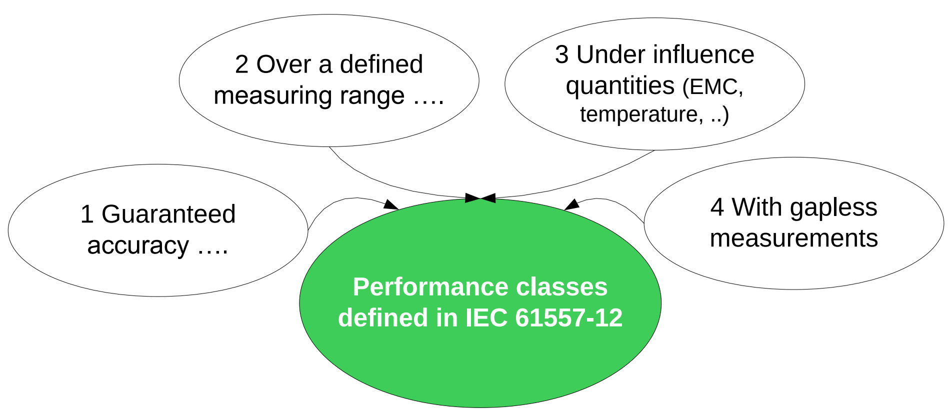
From mere accuracy to performance classes

The accuracy of many measuring devices is specified without referencing a standard or, worse, without any information on the measurement range and environmental conditions.

In contrast, for each electrical quantity measured, the IEC 61557-12 standard specifies the measurement performance of PMDs by a class that encompasses items described in Figure 4.

Figure 4

Items covered by the performance classes of IEC 61557-12.



1. **Guaranteed accuracy:** This specifies the limits of the PMD uncertainty, over the specified measuring range, under reference conditions.
2. **Defined measuring range:** This specifies the minimum and maximum values of quantities between which the limits of measurement uncertainty are defined. For current, the measuring range is specified by manufacturers through:
    - Nominal current (I_n) and maximum current (Imax) for sensor operated PMDs (called PMD/Sx)
    - Base current (I_b) and maximum current (Imax) for directly connected PMDs (called PMD/DD)
3. **Influence quantities:** These are environmental quantities (temperature, climatic conditions, electromagnetic perturbations / EMC, etc.) that may happen in harsh

conditions encountered in switchboards or electrical cabinets. The standard specifies maximum permitted variations of accuracy due to those influence quantities.

4. **Zero-blind (gapless) measurements:** To ensure reliable and accurate measurements, IEC 61557-12 requires zero blind measurements (i.e. gapless measurements) for several quantities, particularly for energy measurements. This means that sampling shall be performed continuously, not from time to time (i.e. with gaps).

Standalone meters and meters embedded in other devices

More and more types of devices are embedding measurement functions. These can include protection relays, remote terminal units (RTU) installed on feeders, LV air circuit breakers (ACB), molded case circuit breakers (MCCB) or miniature circuit breakers (MCB).

Even if these devices comply with a product standard (e.g. IEC 60947), they can also refer to IEC 61557-12 in order to properly specify the performance classes of their embedded measurement functions.

Measurement within the switchboard and panel environment

This standard takes into account various environmental conditions present in switchboards and panels: EMC (according to IEC 61326-1, industrial locations), climatic conditions (temperature, humidity), and mechanical conditions (vibrations).

Requirement of compliance with the IEC 61010-1 standard specified within the IEC 61557-12 standard covers electrical safety. EN 61557-12 is harmonized to both the EMC and LV directives.

Performance classes and accuracy for all measurement functions

A list of available performance classes for all relevant measurement functions is specified in IEC 61557-12, whereas most other standards, such as EN 50470 and IEC 62053-2x series, deal only with active or reactive energy.

Requirements of IEC 61557-12, IEC 62053-2x and EN 50470 for active and reactive energy accuracy are similar.

Figures 5 and 6 provide main testing requirements related to the IEC 61557-12 performance classes.

