Standardization in the field of Current and Voltage measurements

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ABSTRACT

The subject addressed is the standardization for the current and voltage measurements in electrical networks by IEC and CENELEC organizations.

The former IEC Series 60044-X is now replaced for conventional type of instrument transformers by the new Series IEC 61869-X. Concerning new technologies using mostly optical Faraday and Pockels effects, or passive sensors using low power current sensors, Rogowski sensors or R/C divider, the standardization work is in progress. This standardization work includes the definition of digital interface according to IEC 61850-9-2. This work is based on the classical specifications required by the low voltage equipment connected to instrument transformers. However new applications driven by smart grid developments will probably change the requirements of current and voltage measurement devices.

To address these new developments, IEC TC 38 launches New Work Items for the standardization of Fault Passage Indicators (FPI). These devices will be standardized in the future Series IEC 62689-X. In parallel, IEC TC38 circulates a large survey in order to determine the futures requirements of Instrument transformer for the different uses.

This paper will present the state of development of these two Series of IEC Standards and the main conclusions of the survey that will drive the IEC and CENELEC TC 38 standardization works for the next decade.

INTRODUCTION

To manage an electrical network, the measurement of the current and the voltage in real time is needed. To protect an electrical network, the measurement of short circuit current is needed. Modern networks, designed for higher electrical power, need current and voltage measurements during transient conditions. To assure quality of electricity, it is more and more requested to measure harmonic components due to the use of power electronic units (by example for the connection of wind farms to the network, of motors with electronic speed variation, for the development of DC interconnection line...). In addition development of HVDC installations need more and more DC voltage and current measurements.

Distributed energy resources (DER) as solar panels, or small wind turbines connected to the low voltage networks are also changing the management of low voltage lines and of distribution networks. Consequently the need of current and voltage measurements in many places in these networks request the installation of more and more sensors.

All these evolutions show that electrical measurements are a key element for the development of the electrical network.

In the past, instrument transformers were used not only to get information about current or voltage. The instrument transformers were also used to transfer an electrical power needed by the low voltage secondary equipment mainly designed with electromechanical components. The electrical power used by low voltage equipment has become smaller and smaller with the development of analogue electronic devices and now with digital technology.

All these developments are changing the way to use classical instrument transformers. But this evolution opens also the possibilities to use in the electrical networks new concepts of current and voltage sensors.

This paper presents how these changes are taken into account in the IEC standards for instrument transformers and fault passage indicators, to insure interoperability of the products designed by the manufacturers.

IEC 60044-X SERIES

Classical instrument transformers standards

The historical Standards for instrument transformers, in the 80's decade, were IEC 185 for current transformers and IEC 186 for voltage transformers. These two standards described mainly insulation requirements, accuracy classes for measurement and protection (only for steady state conditions), type and routine tests.

Current measurements under transient conditions were under consideration by an IEC working group from the beginning of the 70's... the driver was to avoid saturation of the transformer and to obtain an acceptable error during the short circuit measurements. Different types of current transformers were considered with or without core air gaps, known as TPS, TPX, TPY and TPZ current transformer types.

Based on IEC 185 and 186 and on these proposals for transient performances, the new Series 60044-X was

published by IEC.

IEC 60044-1 was the Standard for Current Transformers, 60044-2 for Voltage Transformers, 60044-3 for Combined Transformers (current and voltage). The Capacitive voltage transformers were standardized through the IEC 60044-5[1] and 60044-6 was the additional transient accuracy specification for current transformers.

These standards represent the state of the art of classical instrument transformers used in the different electrical networks (Low, medium and high voltage).

At the beginning of the 90's technological evolutions were considered enough mature to start the standardization of new kind of instrument transformers.

The development of optical and electro-optical technology, of electronic both analogue and digital components, of new ferromagnetic material... all gave new possibilities to design new kind of instrument transformers, very often named NCITs (for Non Conventional Instrument Transformers).

NCIT in the 90's

For medium voltage applications, manufacturers have developed new passive sensors as: current transformers with integrated burden that deliver a voltage output instead of a current output, rogowski coils[2] with or without passive integrator, R and R/C voltage dividers... The common feature of these new instrument transformers is to make available as their output, a small voltage signal, typically a few tens or hundreds of mV. The consequences are that these devices need to be connected closely to the secondary equipment. It is actually the case for MV cubicles where protective relays are close to the instruments transformers and the circuit-breaker.

For high voltage applications manufacturers have developed active sensors as optical sensors associated with electronic elements (Light sources, diodes, electronics to deliver the output information and also for the compensation of external parameters as temperatures influences, SF6 density, vibrations...). A lot of different solutions were proposed:

- Polari-metric or interfero-metric configurations of Faraday Effect in bulk glasses or in optical fibers for current measurements.
- Rogowski coil on a printed circuit board for current measurement for GIS busbars,
- Pockel cells for voltage measurement.

Hybrid designs were also developed using classical sensors as current transformers, shunts, rogowski coils and voltage dividers, all associated with active electronics.