Figure 5

Uncertainty limits for testing at Power Factor = 1

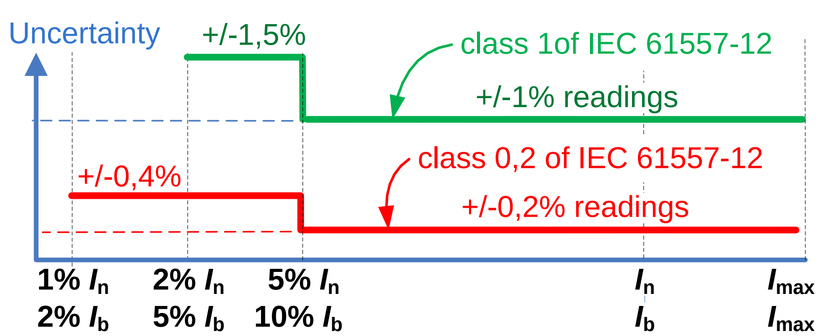
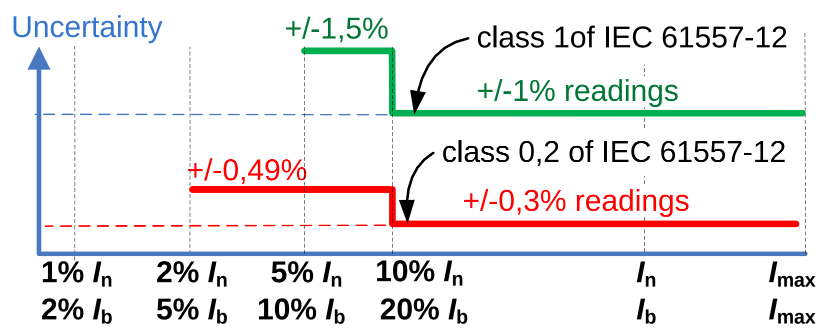


Figure 6

Uncertainty limits for testing at Power Factor = 0,5 inductive and 0,8 capacitive



What is the performance class of devices with external current sensors?

Function performance classes defined in IEC 61557-12 are reflecting measurement functions accuracy. Sensor accuracy classes defined in IEC 61869 set of standards are reflecting sensor accuracy. See Figure 7.

Figure 7

Uncertainties for "sensor operated PMD/Sx" (working with external sensors) and for "directly connected PMD/DD" (working with embedded sensors)

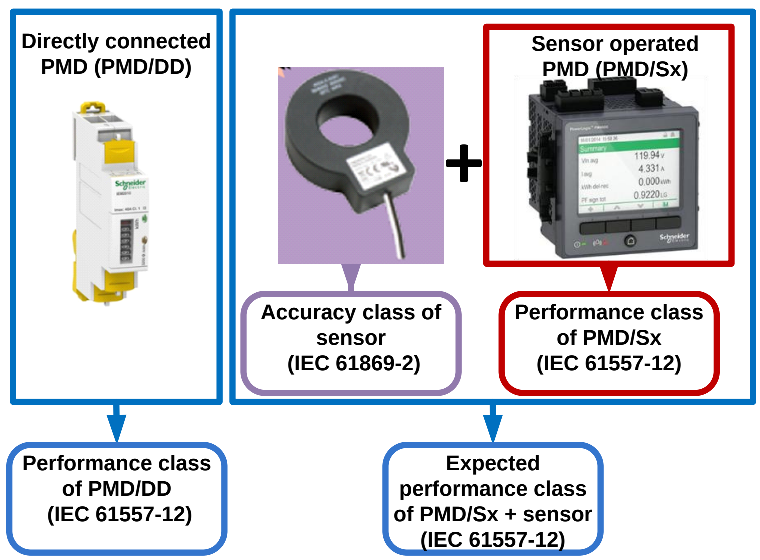


Table 4 provides useful information related to the association of a PMD with a sensor.

Table 4

Accuracy recommendations provided by IEC 61557-12 regarding external sensor to be associated to PMDs, and system expected.

Performance class of the PMD without external sensors	Recommended sensor class to associate to the PMD [b c]	Expected performance class for PMD-Sx or PMD-xS including their external sensors	maximum possible sensor class to associate to the PMD [a]
0,1	0,1 or below	0,2	0,2
0,2	0,2 or below	0,5	0,5
0,5	0,5 or below	1	1
1	1 or below	2	2
2	2 or below	5	5
5	5 or below	10	

Information extracted from IEC 61557-12 table "Table D.1 – PMD SD associated to current sensor or PMD DS associated to voltage sensor".

IEC 61557-12 also provides a formula for calculating operating uncertainty, similar to the concept of Maximum Permissible Error (PME) defined in EN 50470-3 that reflects the worst-case cumulated effect of several influence quantities (temperature + frequency + ...).

Operating uncertainty as well as overall system uncertainty are just quality indicators that should not be mixed up with function performance classes. **Only a function performance class reflects the accuracy of the related measurement function.**

From Table 4 we can conclude that class 1 "directly-connected PMD" is expected to be at least equivalent to a class 0,5 "sensor operated PMD" installed with a class 0,5 sensor. The related measurement ranges are described in Table 5 and Figure 8.

Table 5

Comparison of measuring ranges for PMD/Sx and PMD/DD

Measurement ranges of PMDs for active energy			
for PMD/Sx (specified with In)		for PMD/DD (specified with Ib)	
Class 1	Up to I_{max}, down to 2% I_n, with a starting current of 0,2% I_n	Class 2 [a]	Up to I_{max} , down to 5% I_b, with a starting current of 0,5% I_b
Class 0,5	Up to I_{max} , down to 1% In, with a starting current of 0,1% I_n	Class 1 [b]	Up to I_{max} , down to 5% I_b , with a starting current of 0,4% I_b
Class 0,2	Up to I_{max} , down to 1% In, with a starting current of 0,1% I_n	Class 0,5 [c]	Up to I_{max} , down to 2% I_b , with a starting current of 0,2% I_b

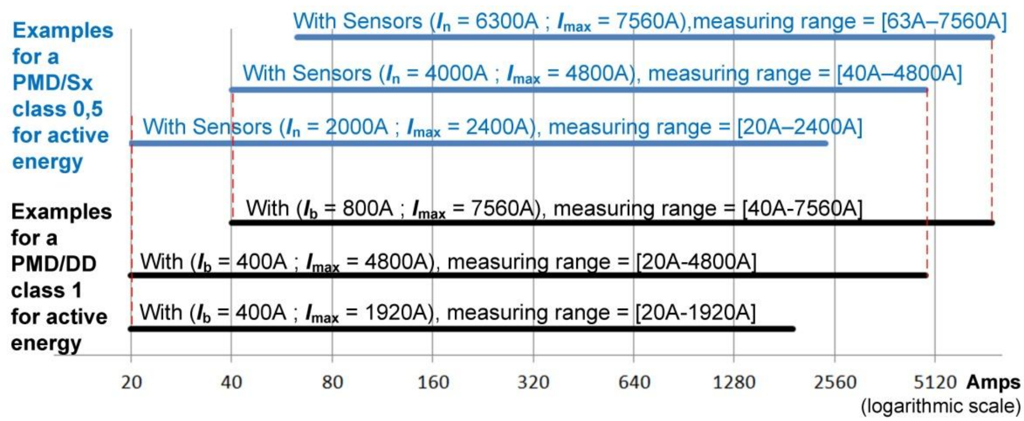
a *Expected to be equivalent to a class 1 PMD/Sx associated with a class 1 sensor*

b *Expected to be equivalent to a class 0,5 PMD/Sx associated with a class 0,5 sensor*

c *Expected to be equivalent to a class 0,2 PMD/Sx associated with a class 0,2 sensor*

Figure 8

Examples of PMD measuring ranges



Recommended device features according to applications

Recommendations for PMDs for each measurement application are summarized in Table 6.

Table 6

Recommendations for PMDs for each measurement applications.

Recommendations \ Applications	**APP1** [a] Cost allocation, bill checking, sub-billing	**APP2** [a] Energy efficiency & cost savings, energy usage analysis	**APP3** [a] Network monitoring, power availability & reliability
Kind of device requested at minimum	**PMD according to IEC 61557-12 edition 1** (and 85/542A/CD)		
	PMD-1	PMD-1 or -2 or -3	PMD-2 or -3
Examples of useful measurement functions	Active energy	Energies, Powers, Power factor, Voltages	Currents, Voltages, Frequency, Harmonics, Unbalance, Dips
Minimum accuracy for 'sensor operated devices" PMD/Sx (device without embedded sensor)	**Active energy:** → Class 0,5 [b]	**Active energy:** → Incomers: Class 0,5 → Feeders: Class 1 → Main loads: Class 1	**Current**: → Class 1 **Voltage**: → Class 1
Minimum accuracy for "directly connected devices" PMD/DD (device with embedded sensors)	**Active energy:** → Class 1 [b]	**Active energy:** → Incomers: Class 1 → Feeders: Class 2 → Main loads: Class 2	**Current:** → Class 2 **Voltage:** → Class 1
Compliance with IEC 61000-4-30 measurement methods	Not relevant	Optional [c]	Optional [c]
Third party certification of active energy measurement [d] [h]	Recommended	Recommended	Recommended
Manufacturing audit (e.g. according to ISO 9001) [h]	Recommended	Recommended	Recommended
Durability tests (e.g. according to IEC 62059-32-1 or mission profile test)[h]	Recommended	Recommended [e]	Optional
Indication of manufacturing date (for periodic verification) [g] [h]	Recommended	Optional	Optional
Anti-tampering (sealing, securing of firmware, data and configuration)	Optional [f]	Not relevant	Not relevant

(a) Applications can be combined and covered by a single device.