The main advantages of these active devices are to improve the insulation behaviour of HV current transformers (source of aging effects and failures) and to give also the possibility to transmit the current and voltage information to the relay room. Moreover, to simplify the transmission of this information, digital communications systems where proposed.

In order to facilitate the development of these new technologies of MW and HV devices it was proposed to start a standardization activity for the completion of the IEC 60044-X Series.

IEC 60044-7 and IEC 60044-8

When the standardization work started for the new technologies of voltage transformers, a choice had to be made: to prepare a product standard for each kind of technical solution or to prepare a functional standard that could be applied for all kind of design.

The proposal of the experts was to prepare a functional standard. A generic appellation was also proposed: Electronic Instrument Transformers. A bloc diagram was defined to cover all kind of application, as shown in Figure 1.

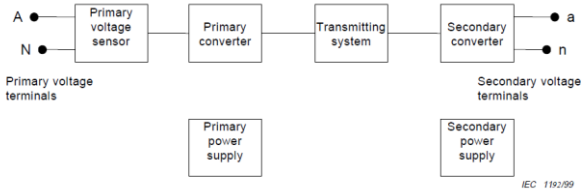

Figure 1 General block diagram of electronic voltage transformers

Only necessary blocs, according to the design, are used for a specific application. This allows to cover in the same standard, all the solutions using only passive sensors (R/C voltage dividers, Low power CT, Rogowski coils...) or using active electronics (analogue or digital), associated to classical sensors or optical sensors. Note that other organizations made a different choice; IEEE, for instance has published a standard for optical current sensors.

The IEC 60044-7 [1] is dedicated to Electronic Voltage

1 IEC 60044-4 was an older standard dedicated to partial discharges measurements. These measurements were included in the relevant parts of the 44-x Series but the reference 44-4 could not be used for other standard products.

2 Rogowski coil could be described as a current transformer without ferromagnetic core. The output is a voltage proportional to di/dt.

Transformers and was published in 1999. The IEC 60044-8 [2] is dedicated to Electronic Current Transformers and was published in 2002.

New technical clauses dedicated to these technologies were introduced in these 2 publications:

- Accuracy tests versus temperature, vibrations, frequency,...
- EMC tests.
- Error limits for the harmonics measurements.
- Rated voltage output for current and voltage measurement outputs.
- Last but not least the specification of a digital output for a three phase voltage and current measurements trough a specific box: ***the Merging Unit***.

The standardized digital output is a point-to-point transmission, based on the IEC 60870-5-1 protocol and using optical fiber cable or classical communication cable.

This digital transmission was adapted later to Ethernet protocol, to be included in the IEC 61850 Series under the reference IEC 61850-9-1.

Feed back on the IEC 60044-x Series

With the publication of parts 44-7 and 44-8, all technologies of instrument transformers were covered. However standardization works never stop and a maintenance process is well described in the IEC procedures!

Different points were considered for the maintenance of this Series:

- General clauses: each part of the Series was independent: this was useful, however clauses that should have been the same were present in different parts... and non-voluntary divergences could appear... Common requirements are generally published in an IEC specific part of a given Series.
- IEC 61850 became the reference for digital substation; digital output of instrument transformers should be in full accordance with it. At least the UCA9-2 LE[3] specification hads to be included in the standardization.
- It was reported that to merge specifications of active (with electronics) and passive (without electronics) instrument transformers in the same functional standard (as it happens in 44-7 and 44-8 parts) is finally not useful. Splitting in 2 parts for active sensors and passive sensors, could simplify the use of the standard.
- A standard solution to digitalise the analogue output of existing instrument transformers is required by the market.
- NCITs could be renamed as LPITs, for Low Power Instrument Transformers, to better describe the difference between the families of instrument transformers (low power being related to the output of the modern measurement devices).

3 UCA is the user group association for the CIM model standardized by IEC and the IEC 61850. The user group published the specification 9-2 LE for application of IEC 61850-9-2 for instrument transformers in the spirit of the IEC 60044-8 and IEC 61850-9-1.

THE NEW SERIES IEC 61869-X FOR INSTRUMENT TRANSFORMERS

Standards for classical instrument transformers

IEC Central Office has attributed to this new Series the reference number IEC 61869. The part 1 [3]: "general clauses" was published in 2007. Since 2013, the Series is available for all kind of traditional instrument transformers with the following additional requirements:

- Part 2 [4] for current transformers including transient performance (former IEC 60044-6).
- Part 3 [5] for voltage transformers.
- Part 4 [6] for combined transformers.
- Part 5 [7] for capacitive voltage transformers.

Each of these Standards shall be used jointly with part 1.

Standards for LPITs

The work is in progress for the LPITs and it is expected that the Series will be completed in 2015/2016.

For LPITs, the Series will be completed by the following parts:

- Part 6, additional general clauses to part 1 for LPITs.
- Part 7, electronic voltage transformers.
- Part 8, electronic current transformers.
- Part 9, requirements for the digital output: this part defines a specific profile of IEC 61850-9-2 for instrument transformers based on logical device MU (Merging unit): association of the logical nodes current and voltage defined in the IEC 61850.
- Part 10, low voltage passive current transformers.
- Part 11, low voltage passive voltage transformers.
- Part 12, combined LPITs.
- Part 13, SAMU. Stand Alone Merging Unit: it's a product standard based on part 9, to get a digital interface for existing instrument transformer (the input will accept any instrument transformers standardized outputs for legacy

systems).
- Part 14, current transformers for DC applications.
- Part 15, voltage transformers for DC applications.

Low voltage considerations

Up to now, the Instrument Transformers Standards have been applicable for all voltage levels. As consequences the standards present a lot of specific technical clauses as insulation, mechanical requirements and do on, related to HV uses.

In recent years, with the development of smart applications (building energy managements, power meters, quality meters,…), LV current and voltage sensors are more and more used. As a matter of facts many devices have been developed without following IEC standards (as example the voltage output 333 mV is very frequent for this kind of sensors while the standardized values are 22,5 or 200 mV) .

A survey was circulated in different Technical Committees of IEC to get a more accurate picture of the different markets and uses of the instrument transformers. The main conclusion of this survey is that it could be better for the users of the standards to publish specific parts for the LV applications. The formal decision was taken during the last plenary meeting of the TC38 in November 2014. It was decided to set up a new working group for the projects IEC 61869-201, -202, -203,… dedicated to low voltage instrument transformers.

SMART-GRID AND ELECTRICAL MEASUREMENTS

New applications driven by smart grid developments are changing the requirements for current and voltage measurement devices in the medium voltage network. As the current flux become bi-directional with the development of the distributed energy resources, new fault detection systems should be developed to drive these systems. If fault detectors have been already existing for a long time, they have not been standardized and they become more and more communicant in the smart world.

To address these new developments, IEC TC 38 launched New Work Items for the standardization of Fault Passage Indicators (FPI). These devices will be standardized in the future IEC 62689-X Series.

Modern FPI are composed by current and voltage sensors, digital electronic treatment units and communication units. The standardization work is also of interest for other Technical Committees:
- TC95 (protection relays), since protective functions could be integrated in electronic units of the FPI system
- TC57 for the data model specification, the additional logical nodes definitions for FPIs and for the communication protocols according to IEC 61850.

The publication of first two parts of this new IEC Series is expected in 2015.

CENELEC CONSIDERATIONS

Dresden agreement between IEC and CENELEC results in parallel vote of the majority of IEC projects. The parallel votes applies for the TC38 projects and all IEC Standards are also published as EN Standards. However, at CENELEC level standards are linked to the relevant EU Directives.

For the classical instrument transformers (part 2, 3, 4 and 5), the EN projects were voted under the LVD (Low Voltage Directive) and these parts are now harmonized to the LVD[4]. As consequence, a CE mark should be applied on each new unit...

This is a new situation, if compared to the EN 60044-x Series. In general, MV and HV devices are not under the scope of LVD, so it was requested to change the harmonized status of the new EN.

However, for LV applications, the CE mark is requested by the manufacturers. When the new LV parts will be ready, CENELEC TC38 will be able to reconsider the listing of the series under the LVD scope.

For the relevant parts of LPITs and FPIs, EMC Directive should be also considered.

CONCLUSIONS

Standardization of LPITs started more than 20 years ago before the development of a mass market. It is sometime considered as too early. Nevertheless it was the opportunity to develop the basic concepts of the standard solutions (data model, Merging Unit concept, rated output) which allows today the development of interoperable devices. This example is also the demonstration that close coordination with different Technical Committees is mandatory to obtain a marker relevant standard.

The new IEC 61869-x Series is the capitalisation of the long experience gained for all type of instrument transformers and will be completed in the next 2/3 years.

4 A harmonized standard give a conformity presumption to the related Directive.

However the start of a maintenance cycle is needed now for part 1 [3].... Standardization work never stops!

REFERENCES

[1] IEC 60044-7:1999 Edition 1.0 (1999-12-17) Instrument transformers - Part 7: Electronic voltage transformers

[2] IEC 60044-8:2002 Edition 1.0 (2002-07-19) Instrument transformers - Part 8: Electronic current transformers

[3] IEC 61869-1:2007 Edition 1.0 (2007-10-09) Instrument transformers - Part 1: General requirements

[4] IEC 61869-2:2012 Edition 1.0 (2012-09-18) Instrument transformers - Part 2: Additional requirements for current transformers

[5] IEC 61869-3:2011 Edition 1.0 (2011-07-13) Instrument transformers - Part 3: Additional requirements for inductive voltage transformers

[6] IEC 61869-4:2013 Edition 1.0 (2013-11-19) Instrument transformers - Part 4: Additional requirements for combined transformers

[7] IEC 61869-5:2011 Edition 1.0 (2011-07-13) Instrument transformers - Part 5: Additional requirements for capacitor voltage transformers