(b) Example: a 4000A LV feeder loaded at 33% on average with a 7,71 cents/kWh tariff, would cost 205k€ per year. A 1% measurement error (class 0,5 PMD/Sx + class 0,5 sensor, or class 1 PMD/DD) could = 2051€ error. A 2% measurement error could = 4102€ error. A 0,5% measurement error could = 1025€ error. Measurement accuracy should be specified according to the acceptable economic ramifications and stakes.

(c) IEC 61000-4-30 class S is recommended when measurements from different devices need to be compared.

(d) Active energy measurement devices independently certified according to IEC 61557-12, IEC 62053-21, IEC 62053-22 or EN 50470-3 fall in this category.

(e) ISO 50001 §4.6.1 is requesting repeatable measurements. This aspect is addressed in Annex I of document AFNOR FD-X30-147 "Energy measurement plan for organizations", see Annex 5 of BT152/DG10049/DC.

(f) The risk of fraud is limited because meters are usually installed in restricted access zones. If required, the meter can be secured or protected against tampering by sealing at switchboard or electrical cabinet level.

(g) A marking such as PMD/cv/Ktt/a/Myy (where yy = manufacturing year 20yy), or similar information provided on a label, in a QR code, on a display or by maintenance reminders can address this need.

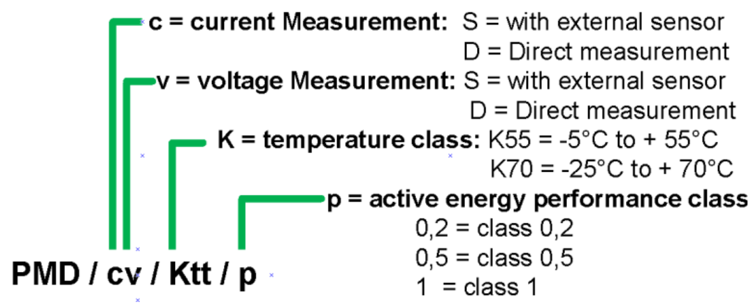
(h) PMDs independently certified for active energy, covered by manufacturing audits, having performed measurement durability tests and providing an indication of manufacturing date are called "C-PMD".

An easy way to summarize essential characteristics

PMDs complying with IEC 61557-12 can be characterized with 3 coding parameters, as described in Figure 9 and Table 7.

Figure 9

PMD coding guide, usually available in technical documentation for each PMD.



Active energy performance is a good indicator of the global performance of the device, since this measurement depends on the accuracies of voltage and current measurements as well as the device's internal time clock.

Table 7

Examples of device coding

Device coding	Meaning
PMD/DD/K70/1	PMD with embedded sensors, working from -25°C to +70°C, with active energy measurement class 1
PMD/SD/K55/0,5 (x5A CT) PMD/SD/K55/1 (x1A CT)	PMD working from -5°C to +55°C, with active energy measurement class 0,5 when associated with 5A sensors, and class 1 when associated with 1A sensors.

Conclusions

As the Smart Grid continues to evolve and facility managers are increasingly tasked with controlling energy costs and power reliability, electrical installations need better measurement capabilities. This requires more extensive metering and monitoring capabilities deeper into each facility, performed by reliable devices. PMDs compliant with the IEC 61557-12 standard are meeting these new requirements, with guaranteed performance.

IEC 61557-12 is a powerful and useful tool for designers to easily select the correct PMDs to support a power and energy measurement plan. Facility managers will be able to trust the accuracy, consistency, and reliability of the data acquired from a metering solution that includes IEC61557-12 compliant PMDs.

Of special importance is the category of APP1 applications. Cost allocation, sub-billing, and bill checking all require a maximum level of confidence. For these, the C-PMD class of devices should be used. These offer independent certification of active energy accuracy according to the IEC 61557-12 standard, covered by manufacturing audits. They also meet measurement durability requirements and provide an indication of manufacturing date.

Next steps

It is recommended that electrical system designers refer to the technical documentation provided by each PMD vendor, to ensure compliance with the IEC 61557-12 standard, and for specific reference to PMD application coding.

The author also encourages designers and facility managers to refer to papers and reports from international standards organization, industry organizations, and vendors for information on relevant energy management applications, methods, and product standards. Some of these resources have been provided in this paper.

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

IEC web site
www.iec.ch

Resources

Guide to energy measurement applications and standards
White Paper 998-19721656_GMA-US